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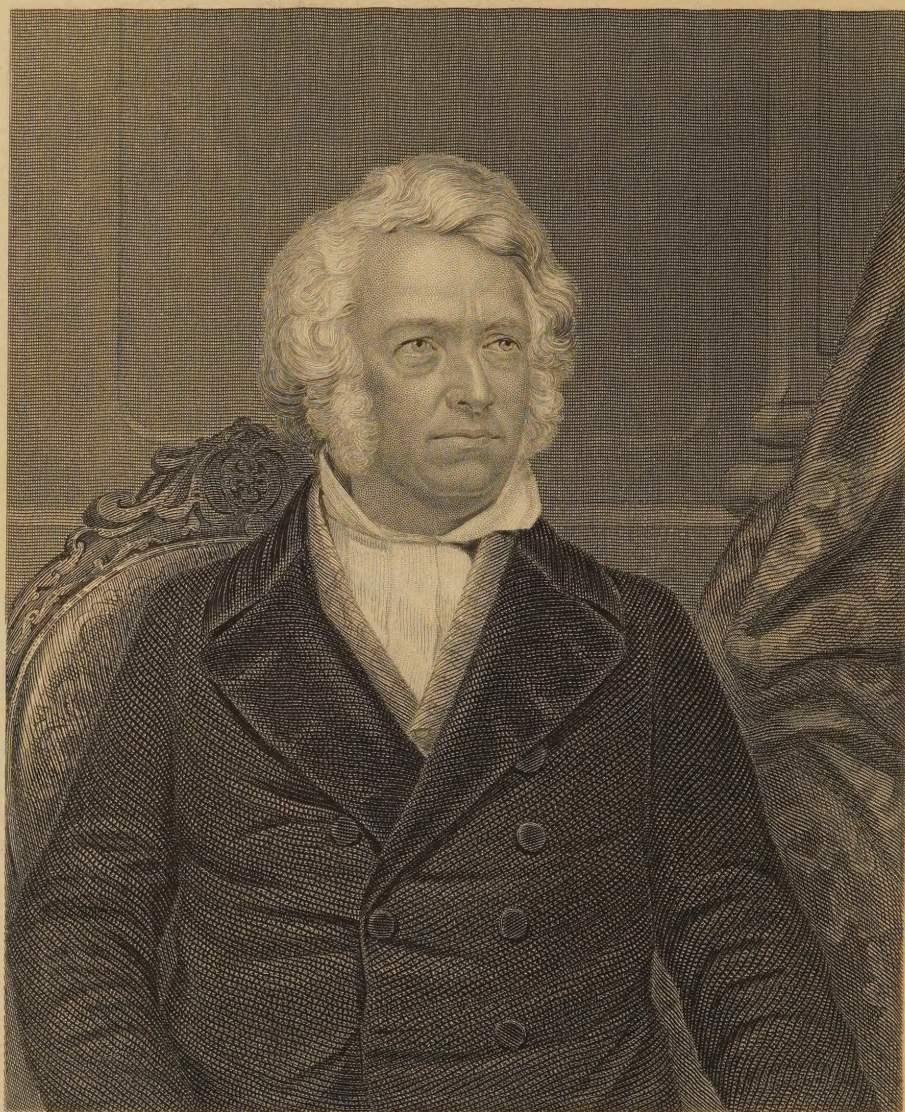
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VOL. II.



*Presented to
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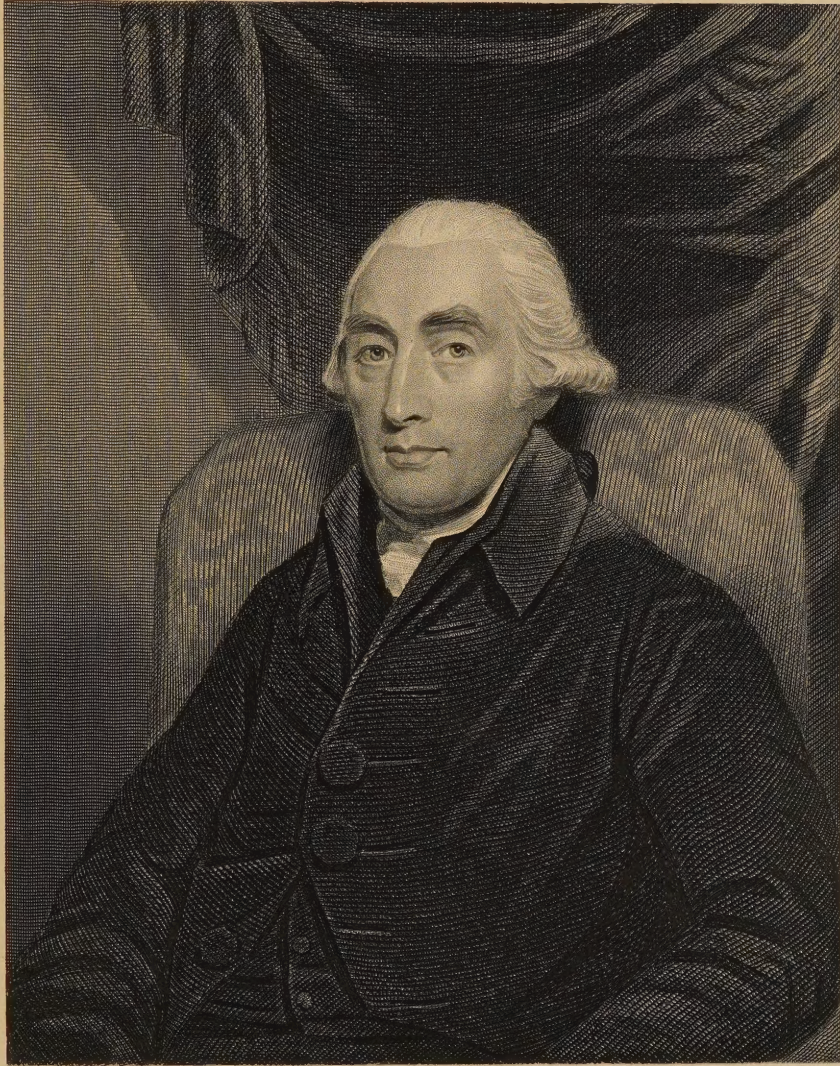
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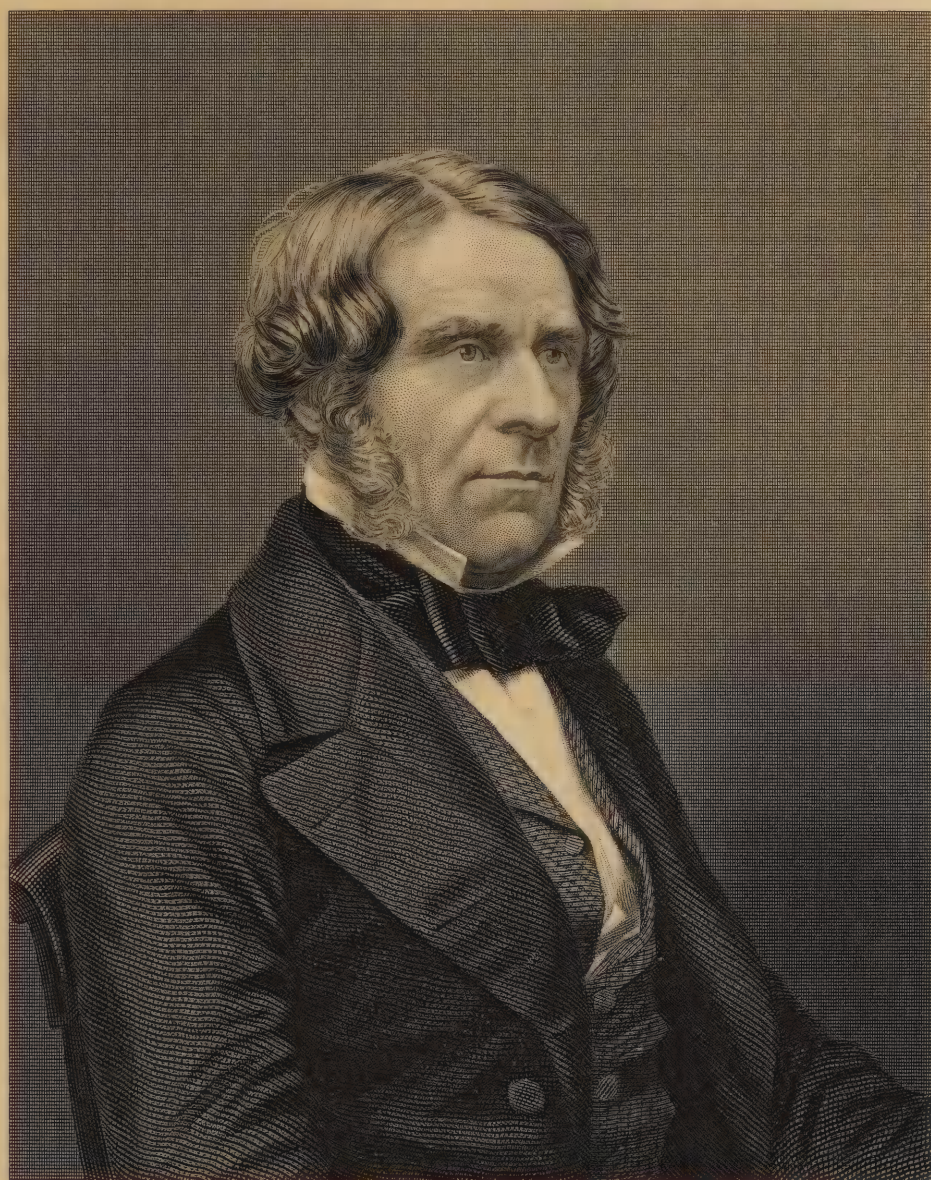
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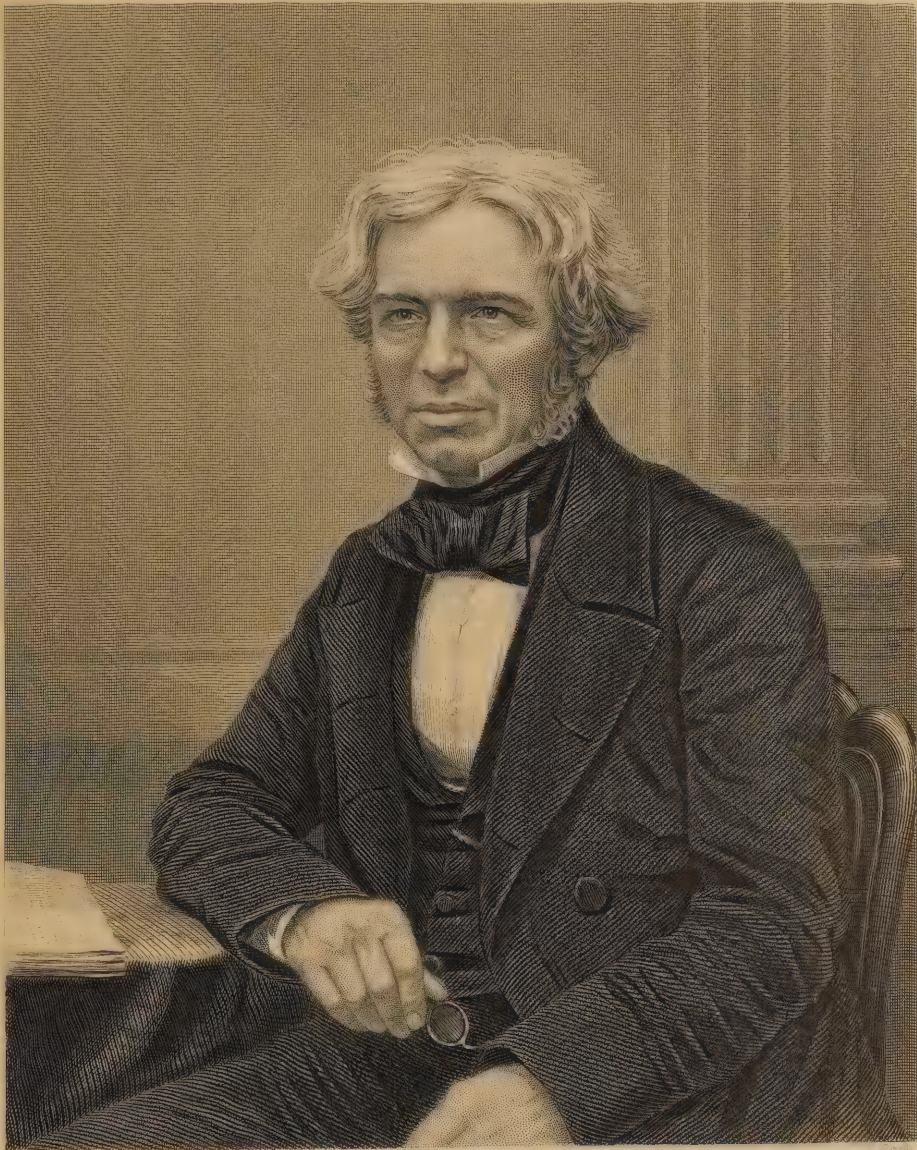
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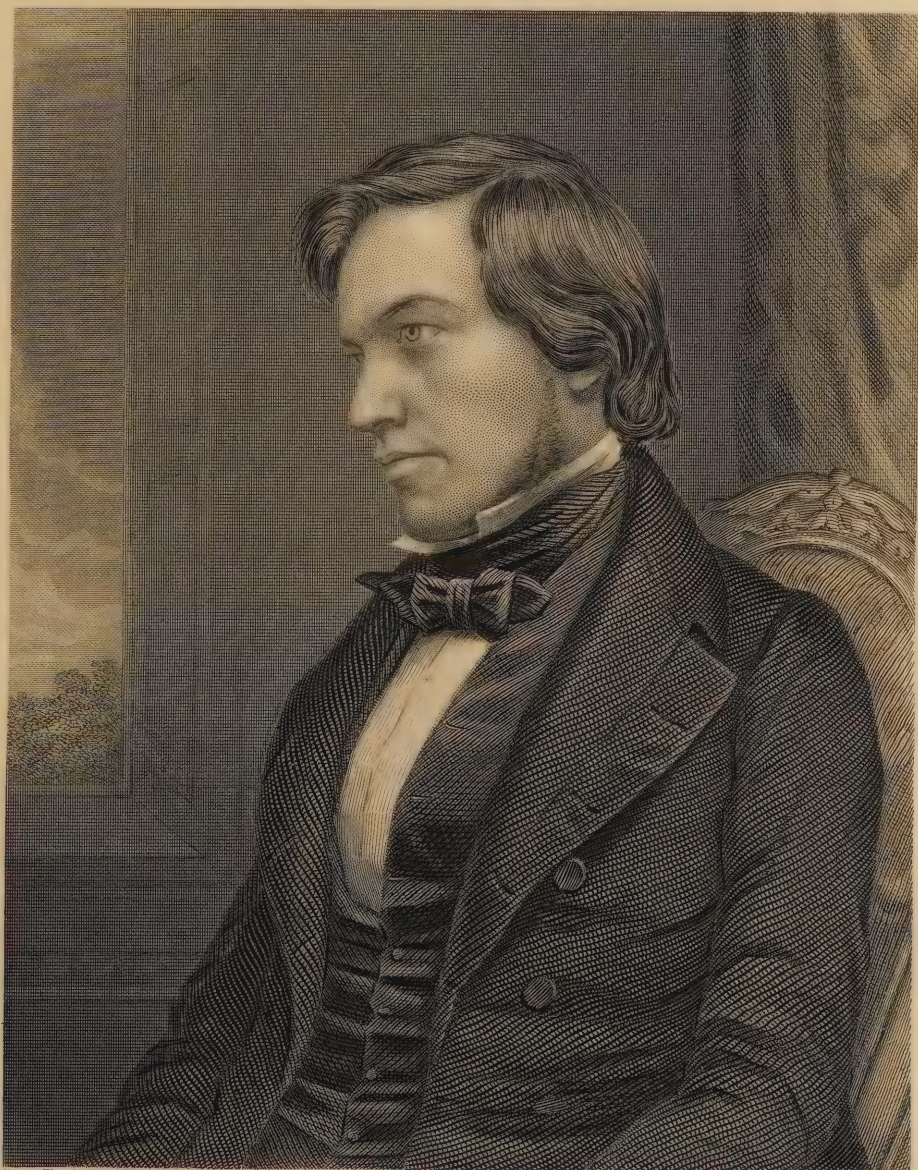


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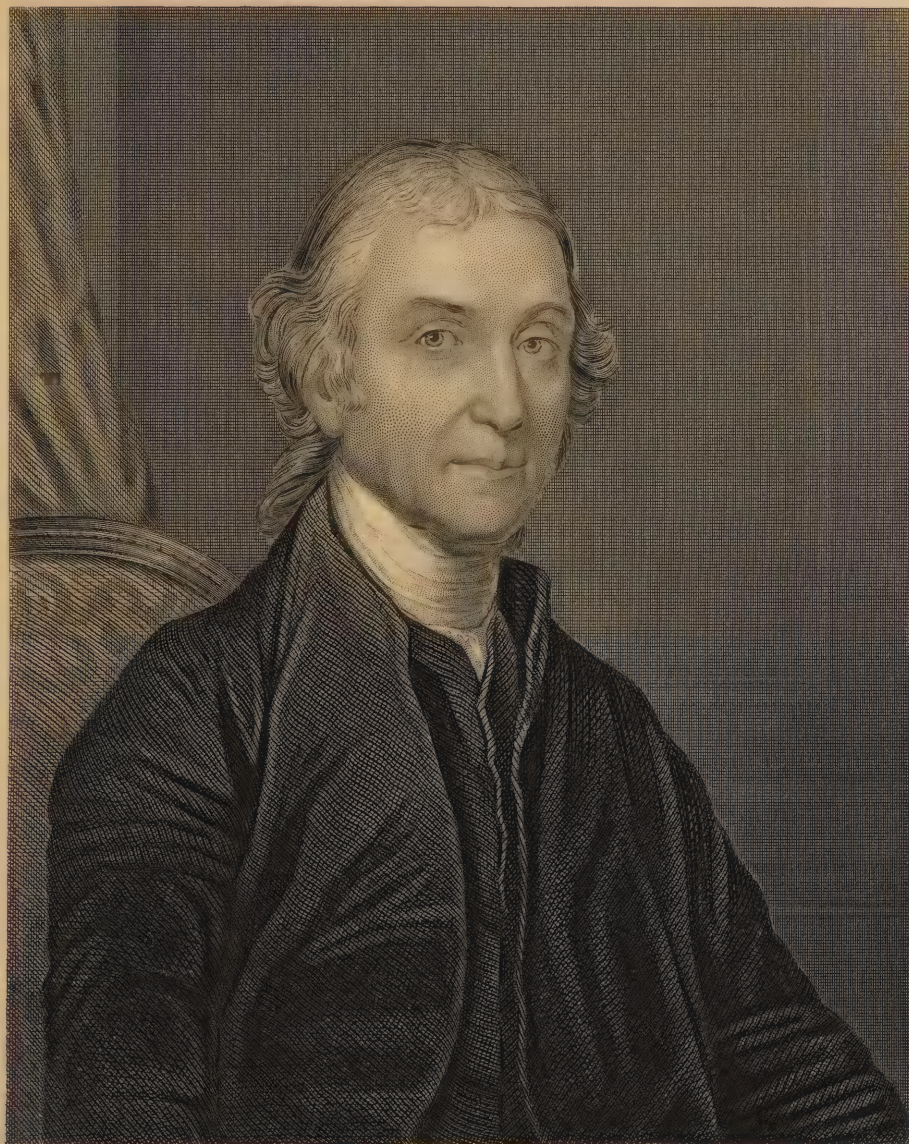
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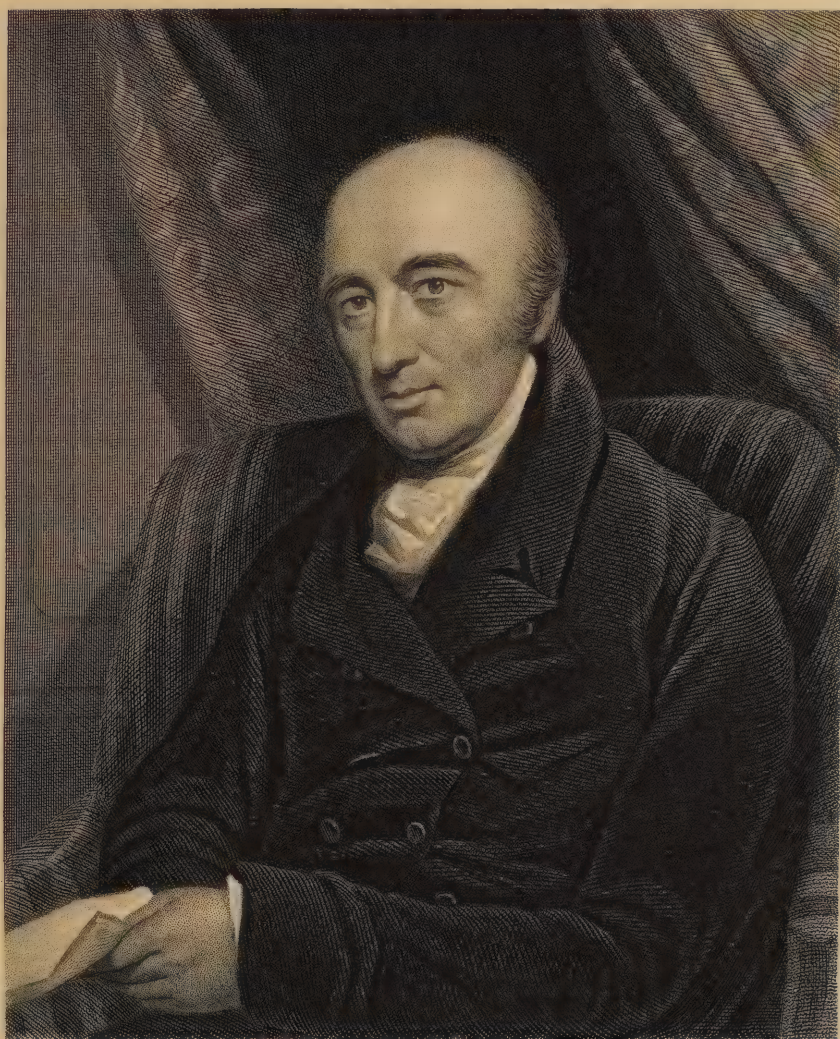
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CHEMISTRY

THEORETICAL, PRACTICAL, AND ANALYTICAL,

AS APPLIED AND RELATING TO

THE ARTS AND MANUFACTURES.

There are qualities in the products of Nature yet undiscovered, and combinations in the powers of Art yet untried. It is the duty of every man to endeavor that something may be added, by his industry, to the hereditary aggregate of knowledge and happiness.—Dr. JOUSSON.

FUEL—NATURE AND PROPERTIES OF CALORIC.

FUEL.—*Combustible*, French; *Brennstoff*, German; *Fomes*, Latin.—The importance which must have been attached in every age, from the earliest period of human existence, to fire, and the necessity which has ever impelled mankind to provide it, not so much for purposes of luxury, as an absolute essential, to enable them to counteract the effects of climate and other external influences which affect the frame, are sufficient, apart from any other consideration, to impress every one with a sense of its usefulness. It is not in reference to these primary applications, however, that the full value of fire, or the extent of its influence, will be understood, but only when it is studied in connection with the various natural and artificial transformations of matter which it produces.

Nations, however rude or barbarous they might have been, always made use of fire: Firstly, as a means of preservation; Secondly, as a source of comfort or luxury; and lastly, as a destructive agent. The history of its application in relation to these three objects would offer a comprehensive view of the advance of civilization. Not only do the attributes of fire exert a gigantic influence in the various social requirements, but in the most minute as well as the most elaborate changes which take place in nature. Heat and light, indeed, seem to be the life-giving principles of the material world, and are not less essential to man in subduing matter to his service.

Among the material sources of heat, all the substances chemically termed *combustible*, such as carbon, sulphur, phosphorus, potassium, iron, *et cetera*, may be regarded as particular kinds of fuel, although the name is usually restricted to organic products of ligneous origin, such as woody matters, coal, peat, and the like.

As the consideration of fuel is intimately associated with heat, and as this is a subject of great practical importance, it will be necessary to enter into somewhat

lengthened details in regard to the nature of caloric—the term applied to the substance or cause of heat, in contradistinction to the sensation which it produces. This theoretical inquiry is essential to a full understanding of various processes and instruments mentioned in the present work, and more especially is it indispensable to a complete elucidation of the nature and action of fuel; or, in other words, of those substances employed to generate that principle which constitutes the great agent, not only in impelling machinery, but in most manufacturing operations. The Editor will, therefore, make no apology for entering here at considerable length into a preliminary exposition of the nature of heat or caloric.

NATURE AND PROPERTIES OF CALORIC.—Of the three imponderables—caloric, light, and electricity—caloric is that which produces the sensation of heat or warmth in animal bodies. It exists, however, in considerable quantities, even when it cannot be distinguished by this test.

Substances communicate a warm sensation when their contained heat exceeds that of the part of the body which touches them; and they are said to be cold when the heat of the latter is greater. Hence it is evident that heat and cold are merely relative terms, and do not indicate the actual amount of caloric which is contained in any body. This can be readily proved by exposing the two hands to unequal degrees of temperature, and then bringing them in contact with a body containing an intermediate quantity; the heated hand will experience the sensation of cold, and the other of heat; that is to say, the same substance will communicate the sensation of heat or cold, according to the temperature of the part of the body touching it.

Caloric is self-repulsive, and eminently destroys cohesion, because it induces the particles of matter to separate to a greater or less distance, according to the

amount of it which combines with them—thus producing what is termed *expansion* or *dilatation*. It pervades and penetrates all bodies, however compact they may be, and seems to be in constant intercommunication between them, more especially if they are possessed of it in unequal quantities. In its passage from any one body to surrounding objects, it emanates in direct lines with a velocity hitherto undetermined, but supposed to be equal to that of light. Its intensity, also, diminishes in the ratio of the square of the distance from the heated body. Thus, if at the distance of one foot from the source of heat the effect be accounted unity, at two feet it will be only one-fourth as much, at three only one-ninth, and so on. Heat may be conveyed from one body to another in three ways: firstly, it may pass from one particle to another when the substances are in contact; secondly, it may be emitted in direct lines to a distance; and, thirdly, it may be received after passing through another body which offers little resistance to it. In the first of these cases, it is said to be *conducted*; in the second, *radiated*; and in the third, *transmitted*. In many of its properties it resembles light—more especially in the facility with which it is reflected and refracted. The phenomena of dew, wind, frost, snow, and other atmospheric changes, are consequences of the unequal amount of caloric combined with water.

Sources of Caloric.—Among the acknowledged sources of heat—namely, the sun, electricity, chemical and mechanical action—some enumerate vital action; but this may be regarded as included in the preceding list, for its operations may be referred to the united effects of chemical and mechanical action.

The heat of the sun has been approximately estimated by POUILLET, as between 2662° and 3202° Fahr. When the rays of this luminary are concentrated either by lenses or reflectors, a great amount of caloric may be brought to operate on bodies at a considerable distance. BUFFON ignited a board of tarred beech with forty reflectors, at a distance of sixty-six feet; with the power of one hundred and twenty-eight mirrors he set on fire a tarred pine plank, which was one hundred and fifty feet distant. Pieces of coin and other metallic matters were readily melted by this means.

Electricity supplies a heat so intense as to be capable of fusing and even volatilizing matters which, under ordinary circumstances, resist the action of the hottest furnace. Indeed, by galvanism, the highest temperature hitherto obtained has been produced.

Chemical action is, next to the sun's rays, the commonest and most useful source of heat, and the methods of generating it in this manner are various; but that which is best known and most frequently resorted to is combustion. By *combustion* is usually understood that change which a body undergoes on being ignited in the air, and by which light and heat are evolved, whilst the substance itself disappears. Chemically considered, however, combustion is the effect of the union of two or more elements, whereby heat is always disengaged, though light is not a necessary consequent in every instance. Thus, in numerous chemical combinations, considerable quantities of caloric are set free, unattended with luminousness. Animal or vital heat is generated principally by the chemical changes which

the food as well as the components of the body are constantly undergoing; and the movements of the members contribute to its more rapid production.

Finally, mechanical action, either by percussion or friction, is capable of disengaging heat from bodies in large quantities. For instance, if a bar of iron be struck with a hammer, a certain amount of caloric will be evolved at every stroke; and by vigorously continuing the action the bar may be made red-hot. But after a rod of metal which has been rendered incandescent by this means has once cooled, no amount of mechanical force is afterwards sufficient to bring it again to a glow, unless it be heated in the fire and allowed to cool. This is owing to the circumstance, that the metal cannot secrete in its condensed state as much latent heat as would be necessary to raise its temperature when further compressed; for the evolution of heat by percussion appears to depend upon the compression of the particles of the body struck. BERTHOLLET measured the amount of caloric emitted from the strokes of a coining-press; he found that, at the first stroke, it gave off 17.3° , at the second 7.5° , and at the third only 1.9° .

Friction is another mechanical means of producing or developing caloric. Instances of this are familiar to engineers, and workers in metal who are engaged in boring, filing, *et cetera*. Even the rubbing of one piece of ice against another may be made to produce an evolution of heat sufficient to melt both, and this will take place more or less quickly according to the amount of force applied in the friction. Count RUMFORD ascertained that the heat liberated in boring a piece of cannon seven and a half inches in diameter, the instrument making thirty revolutions per minute under a pressure of ten thousand pounds, was sufficient to boil eighteen pounds of water in two hours and a half. If a bar of steel be forcibly struck against a piece of flint or other hard body, the caloric which is set free will be sufficient to cause the combustion of the particles of the metal which are disengaged, and which are seen to fly off in sparks.

Expansive Action of Caloric.—The effects of caloric upon matter are various; but that which is most important, and which will require to be considered first, as affording a convenient measure of its intensity, is its *expansive action*. The distribution of matter into aeriform, liquid, and solid bodies depends on this principle. Many bodies possess the quality of uniting with heat and retaining it to such an extent, that they remain permanently liquid or gaseous, whilst other compounds, having less of the same principle, are solid at ordinary temperatures. In rendering solid bodies aeriform and liquid, the self-repulsive action of the heat overcomes the cohesive force with which the particles were held together, and separates them to a certain distance, dependent upon the amount of caloric absorbed. When a bar of brass strongly heated is placed upon another one of a different kind, but which is an imperfect conductor, for instance lead, the repulsive action of heat will be shown by the evolution of sound. This happens in consequence of caloric being communicated by the heated metal to the lead in contact with it, but not being immediately conducted to other particles of the

latter metal, repulsion follows, and the hot body is thrown out of close union; descending, however, by the force of gravity, it again comes in contact with the lead, or nearly so. This contact is immediately broken off, and again renewed, the movement thus continuing in rapid succession till the brass cools. The vibration gives rise to musical sounds. BADEN POWELL ingeniously measured the force of the self-repulsion of heat by means of colored rings. A flat and convex glass plate were strongly pressed together, and the colored rings formed by the refraction of light from the thin stratum of air between, afforded him the means of estimating the repulsive force; for when heat was applied to the lower plate, the rings altered and closed in towards the centre, showing that the glass plates receded from one another. Now, as each of the annular colors has a certain determinate thickness, it is evident that the degree of repulsion may be ascertained from the narrowing which occurs in the breadth of the rings as the temperature rises.

The expansion or dilatation produced in bodies by heat is a familiar phenomenon. Very great difference exists, however, as to the extent to which divers substances are affected by the same amount of heat. In such compounds as are permanently gaseous, no opposition is offered to the distending power of the combined caloric, and the result is, that these dilate in a regular and uniform ratio, no matter how hot or cold they may be when the caloric is communicated. It is different with solids and liquids, in which the resistance offered by the varying force of cohesion must first be overcome before any discernible repulsion of the particles succeeds. Where this opposing force is great, it is evident that a much larger amount of heat will be required to distend them. Hence the difference in the rate of expansion of bodies produced by this agency.

The Thermometer.—The thermometer, or heat-measurer, is constructed upon the principle of the expansion of bodies by caloric. It consists, in its common form, of a glass tube terminating in a bulb containing mercury or some other fluid, which fills the bulb and part of the tube; and the rise or fall of the fluid in the tube, according as the mass of it in the bulb expands or contracts, indicates the changes of temperature in the surrounding medium. This most indispensable instrument was not known previous to the sixteenth century, and, at its first introduction by the Florentine academicians, its indications were not very trustworthy. At first, the change of the amount of caloric was estimated by the expansion of air; but this, although in common with other aeriform fluids more regular than liquids or solids in its alteration of volume by increased or diminished temperatures, offered so much inconvenience in the wide extent of its range, besides being largely affected by the varying pressure of the atmosphere, that it was found necessary to substitute another fluid. Various liquids, such as linseed oil and spirit of wine, were tried with good effect; but, for general purposes, mercury was found to be the most suitable. The range between its points of solidification and ebullition is greater than that of any other known fluid; it is also a good conductor of heat, and is, consequently, rapid in

its indications, and sensitive to sudden changes of temperature. It is true that it experiences, like other fluids, as will be explained afterwards, a constantly increasing rate of expansion as the temperature rises, but between the freezing and boiling points of water this irregularity is so minute, as to be really of little or no moment even in very accurate investigations; indeed, the slight deviation which takes place is nearly compensated by the glass, which expands in much the same proportion as mercury.

There are three varieties of this instrument, differing merely in the notation. FAHRENHEIT, whose thermometer is generally used in this country, fixed the zero of his scale at the temperature of a mixture of snow and salt, and divided the interval between this and the boiling point of water into two hundred and twelve equal parts or degrees, so that on this scale water freezes at 32° , and there are 180° between its freezing and boiling points. CELSIUS, in constructing his modification of the thermometer, assumed as the zero of his scale the freezing point of water, and, proceeding on the decimal principle, divided the interval between this and the boiling point into one hundred equal parts, so that on this scale the point of ebullition is indicated by 100° . Hence, his instrument, which is used extensively on the Continent, has been called the Centigrade. In REAUMUR's scale, as in the Centigrade, the freezing point is the zero; but the distance between the freezing and boiling points is in REAUMUR's divided into 80 equal parts, instead of 100, so that on this scale the boiling point of water is at 80° . In each of these thermometers the degrees of temperature under the zero are indicated by the sign *minus*. Thus, -15° Fahr. indicates fifteen degrees of that scale below the temperature of a mixture of snow and salt; while the same notation on the Centigrade or Reaumur scale signifies a temperature fifteen degrees of the one or the other of these scales below the freezing point of water.

By very simple formulæ, the degrees of any of these thermometers may be converted into the equivalent of the others. The same distance is divided in the three thermometers into 180° in Fahrenheit's, 80° in Reaumur's, and 100° in the Centigrade. Now, dividing by twenty, it will be seen that these numbers are in the ratio of 9 : 4 : 5; or, in other words, nine degrees of Fahrenheit's scale are equivalent to four degrees of Reaumur's, and five of the Centigrade. Hence, indicating the respective thermometers by the initials F., R., C., the length of a degree in each will be as follows:—

$$1^{\circ} \text{ F.} : 1^{\circ} \text{ R.} : 1^{\circ} \text{ C.} :: \frac{1}{9} : \frac{1}{4} : \frac{1}{5}$$

But the temperature is measured by the number of divisions contained in equal portions of the stem of the respective thermometers. Now, the zero point of Fahrenheit's is 32° below freezing point. If, therefore, $F.^{\circ} - 32$, $R.^{\circ}$, $C.^{\circ}$, indicate the same temperature on each of the three thermometers, one has the proportion:—

$$F.^{\circ} - 32 : C.^{\circ} : R.^{\circ} :: 9 : 5 : 4$$

whence result the following equations for converting one scale into another:—

$$\begin{aligned}
 4 \text{ (F.}^\circ\text{--32)} &= 9 \text{ R.}^\circ \\
 5 \text{ (F.}^\circ\text{--32)} &= 9 \text{ C.}^\circ \\
 5 \text{ R.}^\circ &= 4 \text{ C.}^\circ \\
 &\text{or,} \\
 \frac{1}{9} \text{ (F.}^\circ\text{--32)} &= \frac{1}{4} \text{ R.}^\circ = \frac{1}{5} \text{ C.}^\circ
 \end{aligned}$$

The divisions principally used are those of Fahrenheit and the Centigrade, and the equations for passing from the indications of the Centigrade to those of Fahrenheit, and *vice versa*, are—

$$\begin{aligned}
 \text{F.}^\circ &= 32 + \frac{9}{5} \text{ C.}^\circ \\
 \text{C.}^\circ &= \frac{5}{9} (\text{F.}^\circ - 32)
 \end{aligned}$$

that is, add thirty-two to nine-fifths of the number indicated on the Centigrade, and the result is the number which would be indicated by Fahrenheit; subtract thirty-two from the number indicated by Fahrenheit, and five-ninths of the remainder is the number which would be indicated by the Centigrade.

When very low temperatures, under -40° Fahr., have to be estimated, a mercurial thermometer cannot be employed, since this metal solidifies at that point; in such cases, alcohol colored by some matter is used in the bulb of the instrument. On the other hand, mercury boils at about 600° Fahr., and, therefore, when very high temperatures are to be estimated, a different instrument, termed the pyrometer, is employed, which will be described in the sequel.

Whatever be the form of thermometer, it is evident that the indications are merely relative, and do not express the actual amount of caloric which a substance contains. The use of the thermometer, therefore, is merely to indicate the sensible heat, or that which is capable of being radiated or communicated from one material to another; and for this purpose it is of most important application in various branches of the arts and manufactures, serving for the guidance of the operatives in numerous processes, to the success of which it is absolutely indispensable.

Expansion of Solids.—The rate of expansion in solid bodies is greatly dependent on their state of aggregation; hence it will be evident that the same amount of caloric will operate differently on different solids, but the effect is more visible in the metals than upon other solid non-metallic substances.

The following table exhibits the rate of expansion of a few solids when heated from 32° to 212° FAHR.

TABLE OF EXPANSION FROM 32° TO 212° FAHR.

Name.	Expansion in length.	Do. in bulk.	Authorities.
Zinc, cast,	1 in 323		
„ sheet,	1 „ 340	1 in 113	Smeaton.
Lead,	1 „ 351	1 „ 117	
Tin,	1 „ 516	1 „ 172	
Silver,	1 „ 524	1 „ 175	Lavoisier
Brass,	1 „ 536	1 „ 179	and
Copper,	1 „ 582	1 „ 194	Laplace.
Gold,	1 „ 682	1 „ 227	
Bismuth,	1 „ 712	1 „ 239	Smeaton.
Iron,	1 „ 846	1 „ 282	{ Dulong and
Antimony,	1 „ 923	1 „ 307	Petit.
Tempered steel, . . .	1 „ 926	1 „ 309	Smeaton.
Palladium,	1 „ 1000	1 „ 333	Lav. and Lap.
Platinum,	1 „ 1131	1 „ 377	Wollaston.
Glass without lead, 1 „	1148	1 „ 382	{ Dulong and
Flint glass,	1 „ 1248	1 „ 416	Petit.
			Lav. and Lap.

From the foregoing results it is evident that the expansion in bulk is about three times as great as the

linear expansion; or, in other words, by multiplying the latter by three, the product will approach closely to the increase in bulk. It must be observed, however, that the expansion is not uniform for equal increments of temperature, for all bodies tend to expand more as the heat reaches a high degree. This is especially the case with metals; hence it is that mercurial thermometers are not well adapted for measuring degrees of temperature much higher than that of boiling water, owing to the increase of the metal at high heats being greater than at low. The rates of expansion in mercury from 32° to 572° are—one in 55.08 between the freezing and boiling points of water; one in 54.61 between the latter and 392° ; and one in 54.01 between this and 572° .

The extent to which glass expands when heated within the same range is given in the table annexed:—

Temperature by air thermometer.	Mean absolute dilatation of glass for each degree.	Temperature by thermometer made of glass.
From 32° to 212°	$\frac{1}{55.08}$	212°
„ 32° to 392°	$\frac{1}{54.61}$	415.8°
„ 32° to 572°	$\frac{1}{54.01}$	667.2°

Most solids return to their original volume when they have parted with the caloric which caused the distention of their particles; some, however, are incapable of doing so, and are permanently elongated or enlarged every time they are subjected to the influence of a high temperature. Such is the case, more especially, with zinc and lead—the particles of which, in sliding over each other, are supposed to possess an amount of adhesive friction which prevents their retraction to the full extent they had expanded.

The expansion or contraction of bodies, occasioned by an increase or diminution of temperature, takes place with enormous force. The amount of this has been estimated by BARLOW, who found that a bar of metal, of one square inch section, is elongated one ten-thousandth of its length by receiving an addition to its temperature of 16° ; to produce the same effect mechanically would require a ton weight to be suspended from it, or the application of an equivalent force. A careful attention to this subject is indispensable in the sciences of engineering, horology, *et cetera*. It has been found that within the usual range of the variation of the temperature of England throughout the year, a bar of wrought-iron, ten inches long, will expand about two hundredths of an inch. Were both its extremities secured firmly to other objects, this change would exert a force, tending towards their removal, of fifty tons to the square inch; hence it is to be observed that where beams of wood are to be replaced by iron ones, care should be taken that room for occasional expansion should be allowed them, otherwise very ruinous consequences might result. From the numerous and varied uses to which iron is now applied, this is a subject of very great importance. An accurate calculation must be made, and the structure so formed, as that the expansion or contraction of the metal shall not endanger its stability.

A very ingenious application of the power obtained by the enormous force of the contraction of metals was made by MOLARD, to secure the Museum of Arts and

Manufactures in Paris, by restoring the walls, which were giving way outward owing to the weight of the roof. His method was to insert bars of iron horizontally through the building, so as to protrude a little from the walls at each side. Heat was then applied by lamps suspended over the whole length of the bars, and the metal expanded to some extent, after which iron nuts were firmly screwed on the bars at both ends, and tightened to the wall as much as possible; the heat being now removed, the metal began to contract, and in doing so, it drew the nuts closer together, which had the effect of bringing the walls nearer to the perpendicular. By a repetition of the heating of the bars, and again tightening the nuts or plates, the bulges were entirely removed, and the walls were restored to their vertical position. In many of the ordinary arts of life, a similar advantage has been taken of the effect of heat upon bodies to render peculiar service; the wheel-wright, by heating the tire and fitting it on in an expanded state, and then allowing it to contract, insures the firmness and durability of the wheel; the cooper, in like manner,

heats the hoops of his casks, *et cetera*, when fitting them in their proper place, so that when they cool they may bind the staves more firmly; and the boiler-maker uses red-hot rivets as well for facilitating their plating, as for binding the sheets of metal more tightly by their subsequent contraction on cooling.

The sudden application of heat to many bodies is productive of fracture, owing to a partial expansion of the part heated, while the part not so affected refuses to yield. This is frequently seen in glass and cast-iron plates. Indeed, the most delicate part of the glass-maker's business, as will be seen in a future article, is the annealing; or, in other words, the exposure of the goods to a gradual cooling, which renders them less liable to crack when exposed to sudden changes of temperature.

A tabular statement of the rate of expansion of a few of the metals is subjoined, with a comparative view of the results when the temperature is measured with the air thermometer, and with one constructed of the metals under experiment:—

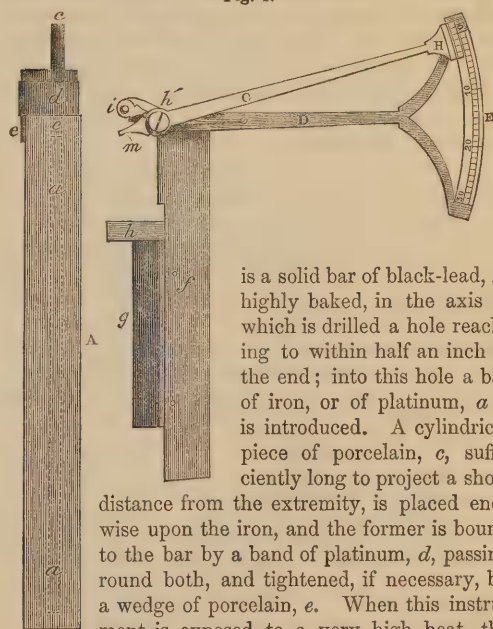
Temperature by air thermometer.	Mean dilatation of iron for each degree.	Temperature by iron rod thermometer.	Mean dilatation of copper for each degree.	Temperature by copper thermometer.	Mean dilatation of platinum for each degree.	Temperature by platinum thermometer.
212°	50160	212°	34120	212°	57380	212°
572°	40678	702°5	31800	623°8	55340	592°9

In estimating the temperature at high degrees by a mercurial thermometer, the observations made as to the rise of the metal indicate only the difference between the expansion of the glass and that of the metal, which, in ordinary cases, is supposed to be uniform; but owing to the increased expansion which the mercury experiences at a high temperature, 572° on the air thermometer corresponds with 586° on the mercurial one. The same temperature estimated by glass alone would be indicated by 667°, thus showing that the dilatation of the glass counteracts the expansion of the fluid metal. Considerable difference will be observed in the table between the indication of the air thermometer and that which is found by measuring the expansion of bars of metal; so that at high temperatures, which liquids and gaseous bodies cannot be employed to measure, the true indication of heat, as compared with the air thermometer, is somewhat difficult to ascertain. A further obstacle stands in the way, inasmuch as the rate of expansion in metals and most solid bodies is unequal. M. BREQUET contrived to overcome this by constructing a solid thermometer, composed of a compound ribbon of three metals—gold, platinum, and silver—rolled out very thin and coiled spirally. The upper end of these was fixed, and the lower one attached to an index which described an arc, as the helix twisted or untwisted, by the greater expansion or contraction of the silver band over the platinum one. By graduating the range of the index, and finding the value of the indications by comparing them with those of a standard thermometer, the instrument was completed.

The Pyrometer.—When the temperature is very high, such as that at which the more infusible metals melt, or of a reverberatory or wind furnace, the common thermometer is unavailable, and other instruments for estimating the heat have been invented, which are called *pyro-*

mers. Of these, DANIELL'S register pyrometer, represented in Fig. 1, is the most accurate. It consists of two parts, namely, the register and the scale. The register

Fig. 1.



is a solid bar of black-lead, A, highly baked, in the axis of which is drilled a hole reaching to within half an inch of the end; into this hole a bar of iron, or of platinum, *aa*, is introduced. A cylindrical piece of porcelain, *c*, sufficiently long to project a short

distance from the extremity, is placed end-wise upon the iron, and the former is bound to the bar by a band of platinum, *d*, passing round both, and tightened, if necessary, by a wedge of porcelain, *e*. When this instrument is exposed to a very high heat, the whole increases in bulk, in proportion to its intensity; but the rate of expansion of the metal and of its casing being unequal, the porcelain cylinder, *cc*, will be protruded to the extent of the difference.

To measure the length of the protruded portion, the scale is applied. This consists of two brass rules, *f*, *g*, joined together by screws, to form a right

angle, and fitting exactly upon the sides of the register. The plate, *h*, rests on the shoulder of the bar, *A*, formed for the platinum band. At the extremity of the rule nearest this, an arm, *D*, movable upon its centre, *i*, is fixed; and at the other an arc of a circle, *E*, graduated into degrees and thirds of degrees. Upon the latter, at *h'*, is another lighter arm, *C*, carrying upon the end of its longer limb a nonius, *H*, which moves upon the face of the arc, *E*, and subdivides the graduations into minutes. The other end of this arm protrudes beyond the centre of motion, and carries a steel knife-edged bar, which fits into the notch cut for it in the termination of the index.

The index bar is pressed firmly down upon the metal encased in the black-lead, and securely fixed there by the wedge and band of platinum; the bar is

then nicely adjusted in the angle formed by the two rules of the scale; the plate, *h*, firmly held against the shoulder, and the knife edge, *m*, resting in the notch in the index bar; the position of the latter is now noted on the scale, and after the register has been heated and allowed to cool, the scale is again applied and the result observed—the difference is the value of the expansion of the metal bar. By comparing this with the indications given by a mercurial thermometer between any two points, say that of the freezing and boiling of water, an expression in degrees of Fahrenheit's scale may be given to any degree of artificial heat measurable by the instrument.

DANIELL, with this apparatus, obtained the following results, in which the expansion is shown at three stages:—

1,000,000 parts at 62°.	At 212°.	At 662°.	At fusing point.
Black-lead ware,.....	1,000,244	1,000,703	
Wedgwood ware,.....	1,000,735	1,002,995	
Platinum,.....	1,000,735	1,002,995	1,009,926 maximum, but not fused.
Iron—wrought,.....	1,000,984	1,004,483	1,018,378 to the fusing point of cast-iron.
Iron—cast,.....	1,000,893	1,003,943	1,016,389
Gold,.....	1,001,025	1,004,238	
Copper,.....	1,001,430	1,006,347	1,024,376
Silver,.....	1,001,626	1,006,886	1,020,640
Zinc,.....	1,002,480	1,008,527	1,012,621
Lead,.....	1,002,323	—	1,000,972
Tin,.....	1,001,472	—	1,003,798

Expansion of Liquids.—In liquids, the expansion produced by heat is much more marked than in solids; they also differ among themselves in the amount of expansion produced by equal increments of heat. The most volatile liquids, or those of which the boiling point is low, are found to be the most expansible under the influence of an increase of caloric, as may be observed from the appended table, showing the comparative increase in volume of several liquids when heated from 32° to 212°:—

Water,.....	0.0466	Dalton.
Saturated solution of chloride of sodium,.....	0.0500	"
Concentrated sulphuric acid,.....	0.0600	"
Hydrochloric acid, specific gravity 1.137.....	0.0600	"
Nitric acid, specific gravity 1.40.....	0.1100	"
Alcohol, specific gravity 0.817.....	0.1100	"
Ether,.....	0.0700	"
Oil of turpentine,.....	0.0700	"
Fat oil,.....	0.0800	"
Mercury,.....	0.02000	"
".....	0.01887	Cavendish.

Mercury,.....	0.01848	Lavoisier and Laplace
".....	0.01818	Hallstrom.
".....	0.01801	Shuckburgh.
".....	0.01800	Petit and Dulong.
".....	0.01786	Deluc.
".....	0.01665	Roy.

A difference in the seething point of liquids, however, does not always show a corresponding variation in their expansion, as was long ago proved by LAVOISIER with regard to alcohol and bisulphide of carbon, two liquids differing in their boiling points by 57°, yet the rate of expansion is the same in both for each increase of an equal number of degrees of heat, reckoned from their respective boiling points. PIERRE found similar results in his researches upon liquids of analogous composition, such as the bromides and iodides of ethyl and methyl. This relation, however, does not appear between some of the isomeric bodies examined, as may be seen from the annexed table, showing the

CONTRACTION FROM THE BOILING POINTS:—

Name of Liquid.	Boiling point Fahr.	Temperature equidis- tant from the boiling point of each group.	Interval between the preceding tem- peratures.	Volume at boiling point.	Volume at equidistant temperatures.
FIRST GROUP.					
Sulphide of carbon,.....	118.22°	22.72°	140.94°	1	0.913099
Alcohol,.....	172.94	32	140.94	1	0.914452
Wood spirit,.....	151.34	10.4	140.94	1	0.905819
SECOND GROUP.					
Bromide of ethyl,.....	105.26	32	73.26	1	0.944375
Bromide of methyl,.....	55.4	17.86	73.26	1	0.944575
THIRD GROUP.					
Iodide of ethyl,.....	158	32	126	1	0.918704
Iodide of methyl,.....	110.84	15.16	126	1	0.916643
FOURTH GROUP.					
Formiate of oxide of ethyl,.....	127.22	20.12	107.1	1	0.910223
Formiate of oxide of methyl,.....	139.10	32	107.1	1	0.918750

With reference to the second law which governs the expansion of liquids—namely, that they are progressively more expansible at higher than at lower temperatures—it is to be remarked, that in this respect considerable difference exists between different liquids; and in mercury the higher expansion at higher temperatures is less than in any other fluid body. Hence, it is better adapted than any of them for the construction of thermometers. The expansion which takes place in each of the substances enumerated in the following table, between the freezing and boiling points of water at the ordinary pressure, is represented by one hundred parts, and the increase which equal increments of heat produce above 212° is proportionally estimated:—

Dulong and Petit.					
Air.	Mercury.	Platinum.	Copper.	Iron.	Glass.
0 .. 0	0 .. 0	0 .. 0	0 .. 0	0 .. 0	0 .. 0
100 .. 100	100 .. 100	100 .. 100	100 .. 100	100 .. 100	100 .. 100
150 .. 151.3					
200 .. 204.6					

In cooling, 22.5° from 219°	to 189.5°, 2000	measures of water contracted 18	measures.
" "	189.5° to 167°	" "	16.2 "
" "	167° to 144.5°	" "	13.8 "
" "	144.5° to 122°	" "	11.5 "
" "	122° to 99.5°	" "	9.3 "
" "	99.5° to 77°	" "	7.7 "
" "	77° to 54.5°	" "	3.9 "
" "	54.5° to 32°	" "	0.2 "

The dilatation of water, when reduced in temperature below 39.4°, serves a purpose of the greatest consequence in the economy of nature—namely, in preventing the transmission of cold beyond the surface of the water in very rigorous seasons, and preserving the chief bulk of the fluid at such a temperature as is congenial to the life of the animals that inhabit it. The fusible alloy of ROSE possesses properties in some respects analogous to water. This substance increases in bulk till it reaches about 111°, after which it contracts when its temperature is being raised from this to 156°, the point of its greatest density, and at which its bulk is less than when at the freezing point of water; after this, however, it continues to expand till it reaches its fusing point at 201°.

Expansion of Gases.—The third class of bodies to be considered in relation to the expansive force of heat, are gases. All these being at ordinary temperatures in a state in which the atomical aggregation manifests a highly repulsive tendency, it is evident that they will be influenced to a greater extent by caloric than either of the foregoing classes. A remarkable coincidence or uniformity, however, is found to exist among the different members of this class; and, knowing the rate of expansion of one when combined with a certain amount of caloric, the same may be taken as the expansive power of the other permanent gases and elastic vapors when subjected to an equal increase of temperature. By former investigations, this was found to amount to about three hundred and seventy-five parts in a thousand of air, when heated from the freezing to the boiling point of water; later researches, however, have shown that the true expansion of air within these limits is three hundred and sixty-six parts, or $\frac{1}{491.2}$ of the whole for each degree of Fahrenheit's scale.

Dulong and Petit.				
Air.	Mercury.	Platinum.	Copper.	Iron.
250 .. 255.1				
300 .. 314.15		311.6 ..	328.8 ..	372.6 ..
350 .. 360				352.9

Water, within the range of its solidifying point and that at which it becomes an elastic vapor, is subject to very great irregularities. The general law, as before expressed, is, that heat exerts an expansive force upon all bodies; but, within a certain range, water becomes an exception. If this liquid be taken in the solid state, or at the temperature of 32°, before it has solidified, and caloric be communicated to it, instead of expanding, it actually contracts till it marks about 39.4°, at which it has attained its greatest density. Above this, it expands in the same ratio that the contraction took place for an equal number of degrees, but beyond that point it obeys the general law.

COUNT RUMFORD found the contraction of water for every 22.5° from the boiling to the freezing temperatures to be as follows, namely:—

Below the freezing and above the boiling point of water, the expansion is in the same ratio. A volume of gas measuring four hundred and ninety-one parts at 32° Fahr. expands, for every degree of heat additional, one part; so that at 60°—that is, with an increase of 28° of the thermometric scale—the volume becomes five hundred and nineteen parts. This ratio continues as long as the temperature rises, so that when the whole is heated to 523° = 32° + 491°, or in other words, is raised through as many degrees as there are original divisions in the bulk of the liquid, the volume will be doubled; and in proportion as multiples of this increase of temperature are applied, so will the air dilate to three, four, or more times its bulk. It was found, however, by MAGNUS and REGNAULT that the operation of this law is not perfectly uniform, especially with reference to the easily liquefied gases, which are more expansible than air when exposed to equal increments of heat, as the following table will show:—

Names of Gases.	Expansion upon one volume from 32° to 212°.	
	Magnus.	Regnault.
Atmospheric air,	0.366508	0.36650
Hydrogen,	0.365659	0.36678
Carbonic acid,	0.369087	0.36896
Sulphurous acid,	0.385618	0.36696
Nitrogen,	—	0.36682
Nitrous oxide,	—	0.36763
Carbonic oxide,	—	0.36667
Cyanogen,	—	0.36821
Hydrochloric acid,	—	0.36812

A sensible increase in the rate of expansion is also found when the gas is submitted to pressure, compared with that which takes place when it is in a rarefied state.

CONDUCTION AND CONVECTION OF HEAT.—Another point of great importance is the comparative

facility with which heat is conveyed or conducted through different bodies. When caloric comes in contact with solids or liquids, it enters into them and traverses from molecule to molecule, till it has permeated the whole. This property of heat, although by many supposed to be due to radiation, owing to the particles of matter not being in absolute contact, is, however, generally acknowledged to be due to a distinct action—that of conduction.

Different substances vary considerably in regard to the freedom with which caloric passes through them—that is to say, in their conducting power; and many very useful applications have been made of this property in the arts and sciences. It is upon this principle that nature protects every species of animal and vegetal life against the injurious influence of meteorological changes. The differences observed in the physical appearance of man and of other races of animals, according to their position on the globe, are ordered in conformity with the laws which regulate the conduction of heat; and the means adopted by various nations for shielding their persons from the opposite extremes of heat and cold, as also the covering of every indigenous species of living being, no matter of what class or kind, are all most admirably suited to the state and condition in which they live. The colored cuticle of the African, whose existence is ordained under a burning sun, is not less requisite for radiating or allowing a free passage for the heat he has to endure, than is the white skin of the European to prevent the sudden ingress and egress of caloric to or from the body. Not only does the natural state give proof of this wise disposition in the human species: it is still more manifest in the lower orders of creation, which have not like man the reasoning power that enables him to provide for the exigencies of his condition; hence they are usually defended by a non-conducting coat of fur or feathers, protecting them from sudden transitions of temperature.

Dense and heavy substances are generally good conductors; light and porous bodies have this property only imperfectly. This may be proved by taking metallic rods, to which small balls of wax are attached at different distances, and introducing one end of them into the flame of a candle. As the heat proceeds from one particle of the metal to another, its progress may be measured by the falling off of the balls successively, owing to the wax being melted by the heat. But if cylinders of wood, glass, or wax be heated in a similar manner, a different result will be observed, owing to the latter being bad conductors of caloric. A practical application of this fact is seen in metallic instruments intended to be used while hot; these are invariably furnished with handles of some badly-conducting material—such as wood or glass—to protect the hand from being scorched.

DESPRETZ instituted a series of experiments for determining the conducting power of metals. His method was to drill holes, at the distance of 3·93 inches apart, in bars of the metal of an equal and determinate thickness; into these holes thermometers were inserted, and the ends of the metals then applied to a heating medium. Caloric was allowed to traverse

the bars as long as the thermometers continued to indicate an increase in the temperature. The observations made in this way furnished the annexed numbers:—

Gold,.....	1000·0
Silver,.....	973·0
Copper,.....	898·2
Iron,.....	374·3
Zinc,.....	363·0
Tin,.....	303·9
Lead,.....	179·6
Marble,.....	23·6
Porcelain,.....	12·2
Fire-clay,.....	11·4

Platinum is a singular exception to the general rule above stated; for, unlike silver, copper, or such other dense bodies, a wire of this metal may be held in the hand and heated to redness at one end, even when only a few inches in length. Glass, although a substance of moderate density, is likewise a bad conductor. The conducting power of a body is much diminished by its being pulverized; thus, metallic filings are worse conductors than bars of the same material; pounded glass and sawdust are also inferior in this respect to solid rods of glass or wood. Charcoal conducts heat very feebly; as also sand, and a number of other bodies, all of which on this account are of importance in cottage architecture, and for other purposes, in which it is desirable to provide against sudden changes of temperature.

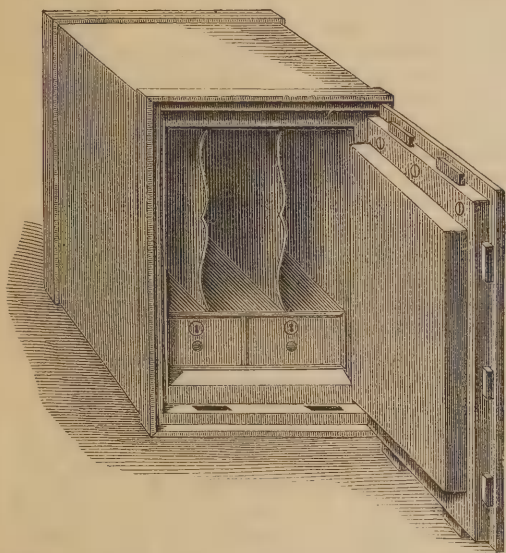
The following are the results which Mr. HUTCHINSON obtained in his researches on the conducting powers of building materials. The substances are arranged in the order in which they resist the passage of heat, the best non-conductors being placed first:—

Name of substance.	Conducting power referred to that of slate, equal 100.
Plaster and sand,.....	18·70
Keene's cement,.....	19·01
Plaster of Paris,.....	20·26
Roman cement,.....	20·88
Beech wood,.....	22·44
Lath and plaster,.....	25·55
Fir wood,.....	27·61
Oak wood,.....	33·66
Asphalte,.....	45·19
Chalk—soft,.....	56·38
Napoleon marble,.....	58·27
Stock brick,.....	60·14
Bath stone,.....	61·08
Fire brick,.....	61·70
Painswick stone, H.P.,.....	71·36
Malm brick,.....	72·92
Portland stone,.....	75·10
Lunelle marble,.....	75·41
Bolsover stone, H.P.,.....	76·35
Norfal stone, H.P.,.....	95·36
Slate,.....	100·00
Yorkshire flag,.....	110·94
Lead,.....	521·34

Besides the use which is made of the property of non-conduction in architecture, there are other departments of the arts and manufactures in which it subserves important purposes. Thus it is applied with good effect in constructing fireproof edifices or apartments, and in the manufacture of chests and boxes intended to preserve valuable property, legal documents, *et cetera*, from the destructive effects of conflagration.

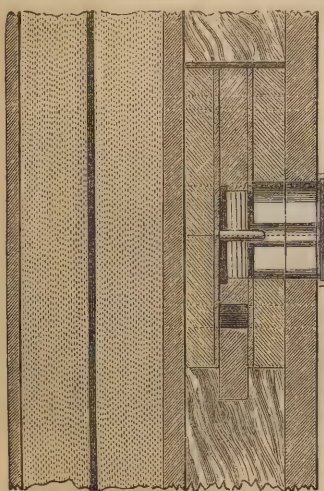
In the latter case, this is effected by interposing some solid body which is a bad conductor of heat between the interior lining and the exterior frame of the chest. The well-known safes of MILNER and SON, of Liverpool, are constructed in this way. The inner chamber is made of stout sheet-iron, firmly secured by riveted bolts to the exterior one, which, by its strength, is calculated to resist fire, and any external violence, either intentional or accidental, to which it is liable. The intermediate chamber is filled with a composition which can scarcely be excelled as a non-conducting material, whilst, at the same time, is heat-absorbing

Fig. 2.



power, or, in other words, its quality of rendering heat latent or insensible, is very great. From repeated test-

Fig. 3.



ings, at some of which the Editor attended, these articles have been proved capable of withstanding a twenty-four hours' fire of intense heat without allowing the contents to be injured in the least. Fig. 2 is a front view, and Fig. 3 a section of one of these safes. In Fig. 3, the chamber containing the non-conducting material is shown. At one time this consisted almost entirely of

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water, and hermetically sealed with a fusible alloy. When the heat reached them, the plug of metal by melting allowed the water to flow out, thus moistening the ingredients, and arresting the passage of the caloric. If the fire were prolonged, the moisture would be disseminated in vapor in the inner chamber where the valuables were deposited, and thus would secure them still more perfectly against combustion. The tubes, however, were found troublesome and expensive, and improvements of a simpler nature adopted. According to the specification of Mr. MILNER, the ingredients now used are quartz, crystallized carbonate of soda or alum, and the dust of hard woods, all of which are blended in such proportions as that twenty-five per cent. of the whole shall consist of moisture, which is capable of being expelled on the application of heat. The water in this case is exclusively derived from the salts—the carbonate of soda containing sixty-two and the alum fifty-five per cent. of water, which is separated slowly even with the application of a very high temperature.

The same principle is brought into requisition when the design is to preserve the heat in rooms and prevent it from escaping. In this case, the object is accomplished by constructing double doors and windows: thus enclosing a partition of air, which is a very imperfect conductor of caloric, and, therefore, the heat of the chamber is retained. In a similar manner, fireproof chambers may be made, having, in connection with the space between the double walls, a means for supplying cold air to occupy the place of that which must pass off as the increased temperature expands it. Unless such provision be made, the pressure which the increased tension of the vapor acquires as the heat increases would be apt to burst the walls.

On similar principles great attention is required in selecting the materials employed in the construction of furnaces. To prevent the escape of the caloric, and thus to economise fuel, the hearth and walls of the furnace are invariably compounded of some non-conducting substance, as Stourbridge clay or powdered brick, mixed with a large quantity of powdered charcoal or coke. For the same reason, boilers are imbedded in bricks or clay, and in many boilers the fire is literally enclosed within them, that none of the heat may be lost, but that all may be rendered available for raising the temperature of the water.

SERAMONT examined the conducting power of crystalline bodies, and proved that, in such as do not belong to the regular system, power varies in different directions according to the inclination of the optic axis of the crystal. DE LA RIVE and DECANOLLE have, in like manner, shown that the conducting power of wood is different according to the direction in which the heat is transmitted, being greatest in the course of the grain or fibre, and least across it. TYNDALL has established the same fact by showing that caloric much more readily traverses from the surface of a log of wood to the centre, than it does in a direction parallel to the annular layers of ligneous matter. In woods, also, as in metals, their conducting power appears to vary with their specific gravity, being

B

least in the lightest kinds; this, however, requires corroboration. Textile fibres which are manufactured into articles of clothing are very bad conductors; but their actual conducting power cannot be exactly ascertained, in consequence of the air which is contained in their pores.

Liquids in general are bad conductors of heat; it was formerly asserted, indeed, by some chemists, that water is an absolute non-conductor; it has been proved, however, that liquids conduct caloric in some measure, subject to the same laws as solids, although, as regards water and other such mobile liquids, very feebly.

The following experiment, among many which might be adduced, will illustrate the weak conducting power of water:—

Let the mouth of a bottomless glass jar, A, be closed by a perforated cork, through which the stem of an air thermometer, E, passes. Invert the jar, and pour into it cold water till nearly half-filled; on the surface of this cold liquid, place a cork disc, and then introduce a quantity of warm water colored either red or blue, to distinguish the two portions of liquid. The disc may now be cautiously removed, and the hot water will remain in a distinct layer upon the other. If the heat were conducted through the cold medium, it would act upon the air thermometer by causing the expansion of the enclosed air, and the expulsion of a proportionate quantity of the liquid from the stem; but no such effect is observed. If the cold water be now drawn off from the bottom by means of a siphon, D, it will still be found that no rise of temperature is indicated by the instrument, till the colored liquid comes in contact with the bulb, when the confined air will be expanded, and the tinged liquor in the stem ejected into the vessel into which the thermometer dips. From this it is evident that the conducting power of water is very feeble, and so with other similar mobile liquids. If, however, mercury be substituted for the cold water, and the warm water poured upon it, the effect upon the thermometer is instantaneous. This proves that fluidity is not the cause of the non-conduction of heat by water, and other similar bodies, but that it depends to a certain extent on the nature of the substance itself.

Moreover, the effect observed is very different when, instead of applying caloric at the upper surface, it is communicated to the under part, or to the bottom of the vessel in which the liquid is contained. In this case, the particles in immediate contact with the heat-giving body acquire a portion of caloric, and are expanded. This, by rendering them lighter than the surrounding ones, causes them to ascend; fresh particles succeed, and these rise in a similar manner. Currents are thus determined in the liquid, and

caloric is readily communicated to the whole mass. This, however, is not a case of conduction from particle to particle; neither is it due to radiation, which will be afterwards explained; but is the effect of *convection*—that is to say, the actual conveyance or distribution of the heated portion throughout the mass.

Very great benefits are derivable from this property of fluids. It has been

advantageously applied in the ventilation of buildings, the hot air rising to the top and escaping, while cool air is injected. It is upon this principle also that PERKINS'S apparatus for the heating of dwellings is constructed. This is represented in its simplest form in Fig. 5; it essentially consists of an iron pipe one inch in exterior diameter, and half an inch in the bore. This being filled with water and distributed throughout the building, a portion of it is heated in a furnace, and a current is thus

established through its entire length. The caloric acquired by the water in its passage through the heated portion of the pipe, is given off by radiation in performing the rest of the circuit, till it returns to be reheated. The several coils, A A A, may represent as many apartments, each embracing a considerable length of pipe; the coil, B C, which is generally about one-sixth of the whole length, and which is represented on a larger scale in Fig. 6, receives the heat of the furnace. The course

Fig. 5.

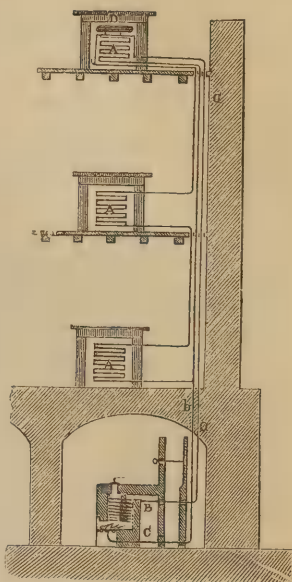
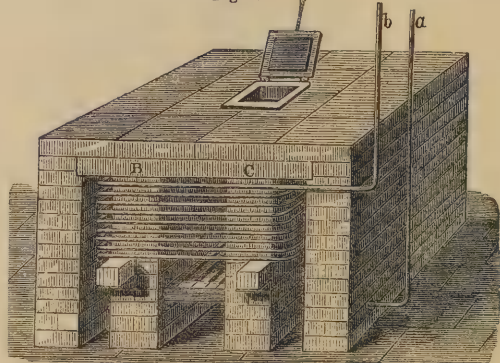


Fig. 6.



of the water from this portion is through the pipe, a a, which rises till it reaches to the top of the building; here it branches off into several conduits to traverse the different parts of the edifice, all reuniting in the

pipe, B, before returning to the furnace. Water is introduced at the open end, D, which is kept tightly plugged while the apparatus is in action; a space, E, is provided in connection with the pipe at the top of the building, to admit of room for the expansion of the heated liquid, and thus prevent the bursting of pipes: its capacity is about one-fifth or one-sixth of the whole.

Apart from the consideration of the useful purposes to which the convection of heat is applied in the arts, a far more important end is served by it in the economy of nature. During the frosts of winter, the process of cooling goes on downward from the surface of the earth and water. The colder water at the top becoming condensed, and consequently heavier than that beneath, sinks and gives place to the latter; this goes on as long as the atmosphere remains at a low temperature, till the water is reduced to its maximum density, a point which it attains at $39^{\circ}4'$. It is a remarkable circumstance, and forms a singular exception to a general law, that water when cooled to this point begins to expand, and consequently remains at the surface. When cooled to 32° it freezes, and during its conversion into ice it experiences a still further expansion, so that the ice, instead of sinking to the bottom, and there accumulating in dense masses, floats on the surface till melted—one of the most wonderful provisions for the preservation of life in the whole economy of nature.

In their mode of conducting heat, gases resemble liquids; that is to say, their power of actual conduction is inappreciable; but by their property of convection, currents are instituted by which the heat is disseminated throughout the mass. To observe this, it is only requisite to hold the hand first at the side of a lighted candle, and then above it, the distance in both cases being equal; it will be perceived that, in the first position, little heat is received, whilst in the second the increase of temperature is immediately obvious, the greater portion of the heat being carried off in the ascending current; which, in gases, is more active than in liquids, owing to their power of expansion being so much greater. The application of these currents of heated air is of great practical importance in the ventilation of dwellings and public buildings. Indeed, in every species of human habitation, provided with a fire-place and chimney, the latter operates as a ventilating apparatus. The heat derived from the combustion of fuel in the grate or on the hearth, dilates the super-imposed atmosphere, and causes its ascent in the shaft, while an influx of air to the fire supplies its place. The transmission of smoke and warm air through the chimney soon raises its temperature, and, on this account, the heat which is received from the fire is retained by the vapor till it passes out at the top. The force of the current or *draught* thus formed will be in proportion to the greater expansion of a column of air of the height of the chimney, than that of an equal column externally. Common air, like other gases, increases one five-hundredth of its bulk for each degree of temperature which it acquires; hence, by ascertaining the internal temperature and height of

the chimney, the force of the ascending atmospheric column may be calculated. When it happens that the apartment is very close, and does not admit sufficient air to supply a stream from beneath, it enters at the top of the shaft, and causes a *back draught*. In such cases the chimney is said to smoke, and the remedy usually applied is to open the door or window, so as to admit sufficient air to maintain the current. To avoid smoke, care should be taken in hanging the doors, *et cetera*, that space be allowed for the influx of air, so as to prevent its entrance from above. It is a well-known fact, that in a heated apartment the warmer portion of air rises to the ceiling, and the colder stratum remains underneath; hence it is obvious, that to maintain a proper state of ventilation, apertures must be provided in or near the ceiling, whereby the warm gases may escape. This, however, will prove ineffectual, unless provision be made for the entrance of a corresponding volume of air at or near the floor, to supply the place of that expelled. In large buildings, where the heat eliminated from fires would be ineffectual towards warming them, heated air is used in nearly the same way as the water in PERKINS'S method, only that the hot air is distributed in the various apartments through gratings in the floorings or side walls. Dr. REID'S apparatus for ventilating St. George's Hall, Liverpool, operates in this way; and several other large enclosures and churches throughout the kingdom are heated on the same principle. The phenomena of winds and oceanic currents are all referrible to the same cause; and, as in the case of ventilating apparatus, so on the large scale of the globe, the streams or currents which are induced by differences of temperature tend to equalize the amount of heat which is received from the sun, to distribute it more uniformly over sea and land, and thus to modify the intensity of cold and heat in climates exposed to opposite extremes of temperature.

RADIATION OF HEAT.—On the whole, it may be laid down as a general law, that air, the gases, water, and fluids generally, with the exception of mercury, are bad conductors of caloric, notwithstanding that it is distributed readily by them in the manner already explained. Although, however, it is the natural tendency of convection to operate upwards, yet, if the hand or the bulb of a sensitive thermometer be placed at some distance beneath a warm body, or on either side of it, an increase of heat will be indicated. From this it is evident, that though the permanent gases and the atmosphere do not sensibly conduct caloric, yet, in common with liquids and other transparent bodies, they permit its passage without being themselves appreciably affected by it. All the caloric received by the earth from the sun—the amount of which, to each acre in the latitude of London, is calculated by FARADAY to be equivalent to that which is generated by the combustion of sixty sacks of coal—thus travels through the intermediate space of ninety-five millions of miles, without sensibly affecting the temperature of the atmosphere, or that of the subtle medium beyond it. When heat emanates from any body in this way, it is said to be radiated from it, and the imponderable itself is denominated *radiant heat*. Thus, if a bar of heated

metal be suspended in a room for some time, the excess of caloric contained in it will pass off in all directions, and the metal ultimately indicates only the same temperature as the surrounding objects. During the cooling, the heat passes off at all points of the body in direct lines as from a centre—hence the term *radiated*. To prove that convection and radiation are distinct processes, and that the latter is not a consequence of the former, all that is necessary is to expose a heated body in the vacuum of an air-pump, in which case it will be observed that the emission of caloric is much quicker even than if it were allowed to cool in contact with the air.

In simple language, the rate of cooling expresses the radiating power; and LESLIE ascertained that the radiating power of bodies was more influenced by the state of their surface than by the nature of the material. A bright tin globe filled with water at a certain temperature was allowed to cool, and the time being carefully noted, it was found that the contents of the vessel cooled half way to the temperature of the room, in one hundred and fifty-six minutes. When the same experiment was repeated with the surface of the globe coated with lamp-black, it was observed that the mercury in the thermometer fell through the same space as it did in the first experiment in eighty-one minutes: thus showing, that by the alteration of the surface the radiating power was doubled. Count RUMFORD corroborated this observation by another experiment. Taking two brass cylinders of equal size and capacity, and investing one of them tightly with linen, while the other was left bare, he filled the two with boiling water, and allowed them to cool. During this process, he observed that the coated cylinder lost 10° of its original temperature in thirty-six minutes and a half, while the other required fifty-five minutes to pass through an equal range. Hence may be deduced the important practical inference, that liquids are best kept warm in highly polished vessels, and that it is an error to wrap them round with cloths or other coverings, which radiate the heat more rapidly than polished metals.

By following the method of LESLIE and Count RUMFORD in the foregoing experiments, namely, coating the heated surface with various materials, and observing the time required in cooling, or, as will be presently noticed, by concentrating the rays radiated from a certain extent of surface, and ascertaining their intensity by their action upon a delicate thermometer, the comparative radiating power of different bodies may be ascertained. By this method it has been found that lamp-black is superior in radiating power to any other substance hitherto submitted to experiment, and that if this be represented by 100

Writing paper will be	98
Resin	96
Sealing wax	95
Crown glass	90
Indian ink	88
Ice	85
Isinglass and red lead	80
Plumbago	75
Tarnished lead	45
Polished lead	19
“ tin plate, gold, silver, copper	12

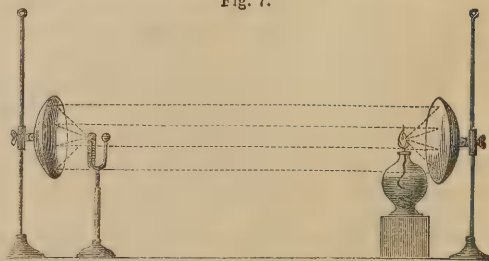
From this table it will be seen that lamp-black irra-

diates five times as much of the caloric of boiling water as clean lead, and eight times more than bright tin. The general low radiating power of the metals is increased if these be allowed to tarnish, as exhibited in the case of lead in the preceding table. Smoothness of surface, however, does not always act in relation to other bodies as it does in metals, for glass and porcelain, although their surface is smooth, always radiate very powerfully. When the actual radiating surface is metallic, it is not affected in a sensible manner by the substance under it; thus glass, coated with gold leaf or tinfoil, possesses the radiating power of the superimposed metals.

In general, the rapidity of cooling of any body depends upon the excess of its temperature over that of the external air; the hotter it is, the more freely does it give out caloric in a given time, and, as its temperature sinks, the longer is it in parting with the excess. DULONG and PETIT found that the rate of cooling differs according to the nature of the atmosphere surrounding the heated bodies; they also observed, whilst making experiments upon bodies in vacuo, that if they acquired heat in an arithmetical ratio, the same would be radiated in a geometrical one.

Radiant heat is absorbed, reflected, or transmitted, according to the nature of the body on which it impinges; and the absorption, reflection, or transmission is in every case governed by peculiar laws. Polished metallic surfaces reflect the greater portion of the heat which falls upon them; and the incidental and reflected rays are in the same plane, and make equal angles with the reflecting surface. If two concave metallic mirrors be placed directly opposite to each other at some distance, and a lighted candle be fixed in the focus of one of them, the rays of heat received by the latter will be found reflected to the opposite mirror, where, instead of being absorbed, they will be further reflected and concentrated in the focus of this one; and, if a delicate differential thermometer be placed at this point, the quantity of heat thus concentrated may be registered. Such was the method adopted by LESLIE, MELLONI, and others, in their researches upon heat, as shown in the annexed engraving, Fig. 7. In this case the reflectors, if thoroughly

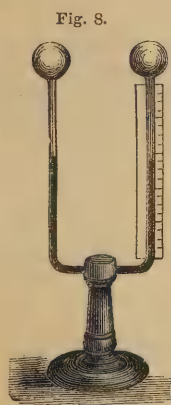
Fig. 7.



polished, do not acquire a perceptible increase of temperature, nor indeed do any of those bodies which throw off by reflection the rays of heat incident upon them. It is only when the reflection is incomplete, either from the nature of the body or the want of a sufficient polish, that heating of the mirrors takes place. If in the above experiment a reflector of glass were

used instead of one of metal, only a very small portion of the calorific rays would be reflected, the greater part being absorbed by the disk, which in consequence would readily indicate a higher temperature; but by coating the surface of the glass with gold leaf or bright tinfoil, it will then become a polished metallic mirror, capable of powerfully reflecting the calorific rays. By experiments such as these, LESLIE demonstrated that the reflecting power of a body is chiefly dependent on the nature and condition of its surface, and that those qualities which are adverse to radiation are such as promote reflection. Bright smooth metallic surfaces, such as polished silver, brass, or steel, which are strongly retentive of their own heat, are little prone to receive it from other sources, but cause its reflection in the same plane, and at an angle equal to that at which it strikes the surface. It is to this circumstance that the Dutch oven and meat screen owe their great efficacy in culinary processes.

The *differential thermometer* or *thermoscope*, to which allusion has been made in the preceding passage, and which is represented in the last figure in the focus of the left-hand reflector, is shown on a larger scale in Fig. 8, and consists of two bulbs, A and B, containing



air, united by a tube twice bent at right angles, in which there is a little colored sulphuric acid. This is essentially an air thermometer, from which the atmospheric pressure is excluded. When heat is applied to one of the bulbs, the air within it expands, and draws the fluid towards the other, when either its depression or elevation, showing the amount of the expansion, may be read off on the scale. It is evident that this instrument cannot be employed to indicate general changes of temperature in the surrounding medium. It is not affected by such changes,

which act equally on both bulbs; but when one of these is exposed to any source of heat which does not affect the other, as when it is placed in the focus of a reflector, the *difference* of temperature between the two bulbs is immediately and very sensibly indicated by the recession of the fluid from the heated towards the cold bulb. The *thermopile*, an instrument still more sensitive to slight changes of temperature, will be described immediately.

MELLONI performed a number of experiments with the view of ascertaining the comparative absorbent

power of certain bodies for caloric. He employed a variety of heat sources of different degrees of intensity, and fixed the ball of a thermoscope coated with lamp-black at such a distance from each, that the liquid contained in it recorded the same degree of temperature in every instance. The distance being marked, the ball was removed and coated with other substances instead of lamp-black, and then successively exposed as before to the action of the heat radiated from different sources. The results showed a remarkable variation, according to the source of the caloric. Thus, when the ball was coated with white-lead and exposed to the rays from the flame of an oil lamp, it indicated only 53; but when red-hot platinum wire was substituted for the flame of the lamp, it was found to be 56; with a copper plate, it indicated 89; and, when exposed to a canister of boiling water, it registered 100. In each of the preceding cases, however, the thermoscope when blackened exhibited 100. The subjoined tabulated results, showing the relative absorbability of different kinds of heat, were obtained in this manner:—

Thermoscope coated with	Naked flame from oil lamp.	Incandescent platinum.	Copper at 750°.	Canister of water at 212°.
Lamp-black, ...	100	100	100	100
White-lead, ...	53	56	89	100
Isinglass, ...	52	54	84	91
Indian ink, ...	96	95	87	85
Shell-lac, ...	43	47	70	72
Polished metal, ...	14	13.5	13	13

With regard to the heating of bodies by radiation, KNOBLAUCH has shown that the effect produced when the radiated heat is *intensified* is totally independent of the temperature of the source, and is determined only by the nature of the absorbing bodies, which receive certain rays more readily than others. This was proved by coating one side of a sheet of metal with lamp-black, one half of the reverse being covered with carmine, and the other with black paper, and exposing the latter alternately to the action of an argand lamp, and a metal cylinder raised to 212°, while the side covered with lamp-black was turned towards the thermopile. With this arrangement the following results were obtained:—

Sources of heat.	Direct radiation.	Carmine.	Interposed Black paper.
Argand lamp,	35	9.50	10.75
" "	50	13.75	15.25
Cylinder heated to 212°, ...	35	10.87	10.12
" "	50	15.62	14.00

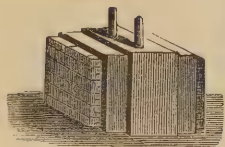
To determine how far the thickness of bodies affected their heating by radiation, he used a metal plate coated with layers of varnish:—

Sources of Heat.	Direct Radiation.	METALLIC PLATE										
		Naked.	Covered with									
			Layers of Varnish.				Layers of Black Lac.				Layers White Lead.	
			1.	2.	4.	8.	Thin.	Thick.	Thicker.	Thickest.	Thin.	Thick.
Argand lamp,.....	35°	6.50°	8.25°	8.25°	8.25°	8.25°	7.12°	8.25°	8.62°	9. 5°	7.25°	8.00°
“ “	60°	10.50°	14.50°	15.12°	15.62°	15.75°	14.50°	16.25°	17.37°	18.12°	16.12°	18.50°
Metal cylinder heated to 212°,	35°	6.50°	9.00°	9.25°	9.50°	9.50°	9.12°	9.87°	11.62°	12.00°	8.75°	9.62°
“ “	60°	10.50°	17.50°	17.50°	20.12°	20.75°	18.62°	20.25°	21.37°	20.17°	17.00°	19.50°

From these results it appears that the substances employed are more strongly heated in proportion as their thickness is greater, within certain limits. MELLONI and LESLIE arrived at a different conclusion, in consequence of having used plates of such thickness that only a small proportion of the heat absorbed could penetrate to the side which was turned towards the thermoscope; KNOBLAUCH, on the contrary, employed media, the thickness of which was not too great to allow each successive layer to be heated, and thus to act upon the metallic surface.

The Thermopile.—MELLONI found that caloric was transmitted by many bodies which were impervious to light, and these he termed *diathermous* or *heat-transmitting*, in contradistinction to *diaphanous* or *transparent* bodies. In conducting his experiments on this subject, he employed, in connection with a very delicate galvanometer, an instrument which he termed a thermopile. This consisted of a number of pairs of bars of bismuth and antimony joined together, and so enclosed in

Fig. 9.



a cylinder—see Fig. 9—that by turning one end of the latter towards the region whence the heat is radiated, it would fall upon the alternate points of junction of the bars of metal, and excite, as is well known, a current of electricity, the intensity of which is in proportion to the amount of heat received. By wires con-

necting both ends, x and y , of this battery with the galvanometer, the electricity was measured; and thus was obtained a ready and delicate method of estimating the amount of heat transmitted. Fig. 10 shows this arrangement, in which the pile is introduced. Both ends of the bars are blackened with soot, in order that the absorption of the rays of heat falling on them may be the more complete. By means of screens, a and b , the pile is preserved from the effects of currents of air; b has a conical shape, and is intended to concentrate the rays of heat when very feeble on the end of the pile. The pile is firmly bound, as represented at p , and fixed to a sliding stand in a perfectly horizontal position. x and y are bars in connection with the opposite ends of those of the pile, to which the wires g and h are screwed at one end, the other being in connection with the helice of coated wire that serves to act upon the galvanometer at m and n . The galvanometer is composed of a carefully selected and well magnetized pair of needles, bound together with fine copper wire, as seen in Fig. 11, and freely suspended in the middle of a glass cylinder, c , by a single fibre of silk which is attached to a ball, f , by turning which the needle may be raised or lowered at will. The helice, or multiplier, in the midst of which the needles are suspended, is constructed by winding

Fig. 11.

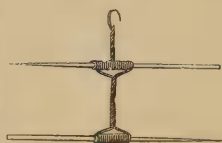
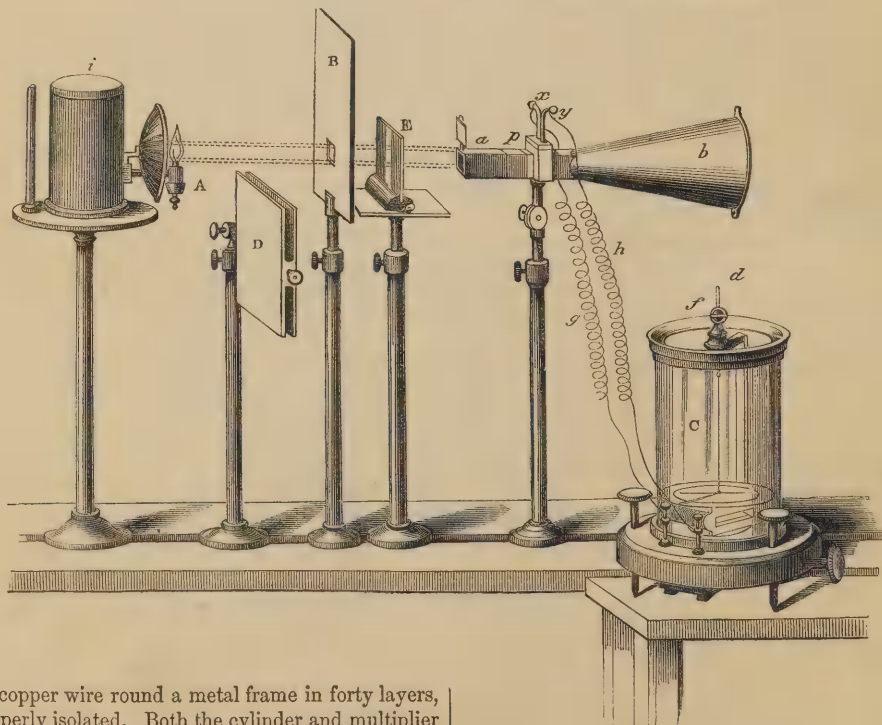


Fig. 10.



coated copper wire round a metal frame in forty layers, and properly isolated. Both the cylinder and multiplier are fixed to a table, so that when the needle hangs freely from f , it will rest in the centre of the closely divided circle, pointing to zero in the plane of the mag-

netic meridian. When the pile and multiplier are connected, the least change of temperature that may

affect the ends of the compound metals deflects the needle, and the amount of this deflection may be noted on the divided circle. When working with this instrument, the first deviation of the needle must be carefully distinguished from the proper angle of deflection—*id est*, from the angle which it makes with the magnetic meridian, when unaffected by any electrical currents. If the equilibrium of the galvanometer is disturbed by a stream of electricity, it returns from the point to which it has been deflected, with a certain degree of velocity, which causes it to go beyond zero; it will oscillate thus for some time before the stationary line is attained. To avoid the delay which these oscillations would occasion, MELLONI ascertained by experiments the ratio between the first and final deflection—*id est*, he determined how large the final deflection is that corresponds to the original one. The knowledge of this relation offers great advantages, inasmuch as each experiment lasts only ten or twelve seconds, whereas, if the operator had to wait till the needle became stationary, several minutes would be required.

If the principle of the apparatus comes to be considered, it will be evident that the relation which exists between the difference of temperature of the soldering points of the pile and the deflection of the needle cannot be ascertained in an absolute manner. To give the deflection a definite value as to the amount of caloric, MELLONI had to determine—after establishing the fact, that the strength of the electric stream from a pile of bismuth and antimony is proportional to the difference of temperature of the soldering points—the relation of the deviation of the needle to the strength of the stream. For this purpose, he placed at either end of the pile a constant source of heat—such as a LOCATELLI'S lamp—at such a distance, that when working alone at one end it caused a deflection of about 40° to the right, and, when placed at the other, the deflection marked 35° to the left side; but, when the sources of heat were permitted to operate on both ends at once, the deflection to the right marked 15° . From this behavior it was inferred that the difference between 40° and 35° corresponded with 15° counted from 0° . By operating in this way, it may easily be understood how, by changing these experiments, a table may be constructed, the first column of which expresses the observed deflection, and the second the corresponding number of degrees which would be arrived at if the deviation were proportional to the strength of the stream, and the action of the latter on the needle were not the weaker the more the latter is deflected. With the apparatus employed by MELLONI, the numbers on both columns up to 20° were equal—that is to say, till 20° the deflection of the needle is proportioned to the strength of the stream; but with the observed deflection, 25, 30, 35, 40, and 45° , correspond the value 27, 35, 47, 62, and 83° of the second column. A stream, therefore, that produces a deviation of 40° is 62 times stronger than another that causes only a variation of one degree. MELLONI so arranged his experiments that the deflections were always less than 30° .

To return to the manner of working the apparatus: if the body emitting rays of heat be fixed in the

focus of a reflector that impels the rays of heat in a horizontal line with the pile, and one of the ends of the latter be exposed to them, the effect upon the needle will, upon the principles already laid down, be indicative of the quantity of radiated heat. When different sources of caloric are thus presented in succession, the register of the deflection of the galvanometer will show the difference of radiation.

Transmission of Heat through Thin Plates.—The bodies employed by MELLONI were a LOCATELLI'S lamp, fixed as at A in Fig. 10; a coil of platinum kept at incandescence by the flame of alcohol, as seen in Fig. 12; a blackened copper foil fixed to a stand, and heated with a spirit lamp to 752° , as represented in Fig. 13; and a brass canister filled with water kept at 212° , as shown in Fig. 14. One or other

Fig. 12.



Fig. 13.

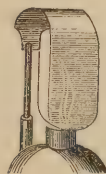
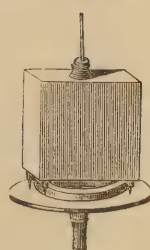


Fig. 14.



of these was placed on a movable support, as at A, behind the perforated screen, B, the rays being concentrated when necessary by the reflector at A, and received at a certain distance from this upon the thermoscope. The sensitiveness of the latter was proved by placing a double screen of polished copper, D, between it and the source of heat, so as to intercept all the caloric rays, and observing the deflection of the needle of the galvanometer in C, when the screen was removed. The elevation of temperature produced by the direct action of the radiating body being thus known, the substance to be examined was then introduced in the place of the screen, as at E. By observing the difference of temperature as indicated by the needle now, and comparing it with the effect produced without the screen, the proportion of heat transmitted by any interposed body was at once ascertained. By this method, MELLONI found that plates of rock-salt of great transparency, and varying in thickness from one-twelfth of an inch to two or three inches, transmitted ninety-two out of every hundred rays of heat which fell upon them, no matter from what source derived. As the remainder of the rays were found to be reflected from both surfaces of the plate, it may hence be concluded that what the colorless plate of glass is to rays of light, the plate of rock-salt is to those of heat. Sometimes the caloric rays which pass through one body are intercepted by a plate of another body, or by another plate of the same. In experimenting upon this, MELLONI found that the caloric which has passed through one plate of glass, becomes less subject to absorption in passing through a second and a third plate of the same material. Thus, of one thousand rays of heat from an oil lamp,

four hundred and fifty-one were intercepted in passing through four plates of equal thickness, and—

Of these the first plate intercepted	381
“ the second “	43
“ the third “	18
“ the fourth “	9
	451

It was found by DELAROCHE that the higher the temperature of the source of heat, the greater in proportion to the whole is the quantity which passes through a plate or screen of glass. He observed that from a body heated to 182° only one-fortieth of the whole permeated, whereas when the temperature was 346° the one-sixteenth passed through, and when the heat was raised to 960° Fahr. as much as one-fourth of the whole amount of heat was transmitted. To show the independence of diathermacy and translucency, MELLONI took a blackened ball of copper heated to 400° Fahr., and placing it midway between the blackened bulbs of two thermoscopes so that they might receive an equal amount of heat, noted the effect; then fixing between the ball and the instruments for measuring the heat plates of rock-salt and glass of equal thickness, it was quickly observed that the temperature of the bulb behind the former was much more elevated than the other—thus showing that more heat passed through it than through the glass one, although in transparency they were equal. In liquids this independence is still more manifest. Thus, out of one hundred rays that fell from an argand lamp on each of four fluids equally transparent—namely, water, oil of turpentine, ether, and sulphuric acid—the number of rays of heat transmitted were:—

Water	11
Sulphuric acid	17
Ether	21
Oil of turpentine	31

The following is a tabulated statement of some of the results ascertained by MELLONI on the subject of the transmission of heat through various bodies of equal thickness:—

Name of the interposed substance. Common thickness 0.102 inch.	Transmission of 100 rays of heat from			
	Naked oil flame.	Red-hot platinum.	Copper at 730° F.	Copper at 212° F.
Rock salt, transparent and colorless,	92	92	92	92
Sicilian sulphur, yellow,	74	77	60	54
Fluor spar, limpid,	72	69	42	33
Rock crystal, cloudy,	65	65	65	65
Beryl,	54	23	13	0
Flint glass,	67	—	—	—
Plate glass,	39	24	6	0
Iceland spar,	39	28	6	0
Rock crystal, limpid,	38	28	6	0
“ brownish,	37	28	6	0
Tourmaline, dark green,	18	6	3	0
Citric acid,	11	2	0	0
Alum,	9	2	0	0
Sugar candy, colorless,	8	1	0	0
Fluor spar,	8	6	4	3
Ice, transparent and colorless,	6	0	0	0

Similar experiments being performed with liquids contained in glass, the stratum being 0.362 inch in thickness, and the source of heat being in each case

flame from an argand oil-lamp, the annexed results were obtained:—

Bisulphide of carbon,	63
Bichloride of sulphur, red-brown,	63
Terchloride of phosphorus,	62
Essence of turpentine,	31
Colza oil, yellowish,	30
Olive oil, greenish,	30
Ether,	21
Sulphuric acid, colorless,	17
“ brown,	17
Nitric acid,	15
Alcohol,	15
Distilled water,	11

The fact that bodies which are pervious to light do not maintain the same relation to heat, is best exemplified by sulphate of copper, which permits the passage of blue light abundantly, but absolutely intercepts caloric. On the contrary, the opaque glass which is used for polarizing mirrors, allows the thermal rays to pass, but quite intercepts the light; and smoked rock-salt and black mica act in a similar way. Radiated heat is not only transmitted, but refracted in the same manner as light. This is proved by the well-known property of convex lenses or *burning glasses*, which concentrate not only the light, but the rays of heat, in the focus. Caloric further resembles light in apparently consisting of rays which possess different degrees of refrangibility, as may be proved by subjecting a beam of light to the action of a transparent prism of rock-salt, and examining the spectrum so obtained by means of a delicate thermometer. In this case it will be found that the heat varies at different parts of the spectrum; and experiment has shown that when the rays of the sun are operated upon, the most part of the rays of heat are less refrangible than even the red light; the maximum temperature being found at some distance below the extreme red. The refrangibility of the rays varies with the source of heat; the higher the temperature the greater is the refraction. For example, the rays of heat emitted from an argand lamp are refracted all over the spectrum, but the maximum intensity is about the middle; from ignited platinum the maximum falls nearer to the red; from copper heated to 750°, nearer still; and so on till the temperature of the source cools to 212°, when it is found to emit scarcely any of the more refrangible rays.

SPECIFIC HEAT.—Bodies have different capacities for heat; or, in other words, the application of the same amount of caloric will elevate the temperature of divers substances unequally. This capacity for caloric, varying in different bodies, is termed their *specific heat*. If a certain weight of water, at the ordinary temperature of the atmosphere, be mixed with an equal quantity of this liquid raised to a higher degree, the mixture will indicate a mean between these extremes; but if another liquid, such as oil or mercury, be added, instead of the second portion of water, a great difference will be observed. When a measure of water at 60° Fahr. is agitated with as much mercury at 140°, the compound, instead of marking 100° as in the preceding case, will indicate only 86.6°. Again, if mercury at 40° be added to an equal bulk of water at 156°, the heat of the latter is reduced by 3.7°, which, being absorbed by the fluid metal, raises it to 152.3°, so that

each degree which the water indicates by the instrument has the effect of 30·35° upon the fluid metal. Taking, then, the capacity of water for heat to be unity, that of mercury will be found from the above results to be 0·033. The capacity of any other body for heat may be determined with tolerable accuracy in the same way; the sides of the vessel, however, are liable to radiate more or less caloric, and will, of course, cause a slight deviation from absolute accuracy in the results.

Many plans have been proposed for estimating the capacity of bodies for heat. The method just described was followed by WILKE, CRAWFORD, KIRWAN, DALTON, and others; whilst DELAROCHE, BERARD, NEUMANN, and REGNAULT proceeded on the principle of allowing equal weights of bodies to be exposed to the same cooling medium, and observing the difference in the time which they required to fall to the same degree; or, inversely, the time was noted which the bodies, when subjected to the same temperature, required to arrive at the marked degree. The difference, of course, depended upon the capacity for caloric, and from this datum the latter was relatively estimated. LAVOISIER and LAPLACE endeavored to arrive at more correct data, by ascertaining how much ice the body dissolved in cooling down to the freezing point; but this method was likewise liable to error, for the ice retains a portion of water which has been liquefied, and, therefore, the measurement of the quantity dissolved cannot afford a perfectly correct estimate; besides, portions of what has been rendered fluid are liable to be frozen again, and in either case the results must be incorrect. DULONG and PETIT conducted their researches by allowing spheres of equal size, equally heated, to cool, and noting the time which they required to fall to a given point; this, of course, will depend on the relative amount of heat which they contain, provided the radiation is rendered equal. The capacity of bodies for caloric is expressed by *relative* and *specific* heat: the former is generally applied when the determination is made as regards the volume, and the latter when it has reference to the weight of the substances.

The following table shows the specific heat of the substances mentioned, between 32° and 212° Fahr. :—

Name.	Specific heat; water = 1.	Authority.
Arsenic,	0·0814	Regnault.
Antimony,	0·0508	"
Animal charcoal,	0·2608	"
Charcoal strongly ignited, ..	0·2415	"
" moderately heated, ..	0·2964	{ De la Rive and Marcet.
Bismuth,	0·0308	Regnault.
Bromine,	5·1350	{ De la Rive and Marcet.
Cadmium,	0·0567	Regnault.
Copper,	0·0951	"
Cobalt,	0·1069	"
Coke—from gas retorts, ...	0·2023	"
" { Anthracite, contain- ing 3 per cent. of ash, ..	0·2017	"
" { from Cannel coal, containing 4 to 5 per cent. of ash,	0·2031	"
Diamond,	0·1469	"
Glass,	0·1976	"
Gold,	0·3244	"

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Name.	Specific heat; water = 1°.	Authority.
Graphite, natural,	0·2019	Regnault.
Graphite, artificial,	0·1970	"
Iodine,	0·0541	"
Iron,	0·1137	"
Ice,	0·5130	"
Iridium,	0·0368	"
Lead,	0·0314	"
Manganese, containing } carbon,	0·1414	"
Mercury,	0·0333	"
Molybdenum,	0·0722	"
Nickel,	0·1086	"
Palladium,	0·0593	"
Platinum,	0·0324	"
Phosphorus,	0·1887	"
Selenium,	0·0837	"
Sulphur,	0·2026	"
Silver,	0·0570	"
Tellurium,	0·0515	"
Tin,	0·0562	"
Tungsten,	0·0364	"
Uranium,	0·0619	"
Zinc,	0·0955	"

The specific heat of bodies varies with their state of expansion, or, in other words, with any alteration in the distance of their particles from each other. Mechanical compression, sufficient to produce a permanent alteration in density, is attended by a corresponding decrease in specific heat. REGNAULT found the capacity for heat of a piece of soft copper to be, in two experiments, from 0·09501 to 0·09455; but after subjecting it to an atomical disarrangement by hammering, the specific heat diminished, and became 0·0936 to 0·0933. When, however, the original state of the bar was restored by annealing, an increase was experienced, and two trials gave respectively 0·09493 and 0·09479. As with solids, so also is it with liquid and aeriform bodies. When these are compressed much heat is liberated; indeed, with aeriform bodies, the heat disengaged is so abundant as to be capable of igniting tinder and other inflammable materials.

The reverse takes place when gaseous bodies are allowed to expand, by withdrawing the pressure; and in proportion as the rarefaction is greater, so also is the capacity for heat of the expansive fluid augmented.

A beautiful example of this law exists in the atmosphere. It is well known from the observations of aeronauts, and those who have ascended high mountains, that the temperature of the air decreases in proportion as the region is elevated, and that this diminution borders closely upon 1° Fahr. for every three hundred feet. Even in tropical climes some of the mountains are perpetually capped with snow, at a definite altitude, subject only to some little variation arising from the nature and distribution of the land beneath. The cause of this cold is the attenuation of the air as it extends from the earth into space, by which its capacity for heat is so greatly increased that a far more elevated temperature would be required to maintain it at the same warmth as the atmosphere near the surface of the ground. The appended table, from DANIELL, gives the approximate distribution of heat by the dilatation of the atmosphere at the equator and poles, supposing the normal temperature at both these places to be respectively 80° at the former and 0° Fahr. at the latter :—

C

Altitude in feet.	Temperature at the Equator.	Temperature at the Poles.
0	80	0°
5000	64.4	— 18.5
1-0000	48.4	— 37.8
1-5000	31.4	— 58.8
2-0000	12.8	— 82.1
2-5000	— 7.6	— 109.1
3-0000	— 30.7	— 140.3

Taking the limit of the atmosphere to be forty-five miles high, it is probable that the most subtle and permanent gases would not only be condensed but even solidified by the degree of cold which would there act upon them, could the ordinary pressure on the surface of the globe be sustained.

Elevation of temperature also increases the capacity of bodies for caloric, and hence it requires the application of a greater heat to raise their temperature when they have combined with a large amount of caloric than in the contrary case. The appended table shows the increasing capacity of the bodies enumerated within the limits assigned:—

Name.	Capacity for heat between 32° and 212°.	Ditto between 32° and 572°.
Mercury,.....	0.0330	0.0350
Platinum,.....	0.0335	0.0355
Antimony,.....	0.0507	0.0549
Silver,.....	0.0557	0.0611
Zinc,.....	0.0927	0.1015
Copper,.....	0.0949	0.1013
Iron,.....	0.1098	0.1218
Glass,.....	0.1770	0.1900

Water ranks first of all bodies yet known in its increasing capacity for heat, at an elevated temperature. Between 22° and 32° Fahr. the specific heat of solidified water is 0.505, assuming it to be unity in the liquid state, and if converted into steam the specific heat of the vapor increases with its state of dilatation. This property contributes in no small degree towards moderating the rapidity of the transitions from heat to cold, and *vice versa*, in the atmosphere, owing to the large quantity of heat which is absorbed by or emitted from the water of the ocean, when the temperature exceeds or falls short of the normal range.

In the determination of the specific heat of vapors, much remains to be done, to arrive at satisfactory results.

DULONG and PETIT endeavored to establish the relation of the specific heat of bodies and their atomic equivalent. This relation they expressed by a general law, that the specific heats of elementary bodies vary inversely with their atomic weights; and that an atom of any one simple substance, whether small or large, has the same capacity for caloric, and requires the same quantity of this imponderable to raise its temperature through a given number of degrees, as an atom of any other element. REGNAULT, by observing that the product of the specific heat into the atomic weight is nearly a constant quantity, represented by 3.2°, advanced a considerable step towards establishing the existence of this general law; still, there are many exceptions which have not yet been reconciled with it.

LATENT CALORIC, OR HEAT OF FLUIDITY.—BLACK asserted, many years ago, that fluidity was owing to the chemical combination of matter with a certain amount of heat, which could not be detected by the thermometer. To this he applied the term *heat of fluidity*, or *latent heat*, assuming that heat, by its chemical combination

with matter, counteracted the cohesive attraction of the atoms of solids, and thus explaining the phenomenon of liquefaction, as that condition in which the cohesive and repellent forces are in exact equilibrium. This view of the subject appears to be well founded; and it is believed that the condition in which matter is found, as solid, liquid, or aeriform, entirely depends on the amount of caloric in combination with it. This has been proved with reference to most substances, and there is strong ground to believe that even the most refractory may be converted into an elastic vapor, and the most permanent of the latter class rendered solid, by the communication of heat on the one hand, and its abstraction on the other.

Solids very much vary in the phenomena which attend their conversion to fluidity; while many of them are transmuted at once to this state, others pass through various stages of softness previous to their assuming it. The following table expresses the melting or solidifying point of a few bodies:—

	Deg. Fahr.
Lead melts at.....	612
Bismuth,.....	476
Tin,.....	442
Sulphur,.....	232
Wax,.....	142
Spermaceti,.....	112
Phosphorus,.....	108
Tallow,.....	92
Oil of Anise,.....	50
Olive oil,.....	36
Ice,.....	32
Milk,.....	30
Wines,.....	20
Oil of turpentine,.....	14
Mercury,.....	—39
Liquid ammonia,.....	—46
Ether,.....	—46

It must be remarked, however, with regard to the above table, that when the preceding substances in a melted state are cooled down, they do not solidify as soon as the foregoing temperatures have been attained. A further quantity of caloric must be abstracted before they assume the solid form; and, under some circumstances, this abstraction of caloric may actually be indicated by a depression of the sensible temperature extending to several degrees before any change occurs. Thus, water, which, in the form of ice, always melts exactly at 32°, may be cooled down to 8°, or even to 5°, without altering its state of aggregation. To produce this curious effect, it is necessary that no solid substance be introduced into the water, and that it be kept perfectly still; for, should the least movement of the liquid be occasioned, it would immediately begin to solidify, and the mass would rise to 32°. The sudden rise of temperature is occasioned by the evolution of the caloric which was required to liquefy the mass, and, consequently, had remained insensible to the instruments usually employed for its detection. This caloric is generally called *latent heat*; but the same term is applied to that which is contained in solid bodies, as well as to the heat of fluidity.

Much caloric is always absorbed and becomes latent by the solution of solid bodies in various menstrua, and the degree of cold which this occasions is often very great. For philosophical, and often for industrial purposes, the method followed to effect a reduction of the

temperature is, to dissolve various mixtures of salts in water or spirit, and the amount of heat which is required for their solution or their reduction to the fluid state, being abstracted from these liquids, and rendered

latent, is sufficient to reduce the temperature of the whole mass to a greater or less extent. The following table expresses the proportions of various substances best adapted for producing cold:—

FRIGORIFIC MIXTURES WITH SNOW.

Mixtures.	Parts by weight.	Therm. sinks—deg.	Degrees of cold.
Chloride of sodium,.....	1	From any temperature	to — 5
Snow,.....	2		
Chloride of sodium,.....	2		
Chloride of ammonium,.....	1		
Snow,.....	5	to — 12	—
Chloride of sodium,.....	10		
Chloride of ammonium,.....	5		
Nitrate of potassa,.....	5	to — 18	—
Snow,.....	24		
Chloride of sodium,.....	5	to — 25	—
Nitrate of ammonia,.....	5		
Snow,.....	12		
Strong sulphuric acid,.....	1	from + 32 to — 23	55
Water,.....	1		
Snow,.....	3		
Concentrated hydrochloric acid,.....	5	from + 32 to — 27	59
Snow,.....	8		
Concentrated nitric acid,.....	4	from + 32 to — 30	62
Snow,.....	7		
Chloride of calcium,.....	5	from + 32 to — 40	72
Snow,.....	4		
Crystallized chloride of calcium,.....	3	from + 32 to — 50	82
Snow,.....	2		
Fused potassa,.....	4	from + 32 to — 51	83
Snow,.....	3		

In making the foregoing mixtures, if snow be not at hand, pounded ice may be employed with equal effect.

When mixtures of salts and water are taken, the

reduction is not so great; yet, when the compounds are finely powdered, and the solution rapidly effected, the cold produced is very intense:—

Mixtures.	Parts by weight.	Temp. falls—deg.	Degrees of cold.
Chloride of ammonium,.....	5	from + 50 to + 10	40
Nitrate of potassa,.....	5		
Water,.....	16		
Chloride of ammonium,.....	5	from + 50 to + 4	46
Nitrate of potassa,.....	5		
Sulphate of soda,.....	8		
Water,.....	16		
Nitrate of ammonia,.....	1	from + 50 to + 4	46
Water,.....	1		
Nitrate of ammonia,.....	1	from + 50 to — 7	57
Carbonate of soda,.....	1		
Water,.....	1		
Sulphate of soda,.....	3	from + 50 to — 3	53
Dilute nitric acid,.....	2		
Sulphate of soda,.....	6	from + 50 to — 10	60
Chloride of ammonium,.....	4		
Nitrate of potassa,.....	2		
Dilute nitrous acid,.....	4	from + 50 to — 14	64
Sulphate of soda,.....	6		
Nitrate of ammonia,.....	5		
Dilute nitric acid,.....	4	from + 50 to — 12	62
Phosphate of soda,.....	9		
Dilute nitric acid,.....	4	from + 50 to — 21	71
Phosphate of soda,.....	9		
Nitrate of ammonia,.....	6		
Dilute nitric acid,.....	4	from + 50 to 0	50
Sulphate of soda,.....	8		
Hydrochloric acid,.....	5	from + 50 to + 3	47
Sulphate of soda,.....	5		
Dilute sulphuric acid,.....	4		

The acids should be prepared by adding two parts by weight of the fuming nitric acid to one of water, and allowing the mixture to cool. When working with sulphuric acid, equal weights of strong acid and water are taken, and used after cooling.

A still more intense degree of cold may be attained by the rapid evaporation of liquids, such as bisulphide of carbon, ether, protoxide of nitrogen, and solid carbonic acid gas. By employing a bath of carbonic acid and ether *in vacuo*, FARADAY reduced the temperature

166° Fahr. below zero; and NATTERER, by means of bisulphide of carbon and protoxide of nitrogen, brought the thermometer to — 220°. The cause which operates in the case of the solution of solids in snow and water, or acids, is the same that induces the frigorific effect by rapid evaporation; but as the caloric which is rendered insensible or latent in the conversion of a liquid body to a gaseous state, is much greater than is necessary to convert a solid to the liquid form, hence it results that the depression of temperature produced by a rapid evaporation can be carried further.

Latent heat, the amount of which differs in different bodies, serves very important offices in the economy of nature, as well as in the chemical manufactures. When the temperature of the atmosphere in winter rises to 32°, masses of ice and vast accumulations of snow would suddenly liquefy, producing destructive inundations, were it not that in melting they must further absorb the heat of fluidity, which becomes latent, and thus the change is retarded and rendered gradual. In the manufactures, the importance of latent heat is illustrated by the employment of steam as the heating agent in numerous processes of distillation, evaporation, and carbonization; but the manner in which it acts in these cases will be better understood after some further explanation of the effect of heat upon liquids.

It has been shown that the change from the solid to the liquid form is the result of the combination of a certain amount of caloric with the substance, and that the heat so united becomes insensible to the thermometer, however delicate its construction. Instances of the absorption and disappearance of heat have been given in the melting of ice, metals, and other substances, capable of passing into the liquid state. In the fusion of metals, the temperature of the bath does not increase a fraction of a degree above the melting point, till the whole has undergone liquefaction, notwithstanding that heat has been pouring into the mass without intermission. The reason of this is, that as long as any of the metal remains solid, it abstracts all the excess with which the liquid may be charged, and combines with it to form more fluid. After the latter stage has been attained, if the temperature be still increased, the bath will continue to indicate a rising temperature till it acquires that degree at which the repulsive force of the caloric will have so far overcome the cohesion of the particles, as to expand them to such an extent that their gravity will be less than that of the air, bulk for bulk. The liquid will then be gradually transformed into vapor, and will manifest the phenomenon of ebullition, which is simply the commotion produced by the evolution of bubbles of the substance itself converted to the gaseous state, and which are generated by its union with the caloric supplied to the liquid. Whatever additional heat be now applied, the boiling fluid will continue to indicate the same temperature as long as any of it remains; and during the process, the vapor which escapes possesses *apparently* only the same amount of caloric as the liquid from which it is produced, but *actually* a greater amount in the shape of the additional *latent heat* by which it is converted into vapor.

These changes are more familiarly known as hap-

pening with water than with metals, for although the latter are frequently fused, they are seldom converted into vapor. During the melting of ice by the application of heat, the ice, or mixture of ice, and water, remains at 32° till the whole is melted; it is evident, however, that the water at 32° must now contain more heat than when, in the state of ice it indicated the same temperature. If heat continue to be applied, the water gradually acquires a temperature of 212°, at which point, provided the atmosphere is at the usual standard barometric pressure, and the liquid be contained in an open iron or copper vessel, it remains stationary. It is now rapidly converted into vapor, but both the liquid and vapor are still at the temperature of 212° Fahr. A little consideration will show that the heat which continues to flow into the liquid, is expended in converting it into steam; for as no indication of an increase is manifest, it must be evident that the surplus is rendered insensible in the process of converting the water into vapor. The quantity of heat necessary to effect this is much larger than is required to reduce the body from the solid to the liquid state. To estimate the amount of caloric expended and rendered insensible or latent in both cases, let a pound of water at 212° be mixed with the same weight of water at 32°, and it will be found that the mixture will indicate a medium between these points—that is to say, the pound of water at 212° will lose 90°, and the pound of water at 32° will gain 90°; so that the mixture will indicate 122°. But now let a pound of water at 212° be mixed with a pound of snow or ice at 32°, and the mixture will indicate only 51° Fahr., showing that the water has lost 161°, while the snow or ice has gained *apparently* only 19°. It is evident that the difference between these figures, or 142°, must have been absorbed or become latent in converting the snow or ice into water.

Applying the same test to steam or vapor of water at 212°, it will be found that one pound of water, which has been converted into steam, is sufficient to reduce six pounds and a quarter of snow or ice to the liquid state, and to raise it to 51°, from which it may be deduced that steam contains 967° of latent or insensible heat. LAVOISIER estimates the amount, in round numbers, at 1000°.

EBULLITION AND EVAPORATION.—During the ebullition of water in common metallic vessels at the ordinary pressure of the atmosphere, no amount of heat applied can elevate its temperature beyond 212°, provided the steam passes off freely; a fact which is well deserving of consideration in domestic economy. Many causes, however, tend to vary the boiling point of water and of liquids in general. If it be contained in smooth glass vessels, ebullition takes place at two or three degrees above the usual standard; hence, if a coil of wire be introduced into water contained in a smooth glass vessel, and near the point of ebullition, this process will commence immediately. All angular bodies, and more especially metals, introduced among the liquid, cause the boiling to take place even in glass vessels at 212°. The adhesion of the liquid to the sides of such vessels seems to be the cause of impeding the boiling, and sometimes of making

it to pass into vapor suddenly; hence in distilling in the laboratory the custom of introducing bits of platinum wire into the retort to facilitate the conversion of the liquid into vapor; without this precaution there is often danger of the retort being broken, or of the liquid operated upon being thrown over into the receiver. At each evolution of vapor that is formed during ebullition under these circumstances, the temperature falls to 212°; but when it has escaped, the contents of the vessel remain quiet till the temperature rises as before. Many substances, such as shell-lac, when applied to the interior of the vessel, prevent ebullition taking place at the usual degree; but the experiments of DORMY have proved that atmospheric air mixed with liquids influences their boiling point more than anything else, except pressure. He showed that the air which is dissolved in water acquires an increased elasticity, and forms minute bubbles in the interior of the fluid into which the steam dilates and rises to the surface. By long-continued boiling the air is nearly expelled; and in the course of some experiments it was found that the temperature could be raised to 360° in an open vessel without the phenomenon of ebullition taking place; finally, however, the disengagement of vapor was so sudden that it caused a loud explosive report, and shattered the vessel in fragments.

From what has been said, it is evident that the boiling point of liquids is not fixed, but is dependent upon various causes. The greatest effect is produced by the varying pressure of the atmosphere, which on an average is about fifteen pounds for every square inch of surface at the level of the sea; but the weight of the air varies at different heights, and according as it happens to be surcharged with watery vapor or not; consequently, at different elevations the boiling point will be different, and even at the same level the pressure or density varies so much as to cause a difference of four degrees or more of Fahrenheit's scale. It is absolutely necessary, therefore, to observe the pressure of the atmosphere when fixing the boiling point of liquids on the thermometer, and to make the necessary corrections. This is done by noting the height at which the mercury in the barometer stands at the time, and making the requisite allowance for any difference between that and the normal height of 29.92 inches, as shown by the following table, which embraces the extreme indications of the barometer at common levels, with the boiling points of water corresponding to these and the intermediate indications:—

Barometer indication. Inches.	Water boils. Deg. Fahr.
27.74	208
28.29	209
28.84	210
29.41	211
29.92	212
30.6	213

It thus appears, that under a diminished pressure water seethes at a lower temperature, and the same happens with other liquids. SAUSSURE found that, on the top of Mont Blanc, water boiled at 184° Fahr. In deep mines, on the contrary, it requires a much higher temperature than 212° to bring it to a state of ebullition. On this circumstance has been based the con-

struction of an instrument for determining the heights of mountains by the boiling point of water or other liquids.

When the pressure is removed by artificial means, as by creating a vacuum, the boiling point of water may be lowered about 145° under the usual temperature at which ebullition takes place. This has been turned to advantage in several manufacturing processes, where an exposure to the temperature of boiling water, under ordinary circumstances, for a length of time, would be prejudicial and sometimes destructive to the substances under treatment. The pharmacist and sugar-refiner are especially benefited by the application of this important fact in their respective processes. By operating under a low pressure, produced by creating a partial vacuum, the former can readily inspissate his vegetal juices to any desired extent without injury; whereas, if the same were attempted in an open vessel under the common atmospheric pressure, most of the active principle would be destroyed. In like manner, if the saccharine liquid of the sugar boiler were to be concentrated to the same degree to which it is usually carried in an open pan or boiler, nearly the whole of the crystallizable sugar would, by an allotropic molecular arrangement, pass to an uncrystallizable sirup. By an increased pressure the converse of this happens, and water may be made to attain a temperature of 300°, 400°, or upwards, before ebullition. An instrument known as PAPIN's digester, which is simply a strong metallic vessel with a safety valve, is constructed on this principle, and is used to macerate bones and other substances in liquids raised to a higher temperature than that of boiling water.

Solid bodies dissolved in water or other liquids produce, to a certain extent, the same effect as high pressure; generally, the elevation of the boiling point varies according to the nature of the substance in solution, but it uniformly increases with the same body till the liquid is saturated. Tables founded upon this law have been drawn up, for the purpose of estimating the amount of saline matter in a liquid from its boiling point.

Ebullition consists mainly in the conversion of the liquid into vapor, and so far is synonymous with evaporation; which differs from it, however, inasmuch as the latter takes place at all temperatures—whereas a certain range of heat is required, under every circumstance, before the former phenomenon is observed. This may be proved by allowing a shallow vessel containing water to remain exposed for some time; upon examination it will be found that a portion will have disappeared—or, in other words, it will have evaporated to the extent of the loss. Most fluids are susceptible of this change, but those which boil at a low temperature are more volatile than others: thus alcohol is evaporated much quicker than water, and for the same reason ether is converted into vapor much more readily than even alcohol.

Evaporation is affected by the temperature and hygrometric state of the air, and the extent of surface exposed. It is evident that the latter must influence the rate of conversion into vapor, because this alteration can only take place at the surface: hence the amount

of evaporation will be, *ceteris paribus*, in proportion to the superficies which the fluid presents. But when the air is surcharged with moisture, the change into vapor will be slow, even although the temperature be elevated, whereas, if it be dry, the fluid will disappear much quicker. In still air the evaporation is much slower than when a breeze or current of air is passing over the liquid; because, in the former case, the stratum of air immediately over the surface of the fluid becomes saturated and unable to take up any more moisture, whereas, when a current is established, a fresh and dry stratum is constantly presented to the liquid, and passes away loaded with vapour.

Evaporation, like ebullition, is greatly promoted by the removal of pressure; thus, by placing a cup containing ether or any other volatile fluid under the receiver of the air-pump and exhausting it, the fluid rapidly disappears, and an atmosphere of vapor is formed.

In all cases, however, where it is expedient that liquids should be quickly vaporized, heat is resorted to as the best and most ready agent. Heat, indeed, is the cause of evaporation at whatever degree or under whatever circumstances it takes place, just as it has been shown to be the cause of liquidity. Hence arises the important question, What is the least quantity of caloric required to effect the evaporation of a given quantity of liquid?—a question which bears on the economy of fuel in the generation of steam, and in many other manufacturing processes. Mr. SHARPE, of Manchester, arrived at the conclusion, that as the latent heat of vapor is increased with its degree of rarefaction, and as subtler vapor is obtained at low than at more elevated temperatures, there is no economy of caloric, and therefore no saving of fuel by evaporating or distilling liquids *in vacuo*. WATT further showed that the same weight of steam, whatever density it may possess, contains the same quantity of heat, its insensible or latent caloric being increased in proportion as its sensible is absorbed. Thus he found that a given weight of steam at 212°, and consequently possessing 180° of sensible heat above the freezing point, gave off 950° more when condensed by injecting upon it water at 32°, making, with the sensible heat, a total of 1130° above the point of freezing. Again, the same weight of steam at 250°, and therefore possessing 218° of sensible heat, gave out, on being liquefied at the same temperature, only 912° Fahr., which, with the sensible heat, amounted exactly to 1130° also. This he assumed, therefore, as the amount of caloric necessary to convert water at 32° into steam, either of a high or low tension; and hence, on this assumption, to ascertain the amount of latent or insensible heat in steam, at any temperature, all that is necessary is to deduct the sensible heat from 1130°, and the difference is the latent caloric.

These experiments appear to lead to the inference that, in the evaporation of liquids, generation of steam, distillation, *et cetera*, no material economy is gained by conducting these processes at low rather than at high temperatures; but the later and more carefully conducted researches of REGNAULT have shown that this assumption is not strictly correct, and al-

though the difference does not lead to serious errors in practice, yet in reality the sum of the latent and sensible heat increases for each degree of Fahrenheit, by a constant quantity equal to 0·305°. This is illustrated in the annexed table, in which it is assumed that steam possesses no sensible heat below Fahrenheit's zero :—

LATENT AND SENSIBLE HEAT OF STEAM AT DIFFERENT TEMPERATURES :—

Pressure in atmospheres.	Temperature.	Latent heat.	Sum of latent and sensible heat.
0·044	0°	1114°	1114°
0·180	32	1091·7	1123·7
1·000	212	966·6	1178·6
8·000	339	877·3	1216·8

The increase here shown offers, however, but a small inducement to perform the processes already alluded to at low temperatures—so far as saving of fuel is concerned; while the increased amount of sensible heat which may be utilized advantageously when the steam is generated under pressure, renders it expedient that the latter mode of generating it should be resorted to. This is the case especially when steam is employed as a source of heat in the carbonization of ligneous matters, in the distillation of liquids, and, occasionally, in the concentration of saline and extractive solutions. The large amount of caloric which steam possesses renders it peculiarly adapted to such purposes; and hence, in all those manufactures where the products are of a salifiable or an extractive nature, steam is now generally employed to concentrate the liquors. In the culinary art, also, it is found to be much more eligible as a source of heat than the common method of exposing the apparatus directly to the action of fire. It is especially adapted for drying manufactured goods and for purposes of ventilation; in the one case, it is conveyed through cylinders over which the goods are conducted, and in the other through iron pipes, so disposed that the heat shall be given off in the most effectual way. In the latter case, experience has shown that the boiler should have one cubic foot capacity for every two thousand cubic feet of air to be heated to a temperature of 70° or 80° Fahr., and that the conducting pipe must present a superficies of one square foot for every two hundred cubic feet of space to be heated.

Elastic Force of Steam.—When different liquids are heated to their boiling points, they produce very unequal quantities of vapor. Water yields it in larger volume than any other known liquid. The following table shows the volume of vapor produced by a cubic inch of each of the liquids enumerated at their respective boiling points :—

Cubic inch.		Cubic inches.
1 of water	expands to	1696 at the boiling point.
1 of alcohol	"	528 " " "
1 of ether	"	298 " " "
1 of turpentine	"	193 " " "

The great value of machinery at the present day in developing the resources of nations, and in fostering and extending commerce and internal intercourse, turns upon the expansive property of water under the

influence of heat. This, as already stated, is such as to make it the most efficient motive power; and although it requires a higher temperature, and consequently a greater consumption of fuel, to generate vapor from it than many other liquids, yet its superior elasticity in the shape of steam is such as to render it preferable to any of them, even supposing they could be had as cheaply. When the vapor of water is heated alone, the rate of expansion is the same as that of air or any other elastic gaseous mixture when subjected to an equal temperature, and it may be confined in red-hot vessels without a great amount of elastic force being acquired. It is otherwise, however, if some water be contained in the vessel or cylinder, for then the generation of fresh vapor causes an addition of elastic force to that already exerted, so that in time the pressure on the walls of the vessel becomes irresistible.

PAPIN's digester, already mentioned, or an apparatus constructed on similar principles, is resorted to for determining the elastic force of steam when subjected to a continued increase of temperature. This apparatus, which is represented in Fig. 15, is a globular vessel, A, furnished with a thermometer, *b*, a stopcock, *c*, and a long glass tube, *d*, affixed to a graduated scale, *e*; the tube is open at both ends—the lower one dipping into some mercury in the bottom of the vessel, and on which the water floats. A lamp, placed under the globe, causes the water to boil, and so long as the tap is left open, this happens at 212°; but if the steam which is produced be retained by closing the tap, the temperature no longer remains stationary at 212°, but rises progressively as the steam is accumulated; and the mercury, which before marked only a height equivalent to thirty inches in the tube, now ascends till it reaches twice or thrice that elevation, according as the elastic force of the steam is increased.

DULONG and ARAGO have made some researches upon this subject, which are valuable, inasmuch as they throw considerable light upon the mechanical effect of steam. The results are, therefore, appended in the following table, from which it may be seen, that as the temperature rises, a given increment of heat produces a greater effect in augmenting the elastic force than at a lower temperature. If the atmospheric pressure, or the elasticity of steam at 212° Fahr., be taken as unity, the elastic force of steam at 240° Fahr. will be about one and a half, and at 250° Fahr. will be equal to two atmospheres. Thus an increase in the quantity of heat indicated by 38° Fahr. doubles the elastic force, and it also appears from the table that a further increase of 25° trebles the elastic force, and a further increase of only 18° quadruples it. Thus the elastic

force evidently increases much more rapidly than the temperature. This circumstance has led to the introduction of high-pressure boilers as affording an increased motive power, with a less consumption of fuel, than when low-pressure boilers are used. The former have been found so advantageous, that, in mining and manufacturing districts, as well as for locomotives and steam vessels, high-pressure steam is now in general use:—

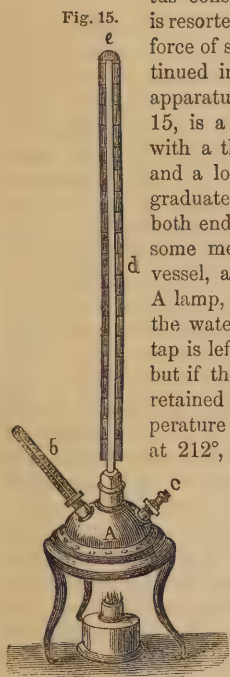
ELASTICITY OF STEAM AT HIGH TEMPERATURES.

Elasticity of steam, taking atmospheric pressure as 1.	Temperature Fahr.	Elasticity of steam, taking atmospheric air as 1.	Temperature Fahr.
1	212°·0	13	380°·66
1·5	239·96	14	386·94
2	250·52	15	392·86
2·5	263·84	16	398·48
3	275·18	17	403·82
3·5	285·08	18	408·92
4	293·72	19	413·78
4·5	300·28	20	418·46
5	307·5	21	422·96
5·5	314·24	22	427·28
6	320·36	23	431·42
6·5	326·26	24	435·56
7	331·70	25	439·34
7·5	336·86	30	457·16
8	341·78	35	472·73
9	350·78	40	486·59
10	358·88	45	491·14
11	366·85	50	510·60
12	374·00		

COMBUSTION.—Allusion has already been made in the preceding pages to various sources of heat; but those which will fall to be considered in connection with the subject of this article, are certain material substances which, in the act of undergoing chemical changes, yield both heat and light. This process is termed combustion. At one period, and among the disciples of LAVOISIER in particular, oxidation and combustion were considered synonymous. It is true, that in most cases of combustion, as in that of a common fire, the effect is produced by the oxidation of the materials; but cases of combustion occur when no oxygen is present. Antimony, for example, burns when heated in an atmosphere of chlorine; copper, or iron, when heated with sulphur; potassium, with cyanogen, *et cetera*. These instances demonstrate the fact that oxygen is not essential to combustion, although it is eminently capable of supporting it; and being so extensively disseminated in the atmosphere, it acts as the almost universal agent in this phenomenon.

Though the term *combustion* is generally limited to cases of chemical combination accompanied with heat and light, yet it is sometimes extended to express the union of bodies with oxygen effected at a low temperature. Iron, for example, when exposed to moist air, undergoes a change in oxidizing, whereby its metallic characteristics disappear; the constituents of the blood are modified by a similar chemical process, but in neither case is light produced; and if heat is generated in the former, it is quite inappreciable even by delicate instruments. In both cases, however, the effect produced is sometimes characterized as a process of *slow combustion*.

In cases of vivid, as distinguished from slow combustion, the heat and light seem to be evolved from the



solid, liquid, or gaseous bodies which burn, and hence they are termed *combustibles*, while the gaseous atmosphere in which they are involved, such as oxygen or chlorine, is termed the *supporter of combustion*. It is evident, however, that this distinction is radically faulty, inasmuch as the phenomena of light and heat may be regarded as proceeding either from the one or the other. The combustible, usually so called, may be represented as supporting the combustion of the atmosphere in which it is enveloped, and the latter, regarded in this view, becomes the real combustible. In strictly philosophical language, the combustion proceeds from the combination, which can only take place at the point of contact; and therefore it is quite impossible to say to which of the bodies so combining is due the evolution of heat and light, or, in other words, which is the combustible and which the supporter of combustion.

Much difference of opinion exists as to the manner in which heat is produced, and the question is far from being solved at the present time. At one period it was thought that heat was a material constituent of the substance, which might be separated from it or combined with it like other substances. On this hypothesis all the gaseous bodies were regarded as compounds of the actual matter with the substance of heat and light, or *phlogiston*, as it was called; and when any one of these, such as oxygen, was made to unite with another body, and heat and light accompanied the combination, these phenomena were attributed to the evolution of *phlogiston*. Moreover, to account for the fact that some bodies, as metals, gained in weight by combustion, the *phlogiston* was supposed to be possessed of a principle of levity. LAVOISIER explained the evolution of caloric when certain bodies entered into combination, on the supposition that the specific heat of the substances before combustion was greater than that of the bodies produced, and that the difference was what was radiated or otherwise evolved from the burning body. Experiment, however, has shown that this theory is untenable, for in the case of the combustion of carbon, which is the commonest instance, the carbonic acid gas produced has a greater instead of a less specific heat than oxygen; and hence, in a case where caloric is actually given off, the result is found to be the very reverse of that which is implied in this explanation. More recently, THOMSON accounted for the effect on the assumption that every atom or molecule of simple bodies contains an equal amount of heat, and that, when a number of them combine, the caloric from one or more is expelled. But all these theories may be ranked as mere ingenious speculations. In the present state of knowledge, all that can be affirmed with certainty is the general principle, that heat is developed by chemical action.

Relative Value of different Combustibles.—The amount of caloric produced in the combustion of different bodies is variable, and the determination of the quantity so produced becomes a matter of the highest importance, as upon this depends the selection of particular substances for the production of heat economically. The course pursued in researches with this object in view is to burn a certain weight of

the combustible, admitting for this purpose only the smallest possible quantity of oxygen or air, and so to conduct the heat through water that it shall be entirely absorbed by it. From the quantity of liquid raised through a certain range of temperature, the value of the combustible under experiment is estimated.

Proceeding upon this plan, and comparing a number of results, WELTER concluded that the heat eliminated depended upon the quantity of oxygen taken up, and that the amount developed by equal weights of oxygen, when made to unite chemically with other bodies, how different soever they might be, was always the same. In this opinion he was supported by the researches of other chemists. DESPRETZ, by uniting one pound of oxygen with any of the following substances, found that the water raised from 32° to 212° Fahr. was, with

Hydrogen,.....	29.5 pounds.
Charcoal,.....	29 "
Alcohol,.....	28 "
Ether,.....	28.5 "

Although the law laid down by WELTER appears to be confirmed by these results, yet there are several facts with which it does not accord. When iron is oxidized and the generated caloric is collected in water, the quantity heated by it from 32° to 212° is fifty-three pounds, or nearly double the weight which the same volume of the gas consumed with the substances above enumerated raises to the boiling point. Zinc, tin, and many other metals, similarly treated, produce effects which differ in like manner from the results tabulated by DESPRETZ. Even the same quantity of oxygen produces unequal effects with the same body, when it is capable of combining with it in various proportions. Thus, when phosphorus is burned slowly, the amount of heat which it evolves in combining with one pound of oxygen is capable of heating only twenty-eight pounds of water to the boiling point; but when the combustion is conducted rapidly, so as to produce phosphoric instead of phosphorous acid, twice as much caloric is disengaged. Again, if charcoal be consumed with a limited supply of oxygen, so as to form carbonic oxide gas, and a quantity of this gas equivalent to one pound of carbon be ignited, it will be found that as much heat will be given off as will raise sixty-two pounds of water to the boiling point; whereas, if the carbon be ignited with its full complement of oxygen in the first instance, the heat obtained will be to the foregoing as 76.62, whilst the proportion of oxygen combined is as 2 to 1. From all these cases it appears that the quantity of heat developed by the combustion of a substance depends greatly upon the nature of the body itself. It cannot be denied, however, that the volume of oxygen which combines with the substance affords in most cases a pretty near approximation to the amount of heat developed in combustion; and hence the method in ordinary use for determining the heating power of combustibles by the reduction of litharge, which will be noticed further on.

But there are other considerations which must likewise be taken into account in estimating the relative value of different kinds of fuel. Very many substances which are capable of giving out considerable quantities of heat cannot be used for that purpose: first, because their

cost would exceed the limits of economy; and, secondly, because a too elevated temperature would be required to induce combustion. Such is the case with a great number of metals, which, under certain circumstances, are capable of evolving intense heat and light during their union with oxygen. On the other hand, there are many substances which may be made to undergo the process with comparative facility, but cannot be usefully turned to account, because they evolve obnoxious products, such as arsenical or sulphurous gases; others again require, for their combustion, a too complex apparatus, and too constant surveillance, to admit of their useful application.

The substances which combine the greatest facility of combustion with the production of a large amount of caloric, are carbon and hydrogen; and there is never wanting in the atmosphere a third, with which to combine—namely, oxygen. The product of the union of the first of these substances with oxygen, that is to say, of its combustion, is carbonic acid gas, a compound poisonous indeed when breathed alone, but destitute of odor, and colorless. Where common means of ventilation exist, there is no danger to be apprehended from this gas, and it cannot accumulate in the air to such an extent as to act injuriously; for on descending again to the earth it becomes the food of vegetals, by which it is analysed into its elements, and these are again rendered available for performing the same service. The combustion of hydrogen, or, in other words, its union with oxygen, yields only water, which, like the carbonic acid, is subjected to other transformations in nature's laboratory, whereby its elements are again separated, and therefore perform the same office over and over again without any diminution or loss of effect. It is impossible not to admire the wisdom and benevolence of that arrangement whereby these three elements are produced in quantities so enormous, they being far the most necessary materials towards the support of animal life. Regarded as sources of fuel, they are all conveniently stored in wood and other vegetals, of which a continual reproduction insures an abundant supply.

ARTICLES OF FUEL.—The substances usually employed as fuel are *wood*, *peat*, and *coal*, either in their natural state, or modified by peculiar treatment. The abundance of these in a country must always constitute a principal source of its wealth, more especially now that steam has become the moving power of manufacturing industry, as well as the great agent in locomotion. It is evident, therefore, that none of the productions of nature should be more carefully husbanded than those which constitute fuel. Every attempt also to improve the quality of inferior materials, so as to increase their efficiency as heat-producers, ought to be liberally encouraged; and some efforts in this direction have lately been made with much success.

Wood, peat, and coal, though so different in physical appearance, are nevertheless very closely allied in composition, all the three being chiefly composed of ligneous fibre, a compound of three simple elements—carbon, hydrogen, and oxygen. Physical effects have induced certain changes in some kinds of peat and

coal, which cause them to differ considerably in their properties from woody fibre; but, by observing the action which analogous artificial agencies exert upon the latter, a remarkable coincidence is observed, and sufficient data are found for inferring that woody fibre is the basis of these substances, although they have passed in the course of time through various chemical transformations. The extent of the changes thus induced may be, to some degree, inferred from the phenomenon of combustion. Woody fibre, when deprived of extraneous moisture, readily bursts into a flame upon being ignited, whilst many kinds of coal do not. The difference is caused, firstly, by the states of density of these substances; and, secondly, by the absence of hydrogen and oxygen in the coal. Porosity and the presence of hydrogen in combustible bodies facilitates rapid combustion. When hydrogen is a constituent, it is liberated at a temperature below redness, in union with a portion of the carbon, from all the pores of the substance, and forms around the latter an inflammable atmosphere, which bursts into flame at slightly increased heats; the evolution of this matter leaves the remainder open to the passage of oxygen, which effects its rapid combustion.

The production of flame is always connected in a remarkable manner with the presence of hydrogen, but in some cases the phenomenon may be observed where this element is absent; thus, when pure charcoal or anthracite coal is burned in a limited supply of oxygen or air, instead of carbonic acid being generated, an inflammable gaseous body results, which re-ignites when a further quantity of air or oxygen is admitted, and produces flame. A characteristic difference is, however, observed between the sheet of light which is given out by a combustible containing hydrogen, and that from carbonic oxide; the former is luminously brilliant, as is seen in gas, whilst the latter is dull, bluish, and attenuated. The property of producing flame determines particular uses for many species of fuel, such, for instance, as choosing cannell for the manufacture of gas, and of inflammable varieties for the heating of reverberatory furnaces where the materials are at a distance from the fire. A selection of this class, for purposes where local heat is wanted, such as in the reduction of ores and in the manufacture of iron, would be injudicious, and, consequently, the less inflammable, or such as have been divested of hydrogen, are in these cases resorted to.

WOOD—*Bois*, French; *Holz*, German.—This is the name given to the hard porous tissue of plants, through which sometimes the liquid sap is raised by capillary attraction, though more generally the latter traverses between the bark and these tissues. The wood of large trees is called timber, and is generally applied to architectural and domestic uses. It is only, however, in connection with its use as a combustible or source of heat that it will be discussed in the following pages.

Chemically considered, wood is composed of several substances, both of an organic and an inorganic nature, but of these the former alone are productive of heat. Woody fibre, or the tissue already noticed, constitutes the basis of the mass, whilst the sap, water, and other matters peculiar to the species of wood, make

up the remainder. All kinds contain water and woody fibre, so that the sap and extractive matters are the substances which determine the particular species of this organic production. Thus, many woods, especially the coniferous, are resinous; others, such as beech and birch, contain extractive matters; and many others, definite chemical compounds, such as tannin, and the like. All these may be removed by the successive action of water, alkalis, and alcohol; and although the principles in the several varieties are different, yet they all afford a close approximation in the quantity of carbon, hydrogen, and oxygen which the wood contains.

Various concurring circumstances tend to enhance the value of wood as a fuel, such as freedom from water, density, *et cetera*, and it is upon these qualifications that its marketable value turns.

Species.	Felling time.	Water.	Felling time.	Water.
Ash.....	End of January,.....	28.8.....	Beginning of April,.....	38.6
Sycamore.....	".....	33.6.....	".....	40.3
Horse Chestnut,.....	".....	40.2.....	".....	47.1
White Fir,.....	".....	52.7.....	".....	61.0

Sap is unequally disseminated in various parts of trees: in the trunk, it is accumulated more in the exterior than in the core, and still more in the branches than even in the outer portions of the trunk. Wood, cut at the proper time, retains from one-fifth to one-half its weight of moisture, part of which is lost by exposure to the air.

SCHUBLER and NEUFFER's experiments give the following as the per centage of water in the several species enumerated:—

	Water Centesimally.
Hornbeam— <i>Carpinus betulus</i> ,.....	18.6
Willow— <i>Salix caprea</i> ,.....	26.0
Sycamore— <i>Acer pseudo-platanus</i> ,.....	27.0
Mountain Ash— <i>Sorbus aucuparia</i> ,.....	28.3
Ash— <i>Fraxinus excelsior</i> ,.....	28.7
Birch— <i>Betula alba</i> ,.....	30.8
Wild Service Tree— <i>Crataegus tormin</i> ,.....	32.3
Oak— <i>Quercus robur</i> ,.....	34.7
Pedicle Oak— <i>Quercus pedunculata</i> ,.....	35.4
White Fir— <i>Pinus abies dur.</i> ,.....	37.1
Horse Chestnut— <i>Æsculus hippocast.</i> ,.....	38.2
Pine— <i>Pinus Sylvestris L.</i> ,.....	39.7
Red Beech— <i>Fagus sylvatica</i> ,.....	39.7
Alder— <i>Betula alnus</i> ,.....	41.6
Aspen— <i>Populus tremula</i> ,.....	43.7
Elm— <i>Ulmus campestris</i> ,.....	44.5
Red Fir— <i>Pinus picea dur.</i> ,.....	45.2
Lime Tree— <i>Tilia europæa</i> ,.....	47.1
Italian Poplar— <i>Populus italica</i> ,.....	48.2
Larch— <i>Pinus larix</i> ,.....	48.6
White Poplar— <i>Populus alba</i> ,.....	50.6
Black Poplar— <i>Populus nigra</i> ,.....	51.8

From the numerous experiments performed by CHEVANDIER, with the view of determining the loss sustained by woods of different ages, and by the several parts of the same tree when exposed to the air during stated periods, it may be inferred, that so far as the abandoning of moisture to air was observed, the soil and locality where the trees grew did not affect the results. The samples submitted to examination were exposed in a shed, which protected them from rain as well as from the sun's rays, and the moisture was determined at the several stages, by drying a portion of the sample in the form of sawdust, at a temperature of 284°

Amount of Moisture in Woods.—A remarkable variation is observed at stated seasons, in the quantity of soluble matter—sap—which is present in all kinds of woods: thus, in spring, when the tree is in active growth, the amount of water, *et cetera*, is much greater than at the close of autumn, or the middle of winter, when it is in a kind of normal state. The practical benefit of this knowledge is, that trees, whether intended for fuel or timber, are, or should be, felled in the latter seasons; although, when they are cultivated for the principle of the sap, such as tannin, quinin, *et cetera*, it is more advantageous to cut them when the flow is at its full.

SCHUBLER found in woods felled at the end of January and the beginning of April, an extensive difference in the amount of contained moisture, as may be seen from the appended results:—

Fahr. *in vacuo*, till it ceased to lose weight. By this procedure, it was found that the maximum loss by exposure was sustained, in the greater number of cases, after a period of a year and a half, although many specimens required two years to reduce their hygrometric contents in the same degree. It appeared, likewise, that the resinous varieties part with their water more freely than the non-resinous; they, on the other hand, absorb water with greater avidity when exposed to moist air than the latter. The softer non-resinous woods always contain more water when cut down than the harder kinds, but they part with it more freely, and can be desiccated to a greater extent than the latter.

The following is a synopsis of the results of researches on this subject, transcribed from the valuable treatise of RICHARDSON and RONALDS:—

1. MEAN QUANTITY OF HYGROMETRIC WATER CONTAINED IN RESINOUS WOODS.

Parts of the Tree.	Per Centage of Water.
Trunk-wood half a-year after felling,.....	29
Brush-wood ".....	32
Young Branch-wood ".....	38
Trunk-wood in the driest state,.....	15
Brush-wood ".....	15
Young Branch-wood ".....	15

2. MEAN QUANTITY OF HYGROMETRIC WATER CONTAINED IN THE NON-RESINOUS WOODS.

Parts of the Tree.	Per Centage of Water.
Trunk-wood half a-year after felling,.....	26
Brush-wood ".....	34
Young Branch-wood ".....	36
Trunk-wood in the driest state,.....	17
Brush-wood ".....	20
Young Branch-wood ".....	19

These results may be viewed as the minima, because the single specimens would be more thoroughly exposed than if made up into stacks; and it may, therefore, be inferred, that after exposure under favorable circumstances during a year, the wood still retains about one-third of its weight of moisture, for the expulsion of which a prolonged heat is required. In

ordinary air-dried firewood, this amount of water, together with that which results from the oxygen and hydrogen contained in it, is vaporized at the expense of the carbon, and the consequence is, that much of its value as fuel is lost when used in this state. In such applications where a brisk temperature is indispensable, the material is never used after merely air-drying, but is exposed to such a degree of heat as will drive off this moisture, so that, when ignited, the entire weight may be serviceable for the generation of heat. To do this thoroughly requires great care, because, unless the heat is sufficiently elevated, the moisture will not be removed, and when it is capable of exerting a thorough hydrotic effect, the constituents of the wood will be apt to arrange themselves so as to form gaseous matters, which are dispelled into the air, and thus a loss to some extent is sustained. Even when so treated that it does not retain any moisture, it becomes so hygrometric, that, upon exposure, it readily assimilates from eight to ten or more per cent. of water even in dry weather.

Density of different Woods.—When felled, nearly all kinds of wood are lighter than water, although the solid portions are possessed of a much higher density than this liquid; a few are, however, heavier than water, but these are the harder kinds, in which the cellulose is so closely packed together, that very little room is left for the retention of air. In their ordinary state, the woody matter, water, and air, concur to confer the gravity, but as the latter bodies considerably vary in amount, much difficulty is attendant upon the proper determination of the density. It will be understood, however, that so far as the moisture is concerned, it acts a neutral part, and the greater gravity of the solid portions is reduced by the volume of air in the pores. Again, as the hydrogen and oxygen of the woody fibre, as will be seen further on, are present in the ratio of their existence in water, or nearly so, and so solidified that they make up about the same volume as when actually combined in the form of water, it is evident that the greater weight of any specimen must be owing to the larger amount of carbon in the same bulk, excepting the slight difference which is due to the mineral constituents. The following table exhibits the density of several kinds of wood, according to BRISSON, water being taken as unity :—

Variety of Wood.	Density.	Variety of Wood.	Density.
Pomegranate,	1.35	Maple,	0.75
Ebony,	1.33	Cherry-tree,	0.75
Dutch Boxwood,	1.32	Orange-tree,	0.70
Heart of Oak—sixty		Elm—the trunk,	0.67
years old,	1.17	French Walnut,	0.67
Medlar,	0.94	Pear-tree,	0.66
Olive,	0.92	Spanish Cypress,	0.64
French Boxwood,	0.91	Lime-tree,	0.60
Spanish Mulberry,	0.89	Hazel,	0.60
Beech,	0.85	Willow,	0.58
Ash—the trunk,	0.84	Male Fir,	0.55
Spanish Yew,	0.80	Spanish White Poplar,	0.52
Apple-tree,	0.79	Female Fir,	0.49
Dutch Yew,	0.78	Poplar,	0.38
Plum-tree,	0.78	Cork,	0.24

When common woods that are thoroughly dried and rasped so as to destroy their porosity are weighed with proper precautions, their density is found to be higher

than that of water; and RUMFORD remarks that the solid portion of all the species of wood, wherever and under whatever circumstances grown, exhibits a remarkable identity in point of gravity, which he estimates at 1.46 to 1.53. It is to be observed, however, that the actual specific gravity of wood varies, in the same variety, with its age, the nature of the soil upon which it has been grown, and its site in relation to the prevailing wind; also, that young woods are specifically heavier than the older ones. The condition of the woods when the preceding densities were taken is not stated; the following table, based on different authorities, is therefore more satisfactory :—

Variety of Wood.	Hartig.		Wernk.	Winkler.	Mushenbroek.
	I. Recently Felled.	II. Dried in Air.			
Common Oak,	1.0754	0.7075	0.6441	0.663	0.929
Pedicle Oak,	1.0494	0.6777	..	0.663	..
White Willow,	0.9859	0.4873	0.4464	0.457	0.585
Beech,	0.9822	0.5907	0.5422	0.560	0.852
Elm,	0.9476	0.5474	0.5788	0.518	0.600
Hornbeam,	0.9452	0.7695	..	0.691	..
Larch,	0.9205	0.4735	..	0.441	..
Scotch Fir,	0.9121	0.5502	0.4205	0.485	..
Sycamore,	0.9036	0.6592	0.5779	0.618	0.755
Ash,	0.9036	0.6440	0.6337	0.619	0.734
Birch,	0.9012	0.6274	0.5699	0.598	..
Mountain Ash,	0.8993	0.6440	..	0.552	..
Fir,	0.8941	0.5550	0.4303	0.493	0.550
Silver Fir,	0.8699	0.4716	0.3838	0.434	..
Wild Service,	0.8633	0.5910	..	0.549	0.874
Horse Chestnut, ..	0.8614	0.5749	..	..	..
Alder,	0.8571	0.5001	..	0.443	0.800
Lime,	0.8170	0.4390	0.3480	0.431	0.604
Black Poplar,	0.7795	0.3656	..	0.346	0.383
Aspen,	0.7654	0.4302	..	0.418	..
Italian Poplar,	0.7634	0.3931	0.4402	..	..
Ground Willow, ..	0.7155	0.5289	..	0.501	..

The numbers given by each of the authorities in the preceding table can only be received as an approximation to the truth; but WINKLER's are probably the most trustworthy, because, in making his observations, the bulk of wood—one cubic inch—was the same in every instance, and the specimens were exposed in a heated chamber during six months, so that all contained an equal amount of water at the time of the experiment.

The principal difficulty experienced in attempting to determine the gravity of different kinds of wood, arises from the absorption of air into the pores and its subsequent expulsion. MARCUS BULL in his experiments removed this cause of error to a great extent, by coating the samples with a varnish having the same gravity as water. This insured the retention of the air in the pores, and admitted of arriving at a true approximation, although this appeared less than when quantities of the enclosed air were allowed to escape, as generally happens on immersing dried wood in water. Before citing his results, however, the appended table, containing KARMARSH's recent determinations, is placed before the reader, as affording a comparative view of the specific gravity of different kinds of wood in the green and in the dried state, with the mean weight of one cubic foot of the dried material :—

contains more carbonaceous matter in the same bulk. The condition of equal dryness, however, should not be overlooked, as without taking this into consideration the gravity deduced would be erroneous. From two-fifths to one-half the bulk of a stack of wood is interstitial space, even when the logs are of fair proportions; this is, however, much increased when small or crooked billets enter into its composition. Hence, in a stack, the per centage of solid matter compared with the bulk of the whole is very much less than that given in BULL's table. At the same time, it is only the quantity of woody matter that renders the material valuable as fuel; and a much nearer approximation to this can be arrived at when it is purchased by weight, than if the content is estimated by measurement. When, however, the purchaser is compelled to adopt the latter course, he should remember that the largest and straightest, as also the driest and densest varieties, are the surest to afford him an adequate value; the light, soft, and green woods not possessing sufficient matter to endue them with heating power in proportion to their bulk.

VALUE OF DIFFERENT KINDS OF WOOD AS FUEL.

—Very many considerations are to be taken into account in selecting wood as fuel—namely, the quantity of heat to be generated, the distance to which its effects are required to extend, and the length of time that the temperature must be sustained.

When soft light woods are burned, their action is brisk but transitory, their porosity favoring the rapid evolution of the volatile inflammable gases to which a part of their substance is converted by the heat; moreover, this looseness of texture allows the transmission of air freely through the mass of charcoal left, and, consequently, effects its rapid combustion. A remarkable exception indeed is cork-wood, which, although very light, affords more charcoal proportionally than any other species. When the wood is hard and compact, the heat cannot traverse it so freely; and the result is, that the interior portions undergo a kind of consecutive distillation, the volatile matters being slowly disengaged from the surface. When these have produced their effect, a charcoal remains of a dense and close character, weighing fifteen or twenty times more than that which light wood produces. Submitted to combustion, the charcoal from dense wood burns much more slowly, owing to the smaller surface which it presents to the air, than that from the softer kinds. These facts lead to the conclusion, that the principal effect of soft light woods is produced by the flame, the charcoal they afford being comparatively of little value. The contrary is the case with heavy woods, the flame from which is feeble compared with the others; but their charcoal is far superior, and more than counterbalances the difference.

It has been shown, in a preceding part of this article, that incandescent charcoal is very much superior to flame in radiating power; or, in other words, the quantity of caloric given off from charcoal is considerably greater than that emitted from flame; and as the denser woods produce, for equal weights, a much larger amount of charcoal than the lighter kinds, it follows that much more heat will result from the former.

Nevertheless, although light woods are less adapted for all heating operations in which radiation plays an important part, yet they may be employed with advantage where it is required to communicate an elevated temperature to objects distant from the fire-place, or a uniform temperature to solid bodies in large masses. Such are the reasons of their being preferred for glass-works, porcelain manufactories, *et cetera*; and even if a naturally dense material be employed for these purposes, it is brought to a suitable state by splitting it up into thin pieces, so as to render the combustion quicker, or to avoid the introduction of a useless mass of air into the furnace. On the contrary, blocks of dense wood are preferable for the heating of boilers, and other similar purposes, because, in this case, the radiant matter is required to act directly on the surface to be heated, which communicates by contact the heat to the liquid in the interior, through which it is then diffused by convection. The superiority of the denser over the softer woods for consumption in ordinary household fires, where radiation performs the most important part, is a fact universally recognised in practice. For stoves, also, and for heating apparatus in general, the former are found to be more advantageous, because they afford a much more regular and prolonged heat than the lighter woods, without involving the necessity of constantly adding fresh material to maintain the fire. On the other hand, apart from these considerations, the actual calorific effect of the same weight of dense and light wood is nearly equal. This has been proved experimentally by MARCUS BULL. Operating with a stove so constructed as to lose the least possible amount of heat, he found that the widest proportions between numerous specimens were as fifteen to sixteen.

In England, where wood is scarce and coal fields are numerous and extensive, the former is little employed as a fuel, except for some special purposes: but this is not the case in all other nations, and some European states in particular are almost entirely dependent upon wood for common consumption. On the Continent, firewood is divided into three kinds, namely, *new wood*, *float wood*, and *peeled wood*. The first is that which has been conveyed by boat or waggon from the forest to the place of its consumption; the second, that which has been floated upon the waters in the form of rafts, a mode of conveyance which causes a considerable quantity to be submerged during the passage; lastly, the peeled wood is limited to oak and certain other species, the barks of which have been removed for the sake of the principle they contain: it is generally composed of the smaller branches, and used in dwellings. Much of the value of the floated wood is lost by its submergence in the water, and this, to a great extent, counteracts the advantages of cheap transport. The loss arises from the solution of the principle of the sap in the water, and is visible in the density as well as in the volume, sometimes amounting to one pound per cubic foot.

SOLID CONSTITUENTS OF WOOD.—Fibrous matter, water, sap, and mineral salts, are the proximate principles of wood of every description. The amount of water contained in different woods has already received a share of attention, and as the sap is of a different

nature in every species, to enlarge upon it in all its varieties would unduly prolong this article. The further explanation of the proximate principles of wood will, therefore, be confined to the cellulose, lignin, or woody fibre, and the mineral constituents.

Lignin.—Woody Fibre or Lignin constitutes, as already stated, the main bulk of trees, and mostly all plants, varying in texture from the delicate and friable pith to the hard shells of the seeds, and the more dense and indurated vegetal ivory or perisperm of the seeds of the phytelphas. Regarded in conjunction with the mineral matters, it may be termed the skeleton of their structure, wherein is contained the various secretions and other principles. When the fine raspings of wood are treated successively with boiling alcohol, water, weak solutions of potassa, dilute hydrochloric acid, and ultimately boiled repeatedly with distilled water, there remains a white substance, which, when dried at 212° , is this *cellulose* or *lignin*. Not only may it be procured from the hard wood; but the pith of trees and plants yields it even more freely. If this pith be reduced by rasping, and then washed successively with hot and cold water, digesting in a weak solution of potassa, and afterwards subjecting it to the action of chlorine gas, the fibrin will be readily obtained. To complete the process, however, the digestion with the alkali is repeated, and this is succeeded by another with acetic acid, when, after affusing well with distilled water, and drying, a very pure lignin results. Many substances—such, for instance, as linen, cotton, paper, *et cetera*—afford lignin in a much purer state than wood, owing to the treatment which the fibre of flax and cotton undergoes to prepare it for those manufactures.

Pure lignin is tasteless, colorless, and insoluble in water, alcohol, ether, and essential oils; it has a specific gravity of 1.5, and is resolvable into other compounds by acids, such as nitric and sulphuric. The latter, in a concentrated state, converts it first into gum or dextrin, which may be afterwards resolved into grape-sugar. To effect this, one hundred parts of lignin—or clean bleached cotton or linen, answers the purpose—are treated with one hundred and forty of concentrated sulphuric acid in such a manner as to avoid the evolution of heat, or any charring; the mixture will readily admit of being triturated into a magma, which is soluble in water. By treating the aqueous solution of this mucilaginous matter with chalk, and straining or filtering, a liquid is obtained, from which alcohol separates a gummy precipitate; and this, after being elutriated with the spirit, and then dissolved in water acidulated with sulphuric acid, and boiled for some time, passes into grape-sugar.

It might be inferred from these results, that strong sulphuric acid converts lignin into amidin and dextrin; and, finally, into glucose or grape-sugar; yet the evidence in proof of the first change is not very distinct, although, on the application of the sulphuric acid to the substance, if a solution of iodine be added, a deep blue tint will appear. To show that the transformation to starch is effected, SCHLEIDEN directs that clean cotton wool be wetted with water, then squeezed dry, and afterwards spread upon a flat dish, and moistened with a mixture of three parts of sulphuric acid and

one of water; after about half a minute, an aqueous solution of iodine is added. With this treatment the blue iodide of starch does not fail to make its appearance.

Sulphuric acid reacts with great vigor upon wood and lignin, especially when heat is applied, giving rise to sulphurous, acetic, and formic acids, besides producing a black magma, from which water washes out those bodies, and leaves the carbonaceous residue to the extent of forty-three per cent. of the wood employed.

Nitric acid, in the concentrated state, decomposes lignin, changing it into the peculiar body xyloidin, which has nearly the same characteristics as that obtained from starch by similar treatment. The *gun-cotton* of SCHÖNBEIN, which is prepared by immersing cotton wool for a short time in equal parts of concentrated sulphuric and nitric acids, and washing under a stream of water and drying, is probably either a peroxide or a nitrate of lignin.

Hydrochloric acid, on being boiled with lignin, turns red, and ultimately brown. In the solid state, it becomes black, but does not dissolve in the acid. When this substance is washed and dried, it burns with flame, showing that it is only modified lignin, and not entirely carbonized. Fused potassa, or a strong solution of this alkali, changes a portion of the matter into oxalic and acetic acids, which combine with the base; the alkaline liquor, when treated with acids, parts with a modified lignin which is blued by iodine.

From what has been said of the behavior of lignin, more especially with sulphuric acid, it may be inferred that its composition is analogous to that of amylaceous compounds, or, in other words, that it is made up of the elements, carbon, hydrogen, and oxygen; the latter two being in that proportion in which they form water. GAY-LUSSAC and THENARD were the first to arrive at the conclusion that this proportion existed between these two elements, and the analyses of PROUT and others corroborated this view of the subject. To show the identity of lignin in the extensive circle of plants in which it is found, was a work undertaken and successfully accomplished by PROUT—not, however, by having recourse to numerous analyses of the principle prepared from different plants, but by taking two products of very opposite physical characteristics, and submitting them to ultimate analysis. These were portions of lignin from the *box* and *willow*; the former being one of the densest, and the latter one of the lightest species of woods. After preparing the lignin by repeated treatments with boiling water and alcohol, *et cetera*, it was submitted, after desiccation in air, to analysis, which gave the following numbers:—

	Centesimally.	
	Box.	Willow.
Carbon,	42.7	42.6
Water,	57.3	57.4
	100.0	100.0

By exposing the lignin thus analysed to a temperature of 212° , as long as loss was sustained, it was found that 14.6 per cent. of the weight of the box and 14.4 per cent. of the willow disappeared. Upon exa-

mination, the dried substance showed the annexed proportions:—

	Centesimaly.	
	Box.	Willow.
Carbon,	50	49.8
Water,	50	50.2
	100	100.0

By comparing these numbers with the figures given by GAY-LUSSAC and THENARD, as representing the composition of the lignin of beech and oak, namely:—

	Oak.	Beech.
Carbon,	52.53	51.45
Water,	47.47	48.55

or specifying the quantity of the water-producing elements thus:—

Carbon,	52.53	51.45
Hydrogen,	5.27	5.41
Oxygen,	42.20	43.14

the coincidence of composition will become apparent. LIEBIG assumes, from the analysis of GAY-LUSSAC and THENARD, that the formula is $C_{36}H_{22}O_{22}$; but calculating from the numbers obtained by PROUT, it is $C_{36}H_{24}O_{24}$.

By the action of heat, the hydrogen and oxygen in this body are made to unite, and, consequently, so far as the estimation of the value of lignin as a fuel is measured by the oxygen assimilated, they play no part, although it must be admitted that a certain quantity of caloric is disengaged by the chemical action which is produced by their union, notwithstanding that this may be rendered latent by the dispersion of the water so generated in the form of steam. It is, therefore, the carbon which operates in developing caloric by combining with oxygen, of which one hundred and thirty-eight parts are required to effect the conversion of one hundred parts of wood, represented by 52 of carbon, into carbonic acid. The caloric produced in this reaction is capable of melting 4,888 parts of ice, or of raising 3,666 parts of water from 32° to 212°. With these theoretical deductions, the practical results of RUMFORD and HASENFRATZ are in perfect accordance, giving 3,600 to 3,680, as the equivalent for dry woods. It must be observed, however, that all the heat is not produced by the carbon of lignin, as assumed in the above calculation; because the principle of the sap is retained. This, however, approaches so near in composition to woody fibre, and its quantity is so minute, that it does not cause any remarkable difference between the results of the ultimate analysis of dry wood and pure lignin, as the following table drawn up from the determinations of SCHÖDLER and PETERSON shows:—

Species of Wood.	Carbon.	Hydrogen.	Oxygen.
Pure woody fibre,	52.65	5.25	42.10
Quercus robur,	49.43	6.07	44.50
Fraxinus excelsior, ...	49.36	6.075	44.57
Acer campestre,	49.80	6.31	43.89
Fagus sylvatica,	48.53	6.30	45.17
Betula alba,	48.60	6.375	45.02
Ulmus campestris, ..	50.19	6.425	43.39
Populus nigra,	49.70	6.31	43.99
Tilia europæa,	49.41	6.86	43.73
Salix fragilis,	48.44	6.36	44.80
Pinus abies,	49.95	6.41	43.65
Pinus picea,	49.59	6.38	44.02
Pinus sylvestris,	49.94	6.25	43.31
Pinus larix,	50.11	6.31	43.58

It should be remembered, however, that the ash which, as will be presently seen, averages from one per cent. to a much higher proportion, has not here been taken into account, and, consequently, that the difference is greater than it would be, if the mineral ingredients were left out. CHEVANDIER has investigated some woods, taking cognizance of this fact, and the several specimens being dried at 284°, afforded the following results:—

ELEMENTARY COMPOSITION OF SOLID WOOD AFTER DEDUCTING THE ASH.

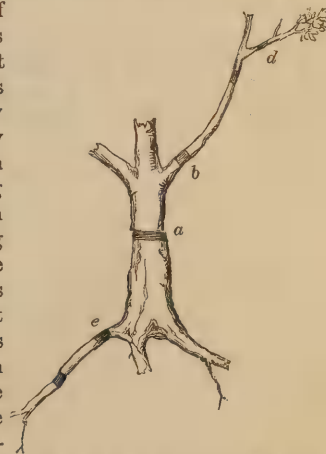
	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Mean of Analyses
Beech,	49.89	6.07	43.11	0.93	7
Oak,	50.64	6.03	42.05	1.28	5
Birch,	50.61	6.23	42.04	1.12	4
Aspen, ...	50.31	6.32	42.39	0.98	3
Willow, ..	51.75	6.19	41.08	0.98	2

ELEMENTARY COMPOSITION OF BRUSHWOOD AND BRANCHES AFTER DEDUCTING THE ASH.

	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Mean of Analyses
Beech, ..	50.08	6.23	41.61	1.08	8
Oak,	50.89	6.16	41.94	1.01	4
Birch,	51.93	6.31	40.69	1.07	3
Aspen, ...	51.02	6.28	41.65	1.05	2
Willow, ..	54.03	6.56	37.93	1.48	2

On the whole, it appears from what has been stated, that carbon, oxygen, hydrogen, and nitrogen, are the essential ultimate elements of vegetal products, and that the proportion in which they combine is very nearly the same in different plants. It is, therefore, not a little remarkable, that the composition of even the same plants is found to vary slightly in different parts. This might be expected in regard to the distinct organs—such as the pith, the wood, the bark, and the leaves—but not in regard to different complete portions of the same organic structure. Even in the latter, however, a sensible variation exists in the root, the trunk, and larger or smaller branches. M. VIOLETTE examined various portions of the completely organized structure of the same tree, with the view of determining this point. The subject of his experiments was a healthy cherry-tree, thirty years old, which was carefully dug up in the month of October, taking care to preserve the roots and rootlets entire and without injury. Samples were taken from the trunk, the branches, and the roots, as represented in Fig. 16, at *a*, *b*, *c*, *d*, *e*, *f*, *g*—all cut of equal thickness and enclosed in paper capsules, which were deposited during five hours in the bottom of a receiver, in which a current of steam from the boiler was made to circulate. By this exposure to air and to the temperature of about 172°, they all acquired an equal desic-

Fig. 16.



cation, and, after this treatment, they were well dried by enclosing them in flasks. The results which were arrived at by submitting these woods to analyses are subjoined, and the operator states that they were not accepted till the repetition of the process corroborated them:—

COMPOSITION OF WOOD CUT FROM VARIOUS PARTS OF THE SAME TREE.

Nature of Wood.	Elementary substances found in 100 parts of wood.			
	Carbon.	Hydrogen.	Oxygen and Nitrogen.	Ash.
Leaves,	45.015	6.971	40.910	7.118
Small branch, ..	Bark, ... 52.496	7.312	36.737	3.454
	Wood, ... 48.359	6.605	44.730	0.304
Middle-sized do.	Bark, ... 48.855	6.342	41.121	3.682
	Wood, ... 49.902	6.607	43.356	0.134
Large do.,	Bark, ... 46.871	5.570	44.656	2.903
	Wood, ... 48.003	6.472	45.170	0.354
Trunk,	Bark, ... 46.267	5.930	44.755	2.657
	Wood, ... 48.925	6.460	44.319	0.296
Large root,	Bark, ... 49.085	6.024	48.761	1.129
	Wood, ... 49.324	6.286	44.108	0.231
Middle-sized do.	Bark, ... 50.367	6.039	41.920	1.643
	Wood, ... 47.390	6.259	46.126	0.223
Rootlet, with branch,	45.063	5.036	43.503	5.007

Mineral Constituents.—When wood is burned, it always leaves a certain amount of residue or ash, which consists of various alkaline and earthy salts that have been taken up from the soil with the sap. The bases or metallic oxides of this ash are potassa, soda, lime, oxide of iron, and sometimes oxide of manganese; one or more of which are united with silicic, carbonic, sulphuric, and phosphoric acids, chlorine and sulphur. All woods have not the same per centage of inorganic matter contained in them, and, as may be seen in the preceding table, it varies remarkably in different parts of the same tree, and also with its age.

According to SAUSSURE, the quantity of ash yielded by—

1000 parts of barked young oak branches was....	4 parts.
1000 parts of their bark,	60 "
1000 parts of an oak trunk 56 feet diameter,	2 "
1000 parts of its bark,	60 "

BERTHIER, KARSTEN, CHEVANDIER, and others, have likewise directed their attention to this subject, employing air-dried wood as the subject of their experiments. The results are appended:—

ASH IN A HUNDRED PARTS.

	Berthier.	Karsten.		Chevandier.		
		In young wood.	In old wood.	Solid stem wood.	Wood of branches.	Brush-wood.
Silver fir— <i>Pinus picea</i> , ..	0.83	0.15	0.15	—	—	—
Birch,	1.00	0.25	0.30	0.57	1.00	0.48
Scotch fir, <i>Pinus sylvestris</i>	1.24	0.12	0.15	—	—	—
Oak,	2.50	0.15	0.11	1.94	1.49	1.32
Lime,	5.00	0.40	—	—	—	—
Fir— <i>Pinus abies</i> ,	—	0.23	0.25	—	—	—
White beech,	—	0.32	0.35	0.73	1.54	0.72
Alder,	—	0.35	0.40	—	—	—
Red beech,	—	0.38	0.40	—	—	—
Aspen,	—	—	—	1.49	2.38	—
Willow,	—	—	—	2.94	3.66	—

ACTION OF HEAT ON WOOD.—Having explained the constituents of wood, it remains now to examine the effects of heat upon it. As the tendency of caloric is to subvert the power of the existing affinity

between the elements of complex bodies, as well as to change their physical appearance, the simpler the substances submitted to its action—that is, the fewer elements composing them—the greater is the force with which they are held in combination, and the better do they resist the influence of caloric. When several bodies enter into the composition of a substance, it readily yields to the decomposing effects of fire, especially if the constituents have an affinity for one another, whereby simpler combinations are produced. Products of organic growth are generally of this class, as they include several elementary matters which have a remarkable tendency to arrange themselves into simpler and more persistent compounds. Some of the ingredients of these bodies are of a volatile nature; hence, as soon as the force of the heat applied overbalances that of the affinity which binds them together in the peculiar state in which the vitality of the plant arranges them, they assimilate and disperse, whilst others are left in the solid state. When the matters submitted to the action of heat are out of contact with air or oxygen, the quantity and number of the compounds formed depend, for the most part, upon the intensity of the temperature applied; but when oxygen or air is admitted, and the action of the heat is still exerted, the bodies, already modified, will undergo another change, from which will result compounds of the simplest and most permanent character. The latter transformation is always accompanied by the phenomena of combustion, whilst the former is termed dry distillation.

The constituents of organic matters, acted upon by heat in the presence of air or oxygen, unite with the latter element, and form with it the simplest and most stable compounds which it is possible for them to enter into. This is shown in the conversion of the carbon, hydrogen, and oxygen of such bodies into carbonic acid, CO_2 , and water, HO —two of the simplest, and at the same time most permanent combinations. In the other method of acting with heat upon organic substances—that is to say, in close vessels or out of contact with air—the results are by no means so simple as those just described; because the conditions necessary for caloric to exert its full effect upon them are not supplied; and hence, although the compounds formed are not so complex, and are more permanent than those from which they have been generated, yet they are far from being the simplest and the most persistent.

From the moment when the decomposing agency of heat begins to overcome the existing affinity of the elements in the organic body, three circumstances concur, either to multiply the formation of distinct but definite compounds, or to yield particular ones in larger quantities: these are, as already intimated, the temperature; the natural affinity of the existing elements, more especially at the moment of their liberation in the nascent state; and, lastly, their volatility. The effects of the temperature are first directed to the expulsion of oxygen and hydrogen, two elements which, from their permanently gaseous nature, are disengaged; they have, however, a very powerful affinity for one another, and, consequently, at the instant of their liberation, this affinity is exerted, and

they pass off, in conjunction, as water. When the two gases are present in that proportion in which they constitute water, a very low temperature, comparatively, will be sufficient to bring about their separation from the burning body in the manner indicated; but, on the other hand, if they be contained in a different proportion, then will the excess of the one or the other, at the instant of its liberation, attack the more fixed element—carbon—and give rise either to permanent gases, such as light carbide of hydrogen and olefiant gas, or to oily products of an analogous constitution.

Products of the Combustion of Ligneous Matter.—The number and nature of the bodies which, by a proper management of temperature, might thus be produced are still open to research. Those which have been identified are water, ammonia, acetic acid, pyroxylic spirit, or wood naphtha, and a mixture of resins and ethereal oils, denominated tar. By submitting the tar, especially if derived from coal, to further distillation and various other chemical agencies, it is resolved into a variety of bodies; such as paraffin, picamar, creosote, kapnomor, pitacall, and naphthaline—compounds discovered by REICHENBACH—pyrogenous resin and numerous oils, besides coal-tar naphtha, which contains various basic and acid bodies. In addition to these, a number of gaseous compounds is produced, such as carbonic acid and carbonic oxide, light carbide of hydrogen, *et cetera*. The nature of the products will vary according as oxygen or hydrogen preponderates in a fuel; thus, when it is rich in oxygen, the greater will be the production of carbonic oxide and carbonic acid, and the formation of hydrogen compounds will be limited, whereas, if hydrogen be in excess, the latter will be most abundant. How large soever the proportion of both elements may be, it will be insufficient to eliminate the whole of the carbon in the substance; hence, when vegetal matters are subjected to destructive distillation in close vessels, a residuary charcoal is always left, which, if wood, compressed peat, and such like bodies be operated upon, possesses the same form as the original substance. The carbon from most kinds of the denser coals does not retain this form, owing to their partial fusion under the influence of the heat, which produces an amorphous mass. Different names have been given to these residues; thus, what is left after the distillation of wood or peat is called *charcoal*, whilst that manufactured from coal is termed *coke*.

Charcoal and Coke.—The preparation of both these substances has become an important manufacture, as well for the sake of the by-products which are obtained in the operation, as for the carbonaceous matter itself. Carbon in some convenient form is of vast importance in the industrial arts, where great local heat is required. It has been already shown that this high temperature cannot be attained with the use of such substances as contain oxygen and hydrogen in definite proportions, since much of the heat which is produced by the ignition of such materials is necessary to disengage the volatile bodies to which they give rise, and when these are liberated, the combustion is only partial; besides, the caloric which results in this case cannot well be

concentrated, and cannot be rendered very efficacious by radiation. It is only charcoal, and such bodies as will develop the greatest amount of heat from the smallest possible extent of surface, that can be employed with advantage in such operations as the smelting of metals, especially iron, and for the purposes of railway transport, *et cetera*.

Not only is carbon valuable as a fuel, it is likewise highly serviceable in many other respects; its uses, as a disinfectant, have been given in Vol. I., p. 563; it is likewise employed as an absorbent of many gaseous bodies, for depurating sirups and extracts, and as a manure. It is chiefly, however, in connection with its application as a fuel, and its superior heating effects, that the various methods of preparing it will be here detailed.

Carbon, of which charcoal, coke, *et cetera*, are modifications, is known in its native purity in the diamond, although, as may be supposed, the quantity of it found in this form is very small. The Ghauts in India, more especially Golconda, Borneo, and the Brazils, furnish this precious gem. In this state it possesses remarkable transparency, brilliancy, and hardness, to such a degree that in no one of these attributes has it a compeer. Its specific gravity is 3.336; it may be burned in an atmosphere of oxygen gas, or in the air, under the influence of a very high temperature, when it is converted into carbonic acid; and ROGERS, by acting upon it in a finely divided state with bichromate of potassa and sulphuric acid, found that it is completely converted into this gas. With a Bunsen's battery of one hundred plates, it may be fused into a mass resembling very compact coke.

A charcoal approaching the diamond in purity, though partaking of none of those qualities which render the latter so valuable, is prepared by heating non-nitrogenous matters, such as sugar, dextrin, and the like, to redness in close vessels; or by passing the vapor of alcohol, ether, or some carbonaceous oils, through tubes heated to whiteness. In either case, a very pure form of carbon is left. As obtained by the latter process, charcoal is a brittle, black, insoluble, inodorous, and tasteless substance, capable of conducting electricity with freedom, but obstructing the passage of heat in a remarkable manner. It is unaffected by air or moisture, a quality taken advantage of in the construction of charring piles, so that they may resist the bad effects of moisture; also, in scorching the interior surface of casks and barrels destined for holding water and such liquids, both that the contents may be preserved wholesome and pure, and that the soundness of the vessel may be secured. In a pure state, it is infusible, or only fused in a slight degree by the greatest known temperatures. As stated in Vol. I., p. 563, it absorbs many gases in large quantities, has the quality of removing many alkaloids and bitter principles from their solutions, and latterly has been introduced by Dr. STENHOUSE as a physico-medical agent.

PROCESSES OF CARBONIZATION.—It is known from ancient records, that the manufacture of charcoal from wood has been practised for more than two thousand years; and very little progress appears to have been made, till lately, in improving the process. Many obvious circumstances would concur to induce the

carbonization of wood in early times, such as the trouble of carriage, and the facility of charring it on the spot where it was felled. It has been shown that wood, by drying, loses sometimes as much as forty to fifty per cent. of its weight; it also contracts in proportion, and if the heat be carried on to the point of charring, this contraction will reach to twenty or twenty-five per cent. of the bulk: hence the advantage obtained by this process in point of carriage. The system followed was such as to require partly the intervention of the air, and involved the destruction of a portion of the woods; the loss being greater or less in amount, according to the care bestowed and the precautions taken. The old course is still adhered to, with some slight modifications. Taken in connection with what has been already said as to the effect of heat upon wood and matters of an analogous composition, the following remarks may suffice to point out how far the admission of air and the application of an increased temperature affect the production of charcoal.

It is evident that when a piece of wood is ignited, the heat which destroys its elementary composition passes gradually inwards from the surface, till the whole is permeated, and as each successive layer of fresh fibrous matter is attacked, the volatile compounds resulting from the oxygen and hydrogen of the substance will issue at every pore, thus producing a mixed atmosphere of aqueous and inflammable matters around the wood. The combustion of these without the surface of the solid matter prevents contact of the latter with the oxygen of the air; hence, as long as they are formed, the charcoal which is left after the decomposition of each successive layer of lignin remains intact. It is different when they cease to be developed, for then the oxygen of the air is admitted, and the temperature being sufficiently elevated to induce combination, the charcoal rapidly decreases, so that, if the oxygen continue to be supplied, nothing will be left but the small quantity of mineral matters contained in the wood.

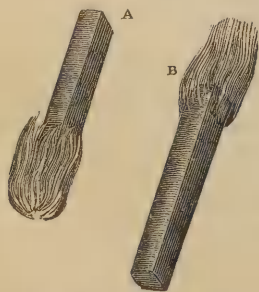
So long as the action of the heat supplied is restricted to the first stage, the results will be satisfactory; but when it enters upon the second, inconvenience and loss are occasioned. In the common process it is impossible to exclude the air altogether, as the charring of the

main bulk is effected through the agency of the complete combustion of a portion of the same material in the mass; nevertheless, by regulating the quantity and direction of the current, much of the loss incidental to this method would be avoided. For instance, in the carbonizing of two pieces of wood, of the same state of dryness and

at A, while the ignited end of the other is averted from the blast, as at B—Fig. 17—it will be found that the first of these will be speedily consumed, whereas the other, the charred portion of which is partly protected by the gases disengaged, disappears much more slowly, and sometimes leaves a residue of charcoal. Were it possible to introduce, as the distillation progressed, the parts of the second sample which was charred, into a tube or vessel where it would be excluded from the air, a much larger amount of charcoal would result. Hence it may be inferred, that in charring heaps of wood with a movable coating of mould covering it from the air, the current should be led from the furthest and coldest extremities, that the gases, as they issue, may protect the matter already decomposed from destruction; and again, that the best course would be to effect what is termed the destructive distillation of the wood, keeping the matter subjected to this process entirely out of contact of air. Such a process of decomposition may be carried out in close vessels, and this is the one best calculated to afford the largest yield of charcoal; besides, by a little additional care and management, the various other constituents of the matter operated upon and modified, so as to exist in states which are more or less valuable in other applications, can be recovered and turned to profit.

Notwithstanding that by the process of destructive distillation in close vessels, the greatest possible control is exercised over the operation; still, if the resulting charcoal be compared with the content of carbon in wood, it will be apparent that a considerable loss is sustained. According to the analysis of the samples of wood already laid before the reader, it would appear that if the elements of oxygen and hydrogen, which exist in all of them in nearly the same proportion as in water, were removed, the charcoal remaining should constitute from thirty-eight to forty, or even forty-five per cent. of its weight, but in actual workings the yield is often so low as fifteen to twenty, and under the most favorable circumstances only twenty-seven to twenty-eight per cent. of the wood are obtained. The difference between the practical yield and that which theory would indicate, is, in these cases, considerable, and is accounted for by the circumstance that the water, which is formed at a certain temperature, reacts upon the remaining charcoal, and, according to the degree of caloric which it possesses, occasions the formation of several other compounds—such as those mentioned in the two previous pages—all of which are rich in carbon, deriving this from the charcoal, to the loss of the manufactured product. These different forms of combination proceed in the order of their oxidation, the richest in oxygen being given off first, and being succeeded by others containing less of this element, till, at the conclusion of the distillation, nothing is left, and the final products are composed of carbon and hydrogen. Thus, in exposing wood to heat in close vessels, the first bodies that are observed to pass off are water and carbonic acid, followed by acetic acid and carbonic oxide. These are succeeded by a highly carbonaceous oil of a deep brown color and empyreumatic odor, which contains but little oxygen, and, lastly, carbides of hydrogen. As

Fig. 17.



having equal dimensions, in a current of air, to which the lighted extremity of one of them is presented, as shown

long as oxygen is in abundance, the latter are not generated, and also they cease in part to exist when the temperature is very high, as the oil and acetic acid are incapable of resisting a high temperature without being mutually decomposed, and resolved into water, carbonic acid, and carbide of hydrogen. The more oxygen and hydrogen that can be abstracted from the wood in the shape of water, the greater will be the bulk of charcoal left; and to insure this the best course is to apply a heat which is only sufficient to cause the combination of those elements, although inadequate to produce the other products of a higher temperature.

The course sometimes adopted, of submitting wood which is much saturated with moisture to the action of heat, for the purpose of charring, is disadvantageous, because the vapor of this body, passing over portions already charred and partly incandescent, transforms them into carbide of hydrogen—CH—and carbonic oxide—CO—and thus diminishes the yield of solid matter; indeed, if this decomposition were thoroughly effected, there would not be as much material as would supply carbon for this end. Woods, therefore, which are treated for the purpose of obtaining the largest amount of carbon or charcoal from them, ought to be well exsiccated, so as to be divested of extraneous moisture, and then the temperature should be so controlled that the material will not attain a red heat, for, under the

latter circumstances, the water produced from the elements of the wood would react in the manner above mentioned, to the detriment of the operation. M. KARSTEN made some experiments, with the view of ascertaining the relative effect of a low and high temperature, and found that if chips of wood are exposed for a long time to a heat of 300°, they will ultimately cease to lose weight. The loss sustained when air-dried wood is so treated amounts to sixty-five or seventy per cent., but when the material is first desiccated at the temperature of the water-bath, the utmost limits are from fifty-six to fifty-nine per cent. The residue in either case resembles charcoal in appearance, and was regarded as such by RUMFORD, who considered it as the skeleton of the plants; but KARSTEN has shown that it is but a modification of woody fibre, still holding matters which, when subjected to a high temperature, pass off as gases. However, the product from the application of a high heat is very different from that obtained when a low progressive one is applied, as shown by the results of KARSTEN's experiments in the subjoined table, to which are annexed the numbers given by STOLZE and WINKLER. The wood taken as the subject of experiment by KARSTEN was dried in air, and that which WINKLER operated upon was exsiccated in a hot room, whilst STOLZE torrefied his at 212°.

TABLE SHOWING THE PRODUCE OF CHARCOAL AT HIGH AND LOW TEMPERATURES:—

Species of Wood.	By the quick process of charring		By the slow process of charring.	
	Karsten.		Stolze.	Winkler.
Young Oak,	16.54	25.60	26.1	22.8
Old do.,	15.91	25.71		
Young Red Beech,	14.87	25.87		
Old do.,	14.15	26.15	24.6	17.8
Young White Beech,	13.12	25.22		
Old do.,	13.65	26.45	23.8	
Young Alder,	14.45	25.65		
Old do.,	15.30	25.65	24.4	17.6
Young Birch,	13.05	25.05		
Poplar,	—	—	23.8	17.7
Old Birch,	12.20	24.70	24.4	17.6
Birch 100 years old, well preserved,	12.15	25.10	23.4	20.6
Young Deal—Pinus Picea D.,	14.25	25.25		
Old do.,	14.05	25.00		
Young Fir—Pinus Abies D.,	16.22	27.72	21.5	20.1
Old do.,	15.35	24.75		
Young Pine—Pinus Sylvestris,	15.52	26.07	23.7	
Old do.,	13.75	25.95		
Lime,	13.30	24.60	22.8	16.2
Ash,	—	—	22.1	19.4
Willow,	—	—	22.2	15.0
Rye Straw,	13.40	24.60		
Fern Straw,	17.00	27.95		
Cane Stems,	14.65	26.45		

It will be observed at a glance that the advantage of a slow process of carbonization in regard to the production of charcoal is in some cases double, and is, therefore, so profitable in this respect, as to warrant its being resorted to upon all occasions. A slight difference exists in the proportion of charcoal which many of the woods in the foregoing table afford, although the same course was followed in their carbonization. The probable causes of these variations are, the changes of temperature which are liable to be experienced even within short periods in the course of manufacturing processes; and agreeably to this sup-

position, the widest range will be found between the results obtained at the high heat, where the variation was more likely to exist than in those samples charred at a low temperature. Taking the numbers in the second column of KARSTEN's results as the maximum quantity which it is possible to obtain on the large scale, and comparing them with those which are arrived at by manufacturers who distil wood with the greatest precaution in close vessels, and who have in view the utilization of all the products resulting from the operation, this remarkable coincidence will be apparent. The general results obtained by these manu-

facturers may be expressed thus for one hundred parts of wood :—

Charcoal,	28 to 30
Acid and water,	28 to 30
Tar,	7 to 10
Carbonic acid, carbonic oxide, carbide of hydrogen, and uncondensed water,	37 to 30

If to these numbers the weight of wood necessary to effect the distillation, and which is generally about twelve and a half parts, be added, the results will agree well with what is arrived at in practice in burning for charcoal. In air-dried wood containing about forty-five per cent. of carbon, this element is distributed in the following manner :—

Charcoal left as residue,	30.00
„ combined in the form of acetic acid,	0.50
„ „ in the state of tar,	6.00
„ „ as carbonaceous gases,	3.50
„ required to effect the distillation,	5.00
	45.00

These results agree as closely as can be expected with the numbers given by theoretical calculation, assuming that there is no further disturbance of the elements beyond the union of the oxygen and hydrogen to form water, and the evaporation of this body together with the heating of the remaining charcoal to incipient incandescence, or to about 932° Fahr. Making these conditions the basis of the calculations it is found, theoretically, that to form the water from the elements in 112.5 parts of wood, and to dispel it together with the moisture in combination, which amounts to about sixty-seven and a half parts, the heat developed by the combustion of six parts of charcoal is necessary. Proceeding in the same way, it is found that to bring the residuary charcoal to the above-mentioned temperature, about 0.77 parts are required, making in all 6.77 parts. Practically, only five parts of charcoal are burned to perform this work; but, unfortunately, much of the carbon is carried away in the gases, so that the last number swells to eight and a half or nine parts of charcoal in the charring of the quantity already named. Even these figures are close enough to those deduced from theory to warrant the inference, that in the charring of wood no very considerable improvement towards producing a larger yield of carbon can be made upon the common method, by which from twenty-five to twenty-seven per cent. of the weight of the original substance is obtained.

Having thus far enlarged upon the theory of the subject, the practical operations will now be considered. The distillation of wood has already been explained under ACETIC ACID, though chiefly with reference to the production of the latter body. It is now to be considered with special reference to the yield of charcoal; and with this object in view, there are several methods of procedure, all differing, more or less, in their practical details, though they may all be classified under two methods, namely, such as require access of air, and those in which the air is excluded. The former includes all the different methods of charring in mounds, to which preference is generally given, to avoid the cost of transport. In purchasing wood for this purpose, its weight is estimated in a rough way in the cutting, and

an approximate valuation of the timber, the charring wood, and brushwood, is made by ocular survey. To assist in this, tables have been drawn up to indicate the probable yield of charcoal from the variety of wood, according to its solidity, and the nature of the principles contained in it. The value of wood, as thus ascertained, is liable, however, to be affected by various causes—the difficulties in working it, the badness of the ways through which it is to be transported, and the conveniences which the locality offers for constructing a mound. In France, the price of a cord of wood consisting of seventy cubic feet is, on an average, from six to seven francs, or five shillings to five shillings and tenpence, but in the province of Champagne, where iron-works abound, the rate is higher. The purchaser of the wood usually cuts it, when too large, into suitable lengths, either by the hatchet or the saw; these lengths are about two feet when the material is to be charred in stalks, but when this process is to be carried on in heaps the logs are left about seven feet long. The workmen engaged in this business are paid from seven to ten pence per cord for cutting, and two or three pence for piling. Sometimes the wood is carbonized immediately, but generally it is left to dry for a certain period. Although the latter method is attended with an increase of interest on the outlay, still the quality and yield which the dried wood affords is more than adequate to repay this.

The site of the mound, or *meiler* as it is termed on the Continent, is carefully chosen by the charcoal maker. Some spot is generally selected which is sheltered either by a declivity or a wood from currents of wind, and at no great distance from the felled timber. The soil must be neither too damp nor very dry; in the former case, the moisture evaporated by the heat and passing over the charcoal, would at the high temperature convert much of the solid into gaseous bodies, and so occasion a loss; and in the latter, currents of air would enter through the interstitial channels, and prove as injurious as the humidity, or even more so. A spot which inclines to neither of these extremes is carefully cleared off in the summer time; and previous to erecting the meiler, if any misgiving is felt as to the fitness of the site, it is covered over with shingle or planks, and these are overlaid with charcoal powder to the depth of several inches. Having thus prepared the flooring, a stout stake is erected in the centre, having its upper end cleft crosswise at right angles; and into these incisions two logs are adjusted, forming right angles with one another in the same horizontal plane. Four logs are then inclined against the vertical post, the upper ends fitting into the angles produced by the intersection of the cross bars at the top. The floor or hearth of the meiler is then formed by placing billets of wood all round, radiating from the central post; the vacant spaces are filled with pieces of wood of smaller dimensions; and to secure the whole in the order in which they are laid, pins are fixed all round the periphery at about a foot distant from one another. Very dry wood, or such pieces as are easily ignited, are now arranged around the central post in a nearly vertical position, so as to form a truncated cone; these are enclosed by layers of billets of about equal length placed

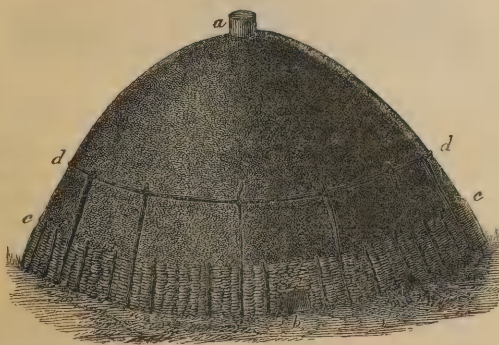
horizontally on the floor, and the vacancies filled up as before. Two or more such layers, forming concentric rings, are added to increase the diameter of the mound, as shown in the sectional drawing, Fig. 18;

Fig. 18.



and these, as they are successively raised, incline at the same angle as the nucleus around the central stake, owing to the logs being all cut of the same length, according to a regulation enforced by the Forest Laws. This is advantageous, inasmuch as it offers facilities for covering the whole more firmly with the soil or mould. When raised to the proper height, the heap is rounded at the top by adjusting logs and brushwood together; and after this the whole is coated with a covering of soil from four to six inches in thickness, interposing grass, leaves, and such bodies between it and the wood. This coating does not extend to the bottom, but rests upon a layer of twigs and branches a few inches in thickness, held in their position by forked uprights—an arrangement adopted to allow of the escape of the aqueous vapors which are discharged by the first action of the heat upon the wood. Were the steam permitted to escape at the superior openings, too much draught would be produced, and more air would thus be admitted than is advantageous to the working. The base of the meiler is protected from unfavorable draughts by an armor of wicker work—as seen in Fig. 19—representing the heap ready for ignition. In this

Fig. 19.



drawing, *a* denotes the quandel, *b* the aperture by which the mass is ignited, and *c* and *d* the armor surrounding the base. A few holes are left in the top and sides of the heap corresponding to the billets

placed at the base. Care is taken to have the cover much more solid at the top, in proportion to the height to which the meiler is raised, so as to resist the draught which chiefly exerts its influence on this part of the heap. The mass is ignited by adding glowing charcoal to a quantity of brushwood which is placed in a channel left at the foot of the meiler for the purpose; the fire rapidly traverses to the interior and attacks the logs which are arranged round the vertical stake; when these are red-hot the upper orifices are closed, and the first stage of the operation, namely, the *sweating*, is then allowed to proceed. Much care is required to prevent a too copious disengagement of vapor at this period, which would destroy the heap; the process is going on well as long as the smoke presents the appearance of a yellowish-grey cloud. Much watery vapor is emitted at this stage, portions of which condense upon the covering of the heap, giving it the appearance of exudation. As the moisture is expelled the gaseous matter assumes a lighter grey appearance, which is the indication of the second stage of the process. The wood of the stake and portions of that surrounding it are now consumed, as well as the brushwood at the top; irregularities are, consequently, formed in the covering owing to portions of its support yielding, and openings for the escape of the products of the combustion are produced. About this period the aperture which was caused by the annular support at the base, termed the *armor*, is closed; after this, and on observing the above indications, the top part of the covering is removed as speedily as possible, the logs near the stake broken up and forced together with a long pole, and the empty space thus formed charged anew with more logs, the whole being secured under the mould as before. The entire combustion of the portion of wood in the centre, and of the smaller branches throughout the heap, now reacts upon the remainder of the logs causing their destructive distillation.

For several days the charring proceeds progressively towards the exterior of the meiler. During this time continual attention is necessary, as well in allowing the tarry vapors to issue at the base by making openings for that purpose, as in supplying air for maintaining the heat required for the charring, and checking the draught where the temperature and the combustion are too violent. As the work progresses and the wood becomes charred, the heap contracts, but this is apt to be very partial unless the workmen control the draught, by making outlets in the covering of that portion where the effect of the fire is slow, and drawing the heat to it, at the same time putting on a thicker coating where the action is likely to be too vigorous. Having done this in the upper part of the heap, it still remains to conduct the heat to the outer surface. The cooling tendency of the coating, and the condensation of water and empyreumatic matters upon it, render the ignition of the logs near the coating impossible under the circumstances hitherto stated; and if the operation were allowed to proceed, the logs in the outer ring would be only half or three-quarters burned, even when the charcoal in the interior would be overdone. To guard against this, a second series of holes must be made in the upper part of the breast of the meiler, in a line

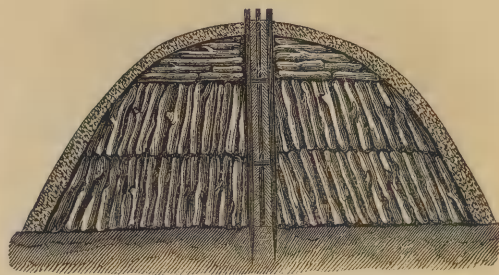
with those at the foot, but more distant; these openings need not, however, be made as high as there is wood uncharred, for the direction of the draught to this quarter will generate as much heat as will be sufficient to carbonize it, even above the temporary chimneys. From these orifices a thick black smoke is discharged, which, after a time, is succeeded by a thin blue cloud; as soon as this is observed the orifices made are closed, and others formed at a distance of two or more feet nearer the base, and the vapors allowed to issue by them till the same appearances are observed as before. According to the size of the heap and the state of completion of the work in hand, a third and fourth series of such perforations are made in the covering, and the combustion of the matter in their vicinity is allowed to proceed till the heat is intense enough to decompose their elementary arrangement, after which they are closed. When the process is finished, flames issue simultaneously from the different apertures around the heap; and should this not be general, vents are opened in other parts in order to expedite the appearance of the flame all round. When this occurs, the process is completed, and the duty of the attendant is now to extinguish the incandescent mass. Were this point overlooked, and the heap broken up before the charcoal was thoroughly cooled, no inconsiderable loss would be sustained; on the other hand, if it were left to part with its caloric spontaneously, too long a time would be required for this purpose, in consequence of carbon being a bad conductor of heat. The course adopted is to coat the whole heap with a thick layer of moist earth, and to leave it thus choked during a period which varies according to circumstances—generally twenty-four hours; if the temperature be not sufficiently reduced by this time, as much of the covering as is possible, without exposing the charcoal to air, is taken away, and replaced with another layer of the humid soil. If two coverings be given, the time allowed for its remaining on the heap is shortened.

When the whole is sufficiently cool for drawing, the covering is stripped off, and the charcoal taken and spread upon the soil in a thin bed; should any sparks remain, it is necessary to exclude the air from these parts by throwing sand upon them. Another method is practised, which, though more expeditious, is nevertheless more open to loss. It is to strip the meiler partly at the base, and by means of a hook to draw out the logs of charcoal separately and cover them instantly with sand, clay, or some such material as will readily extinguish them; water, when convenient, is employed for this purpose. When as many logs are abstracted from this opening as can be easily managed, it is quickly closed so as to prevent, as far as possible, the combustion of the incandescent charcoal; a fresh hole is then made at some distance, and the charcoal taken from it treated as before. This operation is repeated all round the base of the meiler till the whole is extinguished. Night is the best time for conducting this part of the work, as the darkness enables one to observe the smallest spark in the charcoal.

In the methods adopted in the New Forest, a different arrangement of the wood in the construction of the

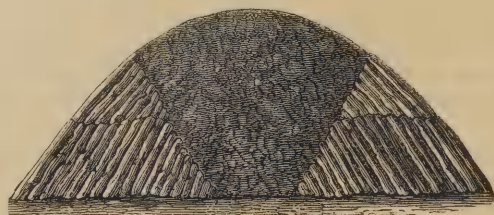
meiler is resorted to. The logs are placed perpendicular, or nearly so, around the central stake, or quandel, to the breadth of the pile, and one or two other rows, all in an erect position, are superimposed upon this; the top of the stack is rounded by fixing shorter logs horizontally, in the manner indicated in the sectional drawing—Fig. 20. In all the other details the

Fig. 20.



working of both forms of meiler is the same, differing, however, in the manner of igniting. With the arrangement here represented, the fire is communicated from the top. The quandel being formed of three stakes fixed at the distance of a foot from one another, at which distance they are retained by introducing blocks of wood between them, the empty space is filled up with dry brushwood and half-burned charcoal. Combustion is commenced by introducing red hot coals into this part, and as fast as the light wood is consumed fresh material is supplied, until the logs of the meiler have in part undergone combustion. The regulation of the draught is attended to with all possible care, and so conducted as to induce the carbonization of the wood after the sweating, in the order represented by Fig. 21.

Fig. 21.



To effect this the draught must necessarily be directed from the burnt towards the unburnt portion. This is managed by forming the temporary chimneys in such positions as to draw the volatile matter from traversing the burnt portion, while the openings at the base are at some distance from that part where combustion is taking place. The effect of the fire is known by the depression of the covering, and this apprizes the attendant where the openings for the draught should be made, so as to keep it from that portion which is already carbonized. In the latter method of constructing the pile, care must be taken not to allow much vacant space between the logs, especially between the ends of the first range and those of the next. If this were neglected, the circulation of air would be too

rapid, causing the fire to spread over a large surface without effecting a sufficient carbonization.

Both these forms of meiler are used generally in the forests, and perhaps it is difficult to say which is preferable. Among the Swedish burners it has been established that more charcoal is obtained when the logs are piled up horizontally, than when they are arranged in a nearly vertical position; but the charring is not so well or so readily effected. With the second or vertical method, the loss by combustion is much greater, but the quality of the charcoal produced is superior to that obtained by the other processes.

Another method of charring is in use, especially at Wienerwald, and also in mountainous districts where there is no great depth of soil, and where resinous wood is operated upon. The form of the heap or pile is shown in Fig. 22—a kind of structure termed *Haufenverkohlung*, and offering facilities of charring uncleft wood of every dimensions. When this mode

is adopted, it is customary to bark the wood, in order that the fire may attack it more readily than it would do if not so prepared. The best period for depriving charcoal wood of the bark is immediately after felling, for then the operation is easy, whereas, if attempted when partly dried in the air, considerable difficulty would be experienced. Besides presenting advantages as to facility of combustion, barked wood has other qualities which ought to be taken into consideration by those engaged in the business; especially a greater freedom in parting with moisture, requiring, according to the experiments of AF UHR, only a fractional part of the time usually allowed for spontaneous desiccation. The results appended indicate the advantage in this respect, the experiments being made on pine-wood, in a shed open at the sides, but protected from the admission of the rays of the sun and from rain. The period of the experiments was—

Species of Wood.	From June to				Per centage of original weight.
	July.	August.	Sept.	Oct.	
Whole logs,.....	0·41.....	0·84.....	0·92.....	0·98.....	}
Logs deprived of bark,.....	34·53.....	38·77.....	39·34.....	36·62.....	

From these numbers it may be inferred, that by using barked wood a vast advantage is gained in point of return of capital, as the quantity of water which is evolved from the wood so prepared is only what the same quantity of timber would lose, how long soever it might be left air-drying.

Heaps of a rectangular form always afford less charcoal than the meiler process, but the loss is in some

where it measures from nine to fifteen feet, according to its length. A small recess is allowed in the lower extremity, as seen in the figure, for the purpose of lighting, when the arrangements have been made for that purpose, and the heap is well covered with moistened charcoal or mould, and beaten as solid as possible. Fire is placed in the chamber just mentioned, and the small wood contained in it quickly undergoes combustion; a draught is instituted by making several holes in the front of the heap, at a distance of about fifteen inches from the level of the ground. As soon as the fire takes hold on the wood of the heap, the first opening is securely closed, and others opened along the front, so as to draw the heat along the base which is being charred, whilst the upper part is undergoing the sweating stage. When a light smoke of a bluish tinge issues through any of these openings, the attendant knows that the charring conditions are favorable in those parts, and that it is time to conduct the draught to other quarters, and for this purpose the openings already made are closed, whilst others are pierced in the covering at a proper distance. After the fire has traversed the entire breadth, the draught is still maintained by making perforations in the sides of the heap near the ground, and corresponding ones in the upper surface of the mound, taking care that the current thus instituted traverses only where the wood is undergoing distillation. The practice is to draw the charcoal from that part of the heap which has been charred, as soon as the fire has extended as far forward as the heap is wide. This is continued partly throughout the operation, but so sparingly, that about half the heap will be left when the more bulky end comes to undergo active carbonization. The necessity of covering all the parts, and of sprinkling the surface of the heap with water to allay the heat in some degree, should not be overlooked. When this method is successfully conducted, the fire traverses about a foot and a half daily, causing

Fig. 22.



measure redeemed by the circumstance, that the operation is more easily conducted in consequence of the vents and draught-holes being more under control in this than in the conical form. The site generally chosen for the heap is a gently inclined plane, about seven to ten feet in breadth, by thirty to forty in length. Posts corresponding to the intended height of the heap are fixed vertically around this space and about two feet apart; to these boards are nailed so as to retain in its place the covering of mould or powdered charcoal, as the case may be; sometimes wicker-work is substituted for boards. The logs of wood are now placed transversely to the length of the parallelograms, taking care to have the larger ones at the base, and to fill up with lesser wood all the intermediate spaces; sometimes, however, they are arranged lengthwise. As the heap increases, the upper surface is made to present a cuneated shape, by heightening the anterior part, and gradually tapering to an angle of 15° to 20° with the horizon. When finished, the heap is no more than two feet in height at the front, whilst it increases gradually to the opposite end,

the operation to last for a time proportionate to the length of the heap. According to DEBETTE, the product from 35·3 cubic feet—one stère—is

In large charcoal, 27·44 cubic feet.
In small charcoal, 0·95 “

Making a total of 28·39 cubic feet, weighing about 185 pounds.

This product is much less, however, when the smaller kind of wood is employed.

The commoner and less economical methods of charring have now been noticed, but the demand for the charred article, as well as for the substances which the dry distillation of wood affords, has tended to induce a modification of the processes, with the view of enabling the charcoal-burner to obtain a larger amount of charcoal than is possible by the methods just described, and also to recover considerable quantities of the products of the decomposition of the wood.

In the first of these deemed worthy of notice, the main features of the meiler are retained, but by enclosing it in sheds, which may be of wicker-work or of boards, the destruction of a portion of the wood from exposure to the wind is prevented. In the construction of this kind of covering, the advantages of its being portable and easily adjusted are obvious; hence it is generally made in divisions which are readily connected with each other, so as to form a complete shed round the pile, large enough to leave an interval of a few feet between. An opening is made at the top, for the escape of the smoke and gases, and another at the side, temporarily closed with a curtain, for the ingress and egress of the workmen. Sometimes the walls of this shed are made of solid materials, such as stone, bricks, *et cetera*, and roofed by planks or stout boards, leaving sufficient room between them for the smoke to escape. By this arrangement, the results of the carbonization are increased to twenty-two per cent. of charcoal.

Another modification of the meiler process, suggested by BRUNE so far back as 1801, and which was examined and reported upon by BLAVIER and BROCHIN, is said to expedite the charring, as well as to increase the yield of charcoal. The heap is in this case constructed, where the meiler is stationary, by digging a circular hole to the depth of a foot, and depositing a frame composed of bars of iron, upon which is laid a cover constructed of sheet-iron plates well riveted, and of the same area as the base of the heap. Instead of excavating the soil, an annular wall of brickwork or masonry may be built, with internal supports for the base. Care is taken to have the plates air-tight before the meiler is formed upon it; this is tested by introducing a few lighted faggots at an opening which is left at one side, and which forms a kind of hearth, and observing if any smoke issues through it. Air is admitted for supporting the combustion of these faggots through three other apertures, one of which is opposite to the hearth, and the others equidistant from it. The meiler being erected and covered, first with brushwood and foliage, and finally with moist powdered charcoal, five or six burning faggots are introduced beneath the plated base at the

hearth, and the combustion is kept up with fresh quantities for about an hour, when the whole base of the meiler will be in a state of ignition. At this stage the vent-holes and the hearth are closed, and other openings made in the usual manner in the covering of the mass, closing them as combustion becomes sufficiently advanced.

The superiority of this mode is attributed to the greater conducting power of the metal than of the soil, by which the heat is distributed so rapidly as to cause the ignition of the whole of the wood in contact with it in a very short time, and without the necessity of admitting any increased volume of air. Nor is it necessary for effecting this, that the whole of the base should be heated; an area of five feet will be sufficient to communicate a decomposing temperature to a meiler of thirty feet diameter at the bottom.

Upon the same principle, although less effective in charring the wood quickly, is the plan of erecting the meiler upon a stationary foundation, so constructed as to yield a portion of the products of the distillation. Fig. 23 represents this bed vertically, and Fig. 24 its elevated section. The structure is built of bricks, and has an inclination either from the circumference to the centre, as shown in the drawings, or reversely. In the former case, the centre of the bed is hollowed perpendicularly, and from the well thus formed, an outlet leads to a brick tank at the side. The central well is represented in the drawings by *d*, the channel by *b*, and the tank by *c*. The well is covered during the carbonizing with a perforated grid to prevent its being filled with the charcoal, and care is taken not to allow the ingress of air through the channel. This method is followed for the most part in the Landes, in Pologne, and in Russia, and where resinous woods are at hand; it is designated the distillation *per descensum*, from the circumstance that the tar, resin, and such heavy products fall through the heap, and flow into the tank *c*, where they are recovered.

Of the various methods of carbonization which chiefly aim at obtaining the greatest amount of charcoal in the readiest way from a given weight of wood, the mode followed in America seems the most advantageous. Not, indeed, that this materially differs from the European systems, or that it does away with the necessity which is involved of consuming part of the material, but that the loss which is unavoidable is confined to matter which has less value than the charcoal. With this view, the interstices of the meiler are filled with powdered charcoal, which, by burning, gives out so much heat as to effect the rapid distillation of the wood, whilst, at the same time, it preserves the carbonized material from contact with the air. By this process it is said that about twenty-two per cent. of charcoal are obtained, which is clean to the touch, and

Fig. 23.



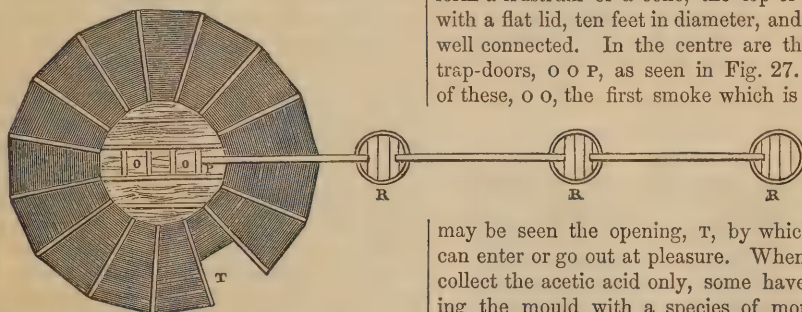
Fig. 24.

in every respect similar to that produced by the distillation of wood in close vessels.

Such are the improvements which have been effected in operating with the ordinary meiler, having no regard to the perfection of the process by turning to profit all the products afforded by the wood; but, from the number of these, and their utility in the arts, their waste could not be long permitted, especially when their value became known. To submit the wood to distillation in close vessels, however, would involve a considerable outlay in costly apparatus, which at the same time would fail to furnish a quantity adequate to the requirements of the trades which consume it, and hence more simple, as well as more effectual methods were a desideratum. The conditions required were, to a great degree, fulfilled by the processes proposed by FOUCAUD, BAILLET, and SCHWARTZ, but others have been suggested and acted upon.

FOUCAUD's method, which is the simplest of these, is founded on the principle of sheds; all the other details being much the same as in the common *pile* process. A covering is provided, which, while it affords all the advantages derived by the use of sheds, adds

Fig. 27.



meiler being ignited passes out; and after this the condensable products are drawn off through the third opening by a pipe bent at right angles, and conducted into the first of a series of condensers, R R R. This arrangement is shown in elevation in Fig. 28, where

Fig. 28.



the decomposition of the contents. It is constructed by digging a circular cavity in the earth of any convenient depth; or, where this cannot be done, building a mould wall round the space corresponding to the size of the furnace. When sunk in the ground, holes are made perpendicular to the base, and at a distance of a foot from the facing of the wall of the cavity; they are made to open inwards at the base. In the other form, the perforations are fixed at the base to open inwards in the same way. Fig. 29 represents this kind of carbonizer, half in plan and half in elevation, and Fig.

the means of collecting the volatile products in suitable condensers; and to render it more efficient, it is so made as to be simple and economical—the diameter of the base being thirty feet, at the top ten feet, and the height eight or nine feet. To form this shed, frames twelve feet long, three broad at one end, and one foot at the other, are constructed of bars of wood two inches square. Upon these, stout twigs in the form of wicker-work are woven; wooden holders are attached to each frame, by which, and the use of an iron or wooden pin, they may be joined together. Before putting them up, it is customary to coat them with a well-tempered

Fig. 25.



Fig. 26.

loam, with which some chopped grass is mixed. Fig. 25 shows one of these frames, and Fig. 26 one side with the holders appended.

When a number of these are adjusted together, they form a frustrum of a cone, the top of which is closed with a flat lid, ten feet in diameter, and made of boards well connected. In the centre are three openings or trap-doors, O O P, as seen in Fig. 27. Through two of these, O O, the first smoke which is evolved on the

may be seen the opening, T, by which the workmen can enter or go out at pleasure. When the object is to collect the acetic acid only, some have proposed coating the mould with a species of mortar made with quicklime; the acid unites with this base, and forms acetate of lime, which may be treated as indicated under ACETIC ACID.

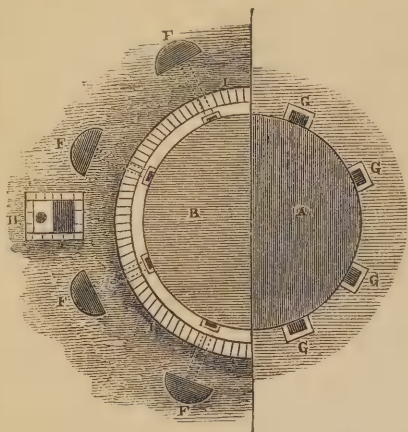
BAILLET's form of carbonizer, reproduced with various improvements in the apparatus of M. LA CHABEAUS-SIÈRE, consists of a cylindrical chamber, covered with a plate of cast-iron, and furnished with orifices, for the admission of air to support the combustion of a portion of the wood, and also for the passage of the products of

30 a section of the same. In the first of these, A denotes half the plan at the level of the base, and B the other elevated portion under a vertical view. The same are seen in section, where C indicates the half section over the chimney, and D the half over the air-channels.

The bottom of the furnace, E, is constructed of refractory clay, well beaten, or of bricks; so also are the side openings, G, of the air-channels in the bottom. F F indicate the mouths of these holes, H is the brick-chest or pipe for conducting the smoke, and I the casing of

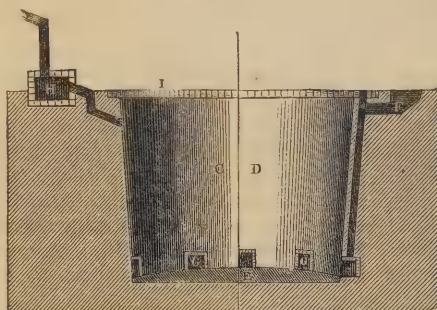
the same material upon which the verge of the lid rests. This most important part of the furnace is constructed of wrought-iron plates, bound by clamps or

Fig. 29.



hoops of sheet-iron. Its form is a segment of a sphere, its diameter is ten feet six inches, being six inches wider than the pit, so that it will rest three inches over

Fig. 30.



the edge of the wall. It ought to be sufficiently solid to bear the weight of a man without being injured. A perforation, *a*, Fig. 31, is made in the centre; this opening, which is nine inches in diameter, and closed by a movable plug of iron, serves as a vent for inducing

Fig. 31.



the ignition of the wood, as well as for introducing red-hot coals for that purpose. There are four other openings, *b b*, equidistant from each other, and six inches from the rim. The diameters of these are only four inches, and they are intended as draught-holes for the escape of the first heavy vapors that are given off when combustion sets in. In diameter the furnace is about ten feet at the base, being a little more at the top, and it is nine to nine and a half feet in depth. About six inches thick of solid flooring, composed of refractory clay, is laid on the bottom, bringing this up to the level of the inlets. It should be well beaten, in order that it may the better resist the heat, as should likewise be that of the walls of the furnace. The air-

holes are generally about two to two and a half inches in diameter, though openings of a less calibre would be sufficient; but by placing a tile upon the orifice, the volume of air may be reduced at pleasure.

The outlet through which the volatile products pass is introduced at about nine inches below the ledge of the furnace; it is nine inches in diameter, and inclines towards the body from the further end, which abuts in a rectangular box, eighteen inches in length, twelve in breadth, and fifteen in height. During the distillation, tar and portions of the acid condense in the box, the walls of which are made of brick, the cover being a movable plate of iron; and when nearly filled, or in such a state as that it would obstruct the passage of the vapors, the excess is drawn off by a stopcock in the side near the bottom. A cast or wrought iron pipe is fixed vertically in the lid of the box, and at the height of about four feet it is bent horizontally, or slightly depressed; the horizontal part is about fifteen feet in length, so that the contents may be cooled during their passage, and prevented from spontaneously igniting. The far end of this pipe discharges itself into a wooden sluice or covered trough, which conducts the products into suitable condensers. Before putting the furnace in operation, it must be well dried by lighting some brushwood, and keeping up the heat till the bottom and sides are thoroughly baked. The charging is commenced by fixing a round stake four inches in diameter in the bottom, and of the same height as the furnace. Around this, some charcoal is placed to keep it upright, and then logs of wood are arranged horizontally, radiating towards the circumference and between the air-holes, observing that the ends reach neither to the central stake nor to the wall of the furnace. The spaces unoccupied between the radii, form so many flues from the draught-holes to the centre. Another layer of logs is laid transversely upon these spaces, and close to each other, thus leaving as few vacancies as possible. Other layers are placed upon this successively till the furnace is filled, and all the spaces round the circumference are charged, either by alternating the logs, or by employing smaller wood for this purpose.

The next step is to withdraw the central shaft, and to fix the cap in its place; the latter operation is facilitated by the use of two iron levers and wooden rollers twelve feet in length, which pass over the furnace and rest on the ground at each end. All the openings in this cover are left free, and the remainder is coated with a layer of loose dry earth or sand, two inches thick, in order to cause it to be as retentive of the heat as possible. The draught-holes round the circular wall of the furnace are likewise opened. At this stage, some red-hot embers are poured down the central vent-hole through a kind of funnel, and these falling through the space previously occupied by the stake, which acts as a kind of chimney, come in contact with the combustible material at the bottom, which is soon ignited. For the purpose of diffusing the flame over the contents of the furnace, the central orifice is closed as soon as the fire has acquired sufficient strength. After the bluish smoke which escapes from the charcoal changes to a whitish shade, the draught-

holes in the cover are partly closed, as are also those leading to the base of the furnace; and when the combustion is thought sufficiently brisk, the openings in the cover are entirely stopped, and the vapors allowed to pass off to the condenser. Sometimes the draught produced by the chimney at the end of the condenser is not powerful enough to cause a rapid transmission of the gases and other volatile products from the furnace, in which case the fire is apt to flag or become extinguished. This state of things is detected by the vapors being driven back in the outlets through which they ought to proceed. To remedy the evil, the air-holes at the top of the cover might be opened and a portion of the products allowed to escape, rather than suffer the fire to go out; but the best contrivance is to have a second opening at the top of the furnace, to which pipes may be appended for conducting the gases off to the condenser, but capable of being closed when not required.

The charring generally requires from sixty to eighty hours to produce a good quality of charcoal, but the period is, of course, variable. The attendant examines the state of the interior by thrusting a pole into the furnace through the central opening, and observing if the reduction in the bulk of the mass be equal in all parts. If this be not the case, the draught-hole is opened near that part where the subsidence is least, as also the air-hole opposite to it at the base, and in a very short time the equilibrium is re-established. As soon as the charring is thought to be completed, either by examination with the pole or from the appearance of the smoke which may be evolved, all the air-channels and draught-holes in the cover are opened, with the exception of the central one; a brisker combustion ensues, and some hydrogen which has been hitherto retained is given off. In consequence of this, the charcoal changes from a reddish-brown to a black color, and is so far rendered more marketable. Immediately on the surface of the charcoal becoming incandescent—a state which may be observed by looking through the orifices in the cover—all the openings by which air entered or vapors escaped are carefully closed; the temporary covering on the cap is removed, and replaced by a coating of thin loam. Thus secured, the whole is left from seventy to eighty hours to cool. The furnace is then uncovered for the purpose of removing the charge of charcoal.

It will be observed that the contents at this period possess no more than half the bulk of the wood originally introduced; this reduction arises not from the actual contraction of the matter in charring to that extent, but from the filling up of the interstices by the burned material.

A workman now descends into the furnace and empties it of its charcoal, by taking the pieces up one by one, using as much precaution as possible that they are not broken. The smaller fragments and charcoal dust are removed with a shovel, and collected in a heap together. Should the contents not be thoroughly cooled, the workman employs an iron tool which protects his hands from the heat. Any live or half-burned charcoal which may be present is assorted by itself, then spread out and occasionally raked about, by which it

becomes extinguished of its own accord, and without the use of water; it would be well, however, to have some at hand, in which to immerse any pieces that may be detected burning, which is known by the appearance of white spots. When the furnace is emptied, it is re-charged in the manner already described, and all the operations are repeated in the same manner, and proceeded with as previously detailed.

Five active workmen have been found sufficient to superintend successfully eight such furnaces, working without interruption, and producing on an average twenty per cent. of charcoal throughout the year. The following statement of the work of these furnaces gives a fair average of their annual produce:—

	Tons.	Cwts.	Qrs.	Lbs.	
5000 stères of oak, weighing	123	0	3	16	produced
16,000 hectolitres of charcoal, weighing.....	24	12	0	21	
Impure acetic acid,.....	22	0	0	17	
Yielding upon distillation a purified article, marking 12°					
Twaddell, weighing from	12	15	3	21	
To	13	15	2	14	

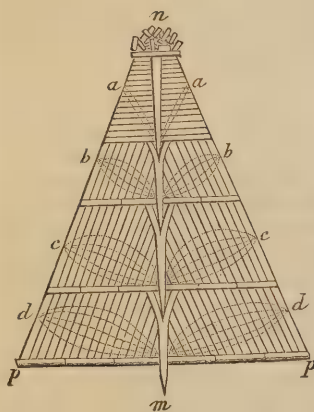
The outlay in the construction of each furnace is said to be four hundred and fifty francs, or about eighteen pounds fifteen shillings, of which sum sixteen pounds thirteen shillings are paid for the cap, the balance being ample for constructing the body of the furnace. The condensing apparatus is not included in this statement.

On reference to the article ACETIC ACID, Vol. I. p. 18, the apparatus of SCHWARTZ will be found fully described; and, therefore, any further description of it will be here unnecessary; but something may be added as to its efficiency compared with the others. In localities where there is considerable demand for charcoal, such as in some parts of France and Sweden, where it is largely consumed in smelting operations, the apparatus of SCHWARTZ is better adapted to yield the requisite supply than LA CHABEAUSSIÈRE'S; it likewise answers better for coniferous woods, as the large amount of tar which these yield is most effectually recovered by it. On the other hand, it must be admitted that the wood is more completely charred in the latter, and the time occupied in proportion to the bulk is much shorter; that the cost of SCHWARTZ'S apparatus is much greater, and that it does not admit of removal like LA CHABEAUSSIÈRE'S, except under an outlay as great as the original cost of erection, namely, from eighty to ninety pounds. The advantage of using either of these forms depends greatly upon the facility with which the wood may be conveyed to the melier, as it is evident that, if the distance were great, the cost and difficulties of the carriage of wood over that of the charcoal would more than balance the value of the products of the distillation, and, in fact, of the greater yield of charcoal. In this case, the first method of carbonizing, in large meliers, enclosed in easily movable sheds, will claim a preference to the other two; but sometimes, when the piles are required to be very large, the removal of these becomes more difficult and troublesome; so that their advantages are considered inadequate to the labor, and they are consequently dispensed with. It is evident, therefore, as DUMAS remarks, that in such districts all

the improvements to be made in the manufacture of charcoal must turn upon the better working of the meiler or pile, as being the most applicable; and hence, the first thing to be aimed at is to render this more independent of the cares of the workmen. Upon this, the difference between the pile system and that of distilling in close vessels turns; for, by the former, the most skilful practitioner may be baffled by circumstances peculiar to the operation; whilst, in the latter, the smallest amount of hand labor will always serve to prepare the charcoal, and in the largest quantity.

It is clear that the first consideration on the part of the burner of the pile is the lighting of the fire, so as to spread it over the largest extent of surface in the shortest possible time, and with the admission of as little air as possible. This is usually done by igniting the mass at the base, establishing a draught at the same time from the exterior and through the centre, as seen in Fig. 32, at *p m a*, till the upper parts of the pile are on the point of entering into incandescence. By closing the chimney, *n*, and opening vents at the points, *a a*, around the mound, a draught will be formed through *p m a*. These perforations will in turn be

Fig. 32.



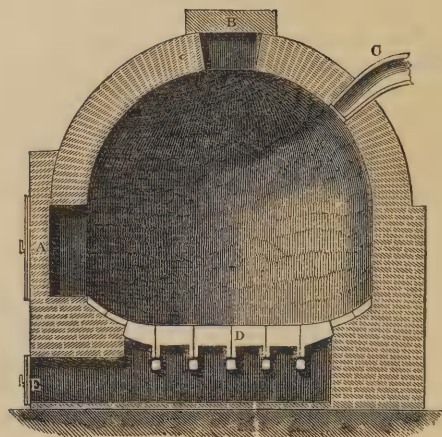
closed, and new ones opened in succession; and as the carbonization advances in *b c* and *d*, care must be taken to bring the force of the combustion in the direction of *p m b*, *p m c*, *et cetera*, so as to char the whole in zones proceeding from the axis to the circumference, and then downwards towards the base. Such is the course which is deemed the most favorable for the charring; but it is evident that this does not include all that is deserving of the operator's attention. An object, indeed, of primary consideration, is to render as much as possible of the caloric disengaged in the process available for decomposing the molecular arrangement of the matter of the wood. Could this end be fully attained, it is evident that the whole of the carbonaceous matter might be obtained in the form of charcoal. How far this is from being accomplished in the meiler system, those engaged in the business are best aware; as likewise how great a loss the slightest variation of temperature inflicts upon them. This regulation of the heat is, however, a problem, the solution of which would involve the removal of serious difficulties—a fact which will be readily admitted when the amount of water to be discharged as steam, the volume of gases liberated, and of air passing through the pile, are considered.

A method adopted in Sweden, which seems to be an improvement on the common plan, is to conduct

the draught downwards instead of in the ordinary way; and if the pile were constructed upon a base sloped from the centre to the exterior, this would allow of the draining of the tar, acetic acid, water, *et cetera*, into a suitable vessel. Pipes might be disposed through it, so as to conduct the draught from the vertex to the base of the cone, and all converging into a tank, where the vapors would be condensed as far as possible, the remainder passing out through a flue into a chimney of sufficient height to generate a draught powerful enough to carry on the combustion. By this course all the heat would be utilized, and the moisture disengaged would be prevented from passing through the ignited wood—a circumstance which causes considerable reduction of the charcoal left.

Another species of charring is that in which the heat is exterior to the wood which is to be carbonized, and is produced in an adjoining fire. Of this description of carbonizers is that represented in Fig. 33, a construction of brickwork, having apertures suited to the convenience of the workmen for charging and withdrawing the products. Of these, *A* shows the orifice through which the wood is introduced till it rises as high as this opening, after which it is closed, and the remainder of the interior charged through the superior aperture, *B*, and the orifice for the passage of the products of distillation is through the pipe, *C*. The fire which serves

Fig. 33.



to bring the contents to the point of decomposition is made on the grate, *D*, and the air which is to maintain its combustion enters by the ashpit, and is regulated by a door, *E*. When the kiln is charged, the apertures, *A* and *B*, are blocked up with bricks, or closely fitting lids. As soon as the walls have acquired so much heat as will be necessary to complete the charring, the communication with the air is cut off by closing the door, *E*. In carbonizing in this manner, the charring is more regularly effected, although the supervision of the attendant cannot be so well exerted as when the ordinary meiler is resorted to; in the latter, however, the influence of the weather can scarcely be controlled, however watchful the workman may be—a condition effected by the walls of the kiln, and hence its superiority.

Differing from the kilns of this description, but still

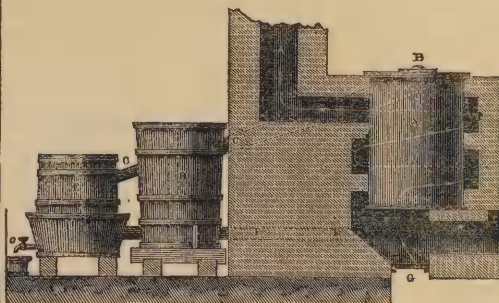
less advantageous in point of execution, are those kinds of carbonizers which char the wood without allowing the products of the combustion to come into contact with the materials to be decomposed. They possess an advantage over others, inasmuch as all the volatile products are recovered in the condenser, without anything being lost from a combustion taking place in contact with them. This advantage is partly neutralized by the large amount of fuel which is required to bring their contents to the proper working temperature, and the necessarily small volume which must be operated upon, owing to the non-conducting qualities of wood and charcoal. No less than a quarter of the product in charcoal is consumed for this purpose, even when the combustible gases which pass through the condenser unarrested are economised in the grate.

The close distillatory apparatus or retorts are the most eligible for the decomposition of pine wood, and such as contain a large amount of resins; and though, at a distance from the site where the wood is felled, they are generally composed of iron, yet near the locality they are sometimes constructed of well-tempered clay. Those known as tar-retorts are composed of two hollow cylinders, one within the other, and differing six or eight inches in diameter. The inner of these receives the wood, and is a little longer than the outer one. The space between them is appropriated to the fire, which is maintained by a current of air rushing in through apertures in the outer walls. A funnel shape is given to the base of the retort, and this is made to terminate in a pipe which traverses the outer cylinder, and abuts in a tar cistern where the products of distillation collect. By means of an aperture at the top of the inner cylinder the wood is introduced, and after the charging is performed, and all the outlets closed with the exception of those at the base, the fire is lighted in the intervening space between the outer cylinder and the retort, and the heat continued as long as volatile matters pass over to the receiver. When these cease, or sooner, provided the walls are sufficiently hot to finish the distillation, the fire is extinguished, and the apparatus allowed to cool.

A very good form of retort for the distillation of wood and the production of tar and charcoal, is that shown in Fig. 34 annexed. The body, A, of the retort is of cast-iron, imbedded in masonry or brickwork, so that the flue from the grate courses spirally to the top, where it turns off to the chimney. In the upper part of this case is a movable cover, B, through which the wood is introduced, and by which the charcoal is removed when the charring is finished. An outlet is made at the top under the rim, to which a pipe, C, is fixed that communicates with a large condensing vessel, D, covered at the top; this is connected with another, E, wherein all the condensable matters which escape from the first are arrested

and conducted to a recipient by the pipe and stopcock, O, whilst the non-condensable gases are reconducted by a pipe, F F, over the grate of the furnace, G, to be burned,

Fig. 34



and thus economise the fuel. The fire is made of faggots and brushwood, and is maintained till gases and vapors are abundantly evolved, at which stage a stopcock in the pipe, F F, is opened, and the inflammable products of the distillation are allowed to flow in over the fire, where, in burning, they produce as much heat, with a little addition of fuel, as will char the remainder of the contents. After the condensable matters cease to flow over, this tap is shut, and the retort is left to cool for a period of sixteen to twenty hours.

Such are the principal methods resorted to for the manufacture of charcoal from wood for the requirements of the smelter, the powder-maker, and others. It is evident, from the nature of the several processes, that considerable difference must necessarily exist between the charcoals produced, as well in their intrinsic value as in their physical appearance. This partly depends on the species of wood employed; but all the difference is not to be attributed to this circumstance. The study of charcoal, with a view to its application in the works where it is chiefly consumed on the Continent, has led to a modification of the usual mode of charring, by which a larger volumetric yield has been insured, answering all the purposes required. This product is designated *torrefied wood*, or *red charcoal*, from its reddish-brown appearance. BERTHIER was the first to call attention to this variety; but lately SAUVAGE conducted some experiments, from which he deduces that the amount of combustible matter obtained by the charring of wood does not increase after exposing the material to a suitable heat during a stated period, but that, on the contrary, a loss is sustained in the quantity. He limits the proper period to five hours and a half. The results of his experiments are transcribed in the annexed table, which shows the loss sustained in weight, and the volume at the intervals mentioned:—

100 lbs. Wood charred for	3 hours.	4 hours	5 hours.	5½ hours.	6½ hours.	Mould Charcoal.
Weighed 100 cubic feet by similar treatment } measured	65·4 pounds. 86 C.F.	53 pounds. 76 C.F.	47 pounds. 58 C.F.	41·5 pounds. 55 C.F.	39·1 pounds. 52 C.F.	17·2 pounds. 33 C.F.

cent. of the wood taken, whilst the produce of the kilns in the same quarters has been shown to be only a mean of about twenty-six per cent.; and this, when the quantity consumed in the operation is deducted, leaves only about twenty-two per cent., or rather less than that afforded by the ordinary process. It must be remarked, however, that the meiler yield was in these cases an exception to their general produce, which is found much lower than the numbers so given, even when thick wood is operated upon; and the proportion is much further decreased when small wood is charred in them. It is a well-known fact, however, that none of the methods give, in the form of charcoal, more than two-fifths of the real amount of carbon in the dry wood. According to EBELMEN, this loss is occasioned not entirely by the products of the distillation carrying off portions of it in combination, but by the direct combustion of the charcoal in an incandescent state, caused incidentally by the oxygen of the air passing through it, and converting it into carbonic acid and carbonic oxide. This he proved by the comparative analysis of the vapors from the temporary chimneys in the meiler, and of those developed in close vessels, where contact of the fire was entirely excluded. Of course, if the portion of carbonic acid which must necessarily be generated is permitted to traverse the incandescent charcoal, it will suffer decomposition at that temperature, and as much more carbon as it contained will be assimilated and lost to the charcoal-maker, the whole passing off in the form of carbonic oxide. The charcoal-burner's efforts should be directed to prevent this, by conducting the air which enters the meiler over the uncarbonized wood; and after it passes that part of the heap where combustion is active, withdrawing it by means of the temporary openings in the cover, over the portion yet undecomposed, so as to be out of the reach of the made charcoal. It is almost impossible to effect this thoroughly, but the efforts made with that view by those engaged in the business show that its importance is appreciated, and doubtless a remedy will soon be found which will render the process more effectual than it is at present.

QUALITY OF THE CHARCOAL.—A few considerations may now be submitted with reference to the quality of the charcoal. Independently of the fact of the densest being the best, it happens that during the making it may be deteriorated, either by imperfect charring, or by pushing the process beyond the proper limits. In the former case the product is not good, on account of the gaseous elements which it retains, and which being disengaged in its subsequent application as fuel, render it less efficient for producing a high temperature; in the latter case it becomes so brittle as to be incapable of being handled without falling to powder: and the same crumbling occurs in the smelting furnace, where it is more injurious.

Good charcoal is very dark, possesses a bright lustre and somewhat conchoidal fracture; it resists gradual pressure to a considerable extent, and produces a sharp sonorous sound when allowed to fall upon a hard body. It should burn when ignited without either flame or smoke, and when handled no stain ought to remain. Although in bulk it floats in water,

owing to the arrangement of the particles, its specific gravity, when ground so as to destroy its porosity, is much higher than that of water. In addition to the carbon of which it chiefly consists, a certain amount of oxygen, hydrogen, and other gases is found in it, together with the mineral matter of the wood. The greater or less proportion of the former affects its calorific power, and renders it more or less eligible for certain uses in the arts.

The following analyses of two samples of charcoal prepared by the meiler system, show the quantity of the different ingredients remaining, even after the charring has been carried to its utmost limits:—

	Centesimally represented.	
	Charcoal from Young Oak.	Charcoal from the Aspen.
Carbon,.....	87.68	87.22
Hydrogen,.....	2.83	3.20
Oxygen,.....	6.43	8.72
Ash,.....	3.06	0.86
	100.00	100.00
Loss by distillation,.....	13.02	17.07

Red charcoal retains a somewhat larger quantity of the above gases, than the product of the meiler or the close retort. The following table embodies the results of M. VIOLETTE'S analyses of the charcoal prepared by the action of superheated steam, according to his process:—

Species of Charcoal.	Elementary Constitution Centesimally Represented.			
	Carbon.	Hydrogen.	Oxygen, Nitrogen, and Loss.	Ash.
Furze,.....	76.629	4.108	17.975	1.288
Iron wood,.....	72.564	4.527	12.510	0.399
Cork,.....	72.362	8.528	19.110	..
Juniper,.....	71.433	5.073	23.324	0.170
Wild pine-tree,.....	71.358	5.948	22.194	0.500
Hawthorn,.....	70.793	4.443	23.419	1.345
Palm-tree,.....	70.724	4.552	23.494	1.230
Ash,.....	70.395	4.539	24.374	0.692
Maple,.....	70.069	4.613	24.892	0.425
Cherry-tree,.....	70.028	3.928	25.289	0.755
Lime-tree,.....	69.829	5.452	23.024	1.695
Yew,.....	69.620	5.864	24.212	0.304
Sycamore—maple,.....	69.229	4.402	25.133	1.236
Medlar,.....	69.209	4.643	25.261	0.887
Chestnut-tree,.....	69.127	4.326	27.126	0.421
Willow,.....	68.900	5.133	24.634	1.333
Yoke-elm,.....	68.835	4.142	26.382	0.641
Poplar—trunk,.....	68.741	4.866	25.540	0.853
Coco-tree,.....	68.268	4.053	23.984	3.695
Hollyoak,.....	68.521	4.741	25.891	0.847
Aspen,.....	68.169	5.512	25.730	0.589
Ebony,.....	68.047	3.868	28.380	0.205
Oak,.....	67.421	4.099	28.480	0.200
Poplar—root,.....	67.020	5.217	26.675	1.088
Elm,.....	66.862	4.669	28.181	0.288
Plum-tree,.....	66.118	5.756	27.530	0.596
Pear-tree,.....	65.924	5.310	28.244	0.522
Hemp-stalks,.....	62.127	4.976	31.501	1.396
Wheat-straw,.....	61.090	4.365	34.786	0.759
Leaves—poplar-tree,...	52.514	4.819	41.289	1.388

In this table considerable difference in the yield of carbon is apparent; but as the samples were prepared by the application of the same temperature, it is evident that the inequality must be owing to a difference in the principles contained in them, and to the greater or less difficulty with which they are decomposed. It must be remembered, however, that the woods them-

selves do not contain the same amount of carbon. Were the water and ligneous matter the same in all, probably the approximation of the results of analysis would be closer. The quantity of inorganic salts in the various samples is very small, much less so than one might suppose, considering that wood containing about twenty per cent. of moisture gives from one-third to one per cent., all of which is retained in the charcoal produced from it, generally amounting to about twenty per cent. The following results obtained by WINKLER are, therefore, more in accordance with what might be expected:—

	Ash Centesimally.
Lime-wood charcoal,.....	3.55
Maple,.....	2.27
Ash,.....	2.27
Elm,.....	2.17
Willow,.....	1.50
Fir,.....	1.44
Pine,.....	1.38
Poplar,.....	1.30
Beech,.....	1.25
Scotch fir-wood,.....	1.11
Birch,.....	0.80
Oak,.....	0.75

Many varieties afford as much as five and even ten per cent. more, especially if the wood has been grown upon silicious soils.

A remarkable property of charcoal is, that it absorbs with avidity gases and vapors, condensing them within its pores to a most surprising extent, as shown in Vol. I., p. 764. In consequence of this property, it cannot be exposed to moist air for any length of time, without exerting a hygroscopic action, and assimilating a variable per centage of water, in proportion to the time of exposure and the humidity of the atmosphere. From experiments made with freshly prepared charcoal, NAU obtained the subjoined numbers after exposing the samples twenty-four hours to an atmosphere loaded with moisture:—

	Amount of water absorbed in twenty-four hours. Centesimally represented.
White beech charcoal,.....	0.80
Ash,.....	4.06
Oak,.....	4.28
Birch,.....	4.40
Larch,.....	4.50
Maple,.....	4.80
Pine,.....	5.14
Red beech charcoal,.....	5.30
Horse-chestnut,.....	6.06
Elm,.....	6.60
Alder,.....	7.93
Scotch fir,.....	8.20
Willow,.....	8.20
Italian poplar,.....	8.50
Fir,.....	8.90
Black poplar,.....	16.30

This proportion slowly increases when the exposure is prolonged, as proved by WERLISCH, who found that one hundred parts of charcoal, weighed on the 24th of June, became—

On the 30th of June,.....	104.35
„ 7th of July,.....	105.63
„ 16th „.....	106.57
„ 29th „.....	107.62
„ 20th of August,.....	108.16
„ 17th of September,.....	108.44

These numbers do not indicate, however, the actual

amount of contained moisture, as the charcoal had not been taken immediately from the meiler, so that it might have already absorbed from three to four parts of water, as the former table shows.

The lower the temperature at which the carbonization has been effected, the proportion of water is greater. The results of VIOLETTE's experiments on this subject are given below. The samples, consisting of charcoal from black alder, prepared at increasing temperatures, were exposed in a room, the air of which was saturated with moisture, and the amount of absorption determined every eight days, no numbers being taken till the results of two successive trials agreed —

Temperature of carbonization. Deg. Fahr.	Quantity of water absorbed by 100 of charcoal	Temperature of carbonization. Deg. Fahr.	Quantity of water absorbed by 100 of charcoal.
302	20.862	554	6.920
320	18.220	572	7.608
338	18.180	590	7.200
356	16.660	608	5.554
374	11.626	626	4.504
392	10.018	644	5.904
410	9.742	662	5.894
428	8.954	810	4.704
446	8.800	1873	4.676
464	6.666	2012	4.444
482	7.406	2232	4.760
500	6.836	2372	2.224
518	6.306	2732	2.204
536	7.879		

To account for the very high numbers with which the table commences, it is to be observed that the product resulting from the low degrees of temperature was not more than half-burned charcoal, hence its proportionally greater hygroscopic power.

The density of charcoal depends chiefly on that of the wood; hence it is evident that the relative weight of the wood will afford a good idea of the nature of the charcoal produced from it. This fact is of much importance, as the value of the material for fuel may, to a considerable extent, be deduced from its specific gravity. The value of this, for several species of wood, as determined by HASENFRATZ, is as follows:—

	Specific gravity.
Birch wood charcoal,.....	0.203
Ash,.....	0.200
Wild service wood,.....	0.196
Red beech,.....	0.187
White beech,.....	0.183
Elm,.....	0.180
Red fir,.....	0.176
Maple,.....	0.164
Oak,.....	0.155
Pear,.....	0.152
Alder,.....	0.134
Lime,.....	0.106

These numbers, however, merely indicate the weight of various samples when the interstices have been filled with air, and, therefore, do not represent the true gravity. In the appended table, the real specific gravity as determined by VIOLETTE is given. The course which the latter adopted was to immerse the sample, already weighed in air, in a flask three-quarters full of distilled water, allowing it to remain exposed to light for eight or ten days; by filling the flask at the end of this period to the usual mark, and then determining the total weight, and from this deducting that of the flask and liquid, the difference by the usual formula gave the specific gravity:—

DENSITY OF THE CHARCOAL OF BLACK ALDER PREPARED AT INCREASING TEMPERATURES.

Heat of carbonization. Deg. Fahr.	Density of charcoal.	Heat of carbonization. Deg. Fahr.	Density of charcoal.
302	1.507	626	1.428
338	1.490	662	1.500
374	1.470	810	1.709
410	1.457	1873	1.841
446	1.416	2282	1.862
482	1.413	2732	1.869
518	1.402	fusing point of	2.002
554	1.406	the retort, }	
590	1.422		

The density in this case is therefore greater than that of water, but still it varies to a certain extent with the temperature at which the substance has been prepared; thus the charcoal obtained between the temperatures 302° and 518° Fahr. decreases in density from 1.507 to 1.402; while, on the contrary, that which is afforded between 518° and 662° increases from 1.402 to 1.500; and from this point the density continues to increase, till, at the fusing point of the vessel, it becomes double that of water.

Before proceeding to the other materials which constitute fuel, a few observations may be made on the power of charcoal to conduct heat, and the facility with which it undergoes combustion.

It is a well-known fact that the product resulting from a high temperature, or in other words, black charcoal, is a much better conductor of caloric than that formed under the influence of a lower heat; it requires also a higher temperature to ignite it; but when this is effected, and an adequate supply of oxygen is kept up, the combustion proceeds steadily, and the heat given off is regular and sustained. Considerable difficulty is found in making accurate determinations of the conducting power of charcoal. The ingenious method of M. VIOLETTE deserves particular notice, as it affords in a simple manner the conducting power of this substance, and may, by a slight adaptation, be rendered available for determining questions of importance concerning the philosophy of heat in bodies.

Fig. 37 shows the arrangement of the apparatus, in which A represents a glass flask half filled with water and heated by a lamp; this is connected with another glass cylinder, B, closed by tightly fitting bungs, by means of a glass tube, *h*. In the superior cork or cap of the tube, B, is an opening which receives a third tube, D, nearly filled with mercury, in which is immersed the sample of charcoal, the conducting power of which is

to be determined. This is seen in the figure at E, and in its upper end there is made a perforation for the reception of a small mercurial thermometer, F, for the purpose of registering the rays of caloric conducted by it. The entire length of the sample, in the experiments made by the inventor of the apparatus, was 0.984 of an inch, of which 0.236 of an inch was immersed in the mercury; 0.195 of an inch of the sample intervened between the latter and the bulb of the thermometer. The source of the heat was the steam circulating in the vessel, B, and escaping through the outlet, c. A portion of the caloric of the vapor was abstracted by the mercury, so that it was retained at about 204.8° Fahr. The numbers given in the annexed table were obtained by noting the register of the thermometer at intervals of five minutes till the indication remained stationary: this happened after fifteen minutes' immersion. By employing a bar of iron of the same dimensions as that of the charcoal, and introducing the bulb of the thermometer in a like manner, a comparison was instituted between the charcoal and this substance of known power of conduction.

CONDUCTING POWER OF CHARCOAL OF THE SAME WOOD—BLACK ALDER—PREPARED AT INCREASING TEMPERATURES:—

Temperature. Of the carbonization.		Indication of the Thermometer.			Conducting power of Charcoal compared with that of iron represented by 100.
		After 5 minutes.	After 10 minutes.	After 15 minutes.	
316° Fahr.	27.00	56.00	57.0	57.5	59.5
392 "	27.00	57.00	57.5	58.0	60.1
482 "	27.00	57.50	57.5	58.0	60.1
572 "	27.00	58.00	59.0	59.5	61.6
1873 "	26.50	61.00	62.0	62.0	64.2
2282 "	26.50	62.00	62.50	63.0	65.2
2732 "	26.00	63.00	63.5	64.0	66.3
Charcoal of gas retorts.	26.00	81.00	82.0	82.0	84.7
	22.00	96.50	96.5	96.5	100.0

The numbers in the last column were obtained by multiplying those of the preceding one by 1.036. Between the temperatures 572° and 752° the conducting power is low, and is nearly the same in the wood and the charcoal produced from it; but when the heat is elevated, the density of the charcoal increases rapidly, till it is about two-thirds that of iron.

Regarding the combustion of charcoal, it will be observed, upon taking pieces of it, produced by different modes of working or by unequal degrees of heat—plunging one end of each in the flame of alcohol till ignited, and then allowing it to rest in tranquil air—that very different phenomena will be exhibited in the combustion. The charcoal made at low temperatures, say between 302° and 482° Fahr., burns with a long yellow flame, disengaging large volumes of smoke, and retaining the temperature of combustion for about fifteen minutes, at the end of which time the cylinder will have burned about half an inch. On the other hand, if the wood has been submitted during carbonization to a heat between 482° and 809°, the combustion of the charcoal under the same circumstances is characterized by a clearer flame, which is less fuliginous and persistent, and by being continued for a longer time, more especially with those samples prepared between 482° and 662°. The charcoal pre-

pared at 809° does not burn so well as any of the samples obtained at a lower heat, nor does the ignition continue so long. When the carbonization is effected at the higher degrees represented in the foregoing table, the cylinder of charcoal, on being introduced into the flame, becomes red-hot like a bar of metal, affording no flame, and is extinguished immediately on withdrawing it, without giving any indication of combustion or leaving a coating of ash. In this last case, the fingers are unable to hold the cylinder whilst its end is in the flame for any length of time, in consequence of the freedom with which it conducts the heat.

All the preceding samples, when reduced to powder, present the same phenomena with respect to combustion as when in solid pieces, only with greater intensity, because, on account of the air interposed, the ignition is easily propagated and maintained. When, however, the experiment is conducted in a very tranquil atmosphere, the burning ceases after a part is consumed. This effect must doubtless be owing to the carbonic acid, which, being heavier than common air, does not ascend with sufficient freedom to permit the oxygen of the latter to come in contact with the burning matter.

In many manufactories where this article is required in powder, great care must be exercised, as it often happens that spontaneous combustion takes place. The most inflammable charcoals take fire at 572°, and those that are prepared at the latter heat invariably ignite at a temperature varying from 680° to 716°, according to the nature of the wood. Charcoal, from light and porous woods, always burns more freely than that obtained from the hard and dense kinds; but even the same wood furnishes charcoal that ignites with greater or less facility according to the temperature at which it has been prepared, as may be seen from the following table:—

TABLE SHOWING THE TEMPERATURE AT WHICH THE CHARCOAL, FROM THE SAME WOOD, PREPARED AT INCREASING TEMPERATURES, BURNS.

Charring temperature.	Temperature at which the charcoal takes fire.	Charring temperature.	Temperature at which the charcoal takes fire.
500°	644	1873	} 1122 to 1472
518	} 644 to 680	2282	
536		2372	
554		2732	
572			
590			
608	680 to 698		
626			
644			
662			
8093	752	Charcoal prepared at the point of the fusion of the cylinder,	} 2282

Other particulars concerning charcoal, so far as relates to the manufacture of gunpowder, will be introduced under that head.

PEAT.—Another article of fuel, much employed for domestic purposes, as well as for many manufactures, in which it has lately found admittance, is *Peat*. Such is the name by which the brownish-black spongy substance, found in almost every country, filling up cavities, and constituting what is termed *bog*, is known. It is a product of vegetal origin, but differing from wood as well in the nature of the growth, as from the change which it has undergone atomically through the combined agency of time and pressure. It was once supposed that this formation was, in point of time, coeval

with the disposition of the face of the country into hills and valleys; by some it was considered a bituminous deposit from the sea—the wreck of floating islands previous to the great convulsions which the earth underwent during the formation of the present continents and islands. By others it was even regarded as an organic substance in a state of vitality, and actually growing; but all these notions are now abandoned, and a more rational and philosophical view of its nature and production has been arrived at. From examining its structure, it has been found that it is constituted of vegetal matters, generally mosses and species of aquatic plants in different stages of decomposition; and from this circumstance, as well as from the general appearance of the localities where peat abounds, its formation is now accounted for in the following manner:—

At the present day it may be observed, that where pools collect, the soil under which is retentive, the water not being absorbed, stagnates, and, provided the surface evaporation is not great, forms a pond. Round the borders of this, various kinds of aquatic plants, sedges, rushes, *et cetera*, soon make their appearance, and by reproduction, gradually creep in towards the centre till the whole surface becomes covered. In course of time, when several races of these have succeeded one another, and mud and slime have accumulated at the roots and round the decaying stems, a spongy mass results, which is well calculated for the propagation of moss. Under a constant supply of moisture, these various species continue to luxuriate, and, by progressive growth and *eremacausis*, ultimately give rise to a composition in every respect similar to that constituting the various peat-bogs. That some such natural process has been the cause of the production of peat appears from its composition and the localities in which it is found. These are chiefly in the temperate zones, where evaporation is slow, and the atmosphere is generally more or less saturated with humidity. It may be conceived that in the origin of these formations, the retention of the water, whether from rain or springs, in extensive basins, led at first to the development of vegetal growth in the manner above indicated, and that the necessary moisture being supplied in abundance, the accumulation became so rapid, that ultimately the surface assumed the appearance of land; and, as decomposition proceeded, a degree of solidity was given to the mass to support denser bodies, such as shrubby plants. It would appear that this organic growth was rarely restricted to the original basin; but that, as it accumulated, it spread over adjacent land, which, in time, became a morass. Evidence conclusive enough of this exists in the fact, that whole forests, of almost every description, such as oaks, firs, ash, birch, yew, willow, *et cetera*, have been overwhelmed under its gradual but steady advancement, and are found in all positions at the bottom of peat-bogs. Generally, this formation is met with in climates of a moist nature, in level countries, where imperfect natural drainage exists, although it is found in considerable beds in upland districts. The very extensive peat moors on the coasts of the German Ocean, especially in Holland and Northern Germany, and in many tracts in Ireland and Scotland, are examples of the

former; whilst the deposits encountered high up the Alps, in the Vosges, and in the Jura, illustrate the latter. In mountainous districts, in addition to the imperviousness of the rock to the moisture, the constant formation of clouds upon those elevated regions favors the growth of the mosses and plants, the decomposition of which contributes to the production of quagmires.

DARWIN states that, in the Southern hemisphere, peat does not occur nearer to the equator than the latitude of 45° ; that the composition there met with results from the decomposition of the plants and grasses. The circumstance that no mosses, so far as can be ascertained by strict examination, enter into the species of peat found in South America, favors this view.

The extent and depth of the peat-bogs vary considerably in the different countries where they are found, and depend on circumstances quite distinct from each other. It is evident that the area which they may occupy is intimately connected with the distribution of the water, from whatever causes. In Holland and North Germany, the water of the ocean seems to have largely contributed to the moisture in which they originated. The peat-moors of the Grand-duchy of Hesse would appear to be occasioned by the overflow of the Rhine, whereby these tracts were irrigated, and the waters remaining, and necessarily becoming stagnant, the place was soon changed, and, instead of remaining a swampy district, it ultimately became a morass. On the other hand, the thickness of the beds of peat, seems, from repeated observation, to be dependent upon the nature of the subsoil. Where the bottom is quartzose, the deposit is invariably not very thick; but if it be such as yields by disintegration a clayey coating, the depth and extent are much more considerable. The morasses of Holland are to a considerable extent about six feet in depth, as are likewise those in upland situations; whilst many of the peat bogs in Ireland are from thirty to forty feet in depth. On intersecting these, it appears from the fact of layers of gravel, clay, shells, *et cetera*, being interposed horizontally, that these tracts have been swept over with violent currents of water; such layers, however, are never more than a few feet in thickness, and, seem to have retained all the conditions favorable for the growth of the plants conducive to the formation of peat.

From its physical constitution, this substance may be regarded as a kind of fossil fuel, and, undoubtedly, it is one of the most extensive sources known. Viewing it as the product of the decomposition of plants carried on through a long succession of ages up to the present, it is natural to expect that when cut vertically, differences should appear showing the advancing state of decomposition. In every instance, almost, this progressive change is exhibited, and, consequently, peat is classed into—

Recent Peat and Older Peat, from the appearance it presents. The former bears distinctive traces of its origin in the roots, leaves, and stems of plants, the structure of which is still retained. It is very porous, tough, and elastic in some tracts; but in others, especially where the bog is well drained, very brittle. The color varies, with the age and the progress of the de-

composition, from a light to a blackish-brown. In the second, to which the preceding gradually inclines, no traces of fibrous matters—such as roots, stems, or leaves—are observed, but it presents when cut a pitchy shining hue—is dense and fine in the grain. Preference has always been acceded to this as a fuel from its superior gravity, and the greater heat which it produces when undergoing combustion. From the change which the vegetals pass through, it is evident that the usual process of putrefaction is carried on in the ordinary way at the commencement; but as the surface grows, and contact with the air is cut off, the mass is left to the play of the affinity of its elements, rendered more active by the pressure which it has to sustain. The alteration is attended with the evolution of marsh gas—bihydride of carbon $C H_2$ —and carbonic acid, in the same way as in every case of partial destructive distillation; but from the excess of moisture present, it is evident that this action cannot, in the case of peat, be so complete as in coal, which is analogous in nature. Many bodies are detected in peat, however, which are not contained in coal, although the ultimate elements of both are the same. SPRENGEL detected in peat considerable quantities of ulmic acid—known also by the names *ulmin*, *humus*, *gein*, and *geic acid*—the composition of which, as obtained from turf, is expressed by the formula $C_{40} H_{15} O_{12} N$; and when procured from mould, by $C_{40} H_{15} O_{14} N$. This principle is dissolved out by alkalies, and precipitated from their solutions by acids in brownish flakes; this, however, as also the other varieties of resins examined by MULDER, are of little use hitherto in the arts.

The density of peat varies with the relative position in which it is found, with the thickness of the stratum, and the amount of mineral matters which it contains. Freshly cut, it is saturated with water to the extent of eighty to ninety per cent. in some cases, and, when subjected to the ordinary process of air-drying, it retains a large quantity of this, amounting sometimes to thirty per cent.

The estimation of the gravity in this state would lead only to relative approximations, even if the percentage of moisture was known, and the species examined had undergone about the same degree of decomposition. As already intimated, however, the latter principally determines the difference of specific weight in peat from the same cutting. KARMARSH arrived at the following results with regard to Hanoverian peat:—

Species.	Specific gravity.
1. Light-colored young grass peat, nearly unchanged moss,.....	} 0.113 to 0.263
2. Young brownish-black peat—an earthy matrix intersected with roots,.....	
3. Old earthy peat without any fibrous texture,.....	} 0.240 to 0.600
4. Old or pitch peat,.....	
	0.564 to 0.902
	0.639 to 1.039

Of twenty-seven samples of peat examined by Sir ROBERT KANE and Dr. W. K. SULLIVAN, the results, as stated in their report in 1851, show that the maximum density was 1.058, and the minimum 0.235, a great many being under 0.600, as may be seen from the following tabulation of their gravities, coupled with the constituents of the ash, to which reference will be made further on:—

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
Specific gravity,	0.297	0.405	0.669	0.450	0.351	0.661	0.335	0.476	0.655
Potassa,	0.362	1.323	0.461	0.401	0.221	0.198	0.491	0.211	0.247
Soda,	1.427	1.902	1.399	1.330	0.712	0.590	1.670	0.651	0.496
Lime,	26.113	36.496	40.920	37.873	33.240	25.860	33.037	29.716	24.944
Magnesia,	3.392	7.634	1.611	5.127	1.904	1.207	7.523	1.204	1.285
Alumina,	4.180	5.411	3.793	0.271	0.240	0.371	1.686	0.298	0.360
Sesquioxide of iron,	11.591	15.608	15.969	14.802	12.760	18.746	13.281	20.372	19.405
Phosphoric acid,	1.461	2.571	1.406	1.257	1.222	0.874	1.438	1.066	0.242
Sulphuric acid,	12.403	14.092	14.507	11.814	21.470	23.630	20.076	22.664	10.742
Hydrochloric acid,	1.568	1.482	0.983	1.367	0.840	0.622	1.747	0.439	0.335
Silica in compounds decomposable by acids,	0.980	3.595	1.111	1.002	1.672	0.896	2.148	0.645	1.082
Sand and silicates undecomposable by acids,	22.519	2.168	2.107	4.722	13.147	14.430	7.683	11.180	26.789
Carbonic acid,	13.695	7.761	15.040	19.722	12.060	12.240	8.340	10.782	13.890
Total,	99.691	100.043	99.307	99.688	99.488	99.654	99.120	99.228	98.817

	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.
Specific gravity,	0.434	0.984	0.681	0.523	0.274	0.394	0.437	0.323	0.924
Potassa,	0.641	0.347	0.181	0.291	0.966	0.407	0.665	0.668	0.280
Soda,	1.875	0.679	0.550	0.586	1.038	2.074	2.605	1.709	2.180
Lime,	22.702	45.581	29.323	38.692	35.113	33.397	33.554	31.553	30.744
Magnesia,	6.809	1.256	3.425	2.372	4.687	11.293	9.229	9.439	9.237
Alumina,	1.109	0.129	0.672	0.408	1.627	1.627	0.677	1.707	2.027
Sesquioxide of iron,	29.854	15.974	19.095	15.537	14.322	18.500	18.366	6.012	19.797
Phosphoric acid,	2.019	0.188	0.975	0.878	0.828	0.744	1.300	1.286	1.290
Sulphuric acid,	16.381	44.371	16.238	14.822	25.409	13.550	23.505	25.602	20.857
Hydrochloric acid,	1.591	0.337	0.636	0.657	1.090	2.804	3.263	0.698	3.128
Silica in compounds decomposable by acids,	0.737	1.043	3.255	5.808	5.607	5.998	4.449	5.159	3.096
Sand and silicates undecomposable by acids,	14.505	2.653	8.884	14.181	4.340	6.593	3.040	6.282	3.163
Carbonic acid,	1.470	16.120	15.984	5.842	5.003	3.006	....	9.864	3.570
Total,	99.693	99.678	99.218	100.074	100.030	99.993	99.653	99.979	99.369

	XIX.	XX.	XXI.	XXII.	XXIII.	XXIV.	XXV.	XXVI.	XXVII.
Specific gravity,	1.058	0.481	0.629	0.280	0.546	0.855	0.402	0.441	0.858
Potassa,	0.744	1.667	0.271	0.146	0.247	0.219	0.370	0.028	0.158
Soda,	0.704	2.823	1.491	0.466	1.150	0.855	2.628	2.832	0.527
Lime,	40.623	20.907	13.667	8.492	22.332	40.079	27.732	26.551	12.432
Magnesia,	4.352	15.252	16.994	4.702	5.608	4.035	6.875	12.580	3.095
Alumina,	1.671	2.034	0.259	10.705	0.932	0.895	1.521	3.298	5.991
Sesquioxide of iron,	10.368	17.040	26.644	15.052	29.970	14.160	7.451	12.116	30.725
Phosphoric acid,	1.114	1.447	1.339	1.557	0.699	0.632	1.670	2.022	0.526
Sulphuric acid,	24.208	23.375	22.691	13.974	31.612	22.295	20.389	22.401	14.518
Hydrochloric acid,	1.052	1.424	1.180	0.196	0.993	0.781	2.932	2.581	0.151
Silica in compounds decomposable by acids,	6.317	6.634	2.719	12.476	2.751	1.295	7.709	5.474	9.101
Sand and silicates undecomposable by acids,	3.710	10.682	11.673	31.198	3.775	5.496	10.088	17.711	22.721
Carbonic acid,	4.981	6.721	....	....	....	9.101	10.460	1.220	....
Total,	99.844	100.006	98.964	98.928	100.069	99.843	99.825	98.751	99.945

The carbonic acid found in the above analyses is, in nearly every instance, much less than what is required to saturate the lime, supposing the whole of the sulphuric acid to exist as sulphate of lime; this is accounted for by the high temperature necessary to incinerate the peat, having driven off the greater part of the carbonic acid.

- I.—Light, spongy, surface-peat, of a reddish-brown color, and composed almost entirely of *Sphagnum*, species of which are still distinguishable; from near Monastrevin.
- II.—Light surface-peat, of a reddish-brown color, containing small roots of *Erica*, also leaves of grasses and *Carex*; from Mount Lucas Bog, near Phillipstown, King's County.
- III.—Rather dense peat, of a dark reddish-brown color, in which the structure of moss is still observable; from the same locality as No. II.
- IV.—Light reddish-brown fibrous moss-peat, in which the *Sphagnum* is almost unaltered, as well as leaves of *Carex* and other plants, and the roots of species of *Erica*; from Twicknevin, Kildare.
- V.—Upper layer of fibrous red bog, composed entirely of *Sphagnum*, *Hypnum*, and other mosses; from Derrymullen Station of the Irish Amelioration Society.
- VI.—Dense peat, of a black-brown color, in which vegetal structure is nearly obliterated, but in which the leaves of grasses and *Carex*, with twigs of hazel and birch, are sometimes found; from Wood of Allen, Great Timahoe Bog.

- VII.—Light surface-peat, of a pale yellowish-brown; from Wood of Allen. The mass is very open-grained and fibrous in this sample, and *Sphagnum* and *Hypnum* are readily distinguishable.
- VIII.—Middle layer of the same bog, of a deep-reddish color. The mass is tolerably compact, but fibrous, having the structure of the mass very indistinct. A very few roots of *Erica*, and small twigs of birch and alder, and fir scales are found in it.
- IX.—Lower layer of the same bog, and from the same locality. This variety is compact and dense, of a deep blackish-brown color, with an earthy almost conchoidal fracture, and exhibiting a resinous lustre when rubbed. Vegetal structure nearly obliterated.
- X.—Good compact peat, of a blackish-brown color, and consisting principally of moss, with a number of *Erica* and grass roots and *Carex*. This sample is from Riversdale Bog, near Kimegad, and is used as fuel in Dublin.
- XI.—An extremely hard and compact peat, having the vegetal structure entirely obliterated, and exhibiting when broken a resinous conchoidal fracture. Scales of fir-trees and twigs of birch and alder, *et cetera*, occur in it; it is a valuable fuel. Locality—Riversdale Bog, near Kimegad.
- XII.—Very dense, dark, reddish-brown peat, from Anadruce and Cloncreim, on the Royal Canal. In this peat the vegetal structure is only occasionally perceptible.
- XIII.—Rather dense peat, of a dark reddish-brown color and compact structure, from bogs of Rathconnell, Wood Down, and Great Down, near Mullingar. *Sphagnum* indistinct, but leaves of the flag and stems and roots of *Erica* occur in a very perfect state in it.
- XIV.—Upper layer of a fibrous bog in the neighborhood of Banagher. It is a spongy mass, of a yellowish-red color, composed of almost unaltered *Sphagnum*, with occasional roots of *Carex*, *Erica*, *et cetera*.
- XV.—Rather compact peat, of a reddish-brown color, from the same locality as the preceding sample. In this kind, vegetal structure is very perceptible, although undistinguishable; the roots of the *Erica* are abundant, but the greater part is evidently derived from moss.
- XVI.—A more compact peat than No. XV., from the same bogs, consisting of fibrous or red bog, of a light reddish-brown color. Like the foregoing, the species is indiscernible in this, although organic structure is visible. Roots and leaves of *Carex* are exceedingly abundant in it.
- XVII.—Light surface-peat, of a pale reddish-brown color, from the bogs of Clonfert and Kilmore, at the mouth of the Suck, near Banagher. The mass is spongy, and is composed of almost unaltered *Sphagnum*, with a few stems and roots of *Erica*.
- XVIII.—Peat from the same locality. It is rather compact but fibrous, and of a light reddish-brown color passing into black.
- XIX.—An exceedingly dense peat, of a conchoidal earthy fracture, from Athlone bog. In this the vegetal structure is almost completely destroyed; but when apparent, indicates remains of *Carex*, grasses, and *Erica* in abundance.
- XX.—A rather dense peat, of a blackish-brown color, in which the structure of moss is no longer visible, but abounding in remains of *Carex*, grasses, and roots and stems of *Erica*; from the Curragh or Clonbourne bogs near Shannon Bridge.
- XXI.—A dense peat, of a dark reddish-brown color, from bogs along the Shannon. Remains of *Carex* and grasses are abundant in this variety, but *Sphagnum* is very indistinct. It is used in steamers plying on the river.
- XXII.—A light fibrous peat, of a reddish-brown color, formed evidently of a great number of plants, and in which the structure of moss is very distinct. Species of *Sphagnum* and *Hypnum* are observed, and also remains of *Carex* and grasses, the roots of *Erica*, the bark of birch, and probably alder-twigs in abundance. It is from the same locality as No. XXI.
- XXIII.—A very dense peat, of a blackish-brown color, of a compact though very indistinct structure. The remains of *Carex* are abundant, as also roots of *Erica*. It forms an excellent fuel. Locality the same as No. XXI.
- XXIV.—A very dense blackish-brown compact peat, from the same locality as No. XXI. In this species, vegetal structure is almost obliterated. It has an earthy fracture, and is full of the tubes of the bark of hazel, birch, and alder; occasionally scales of pine bark and leaves of *Carex* and grass are met in it.
- XXV.—A rather dense reddish-brown peat. The structure of this is indistinct, but altered *Carex* leaves and fragments of twigs and roots are observed in it. Locality the same as No. XXII.
- XXVI.—Rather compact and moderately dense peat, of a dark reddish-brown color. Structure of moss almost obliterated. Fracture earthy. Abundance of leaves, stalks, and roots of grasses, *Carex*, *et cetera*. Same locality as No. XXII.
- XXVII.—A dense jet-black peat. Structure of moss completely destroyed. Fracture earthy, tending to conchoidal; assuming resinous lustre when rubbed. Abundance of remains of *Carex* leaves, and a very few fragments of bark, apparently of hazel. Same locality as No. XXII.

From the results of the ultimate analysis of dried peat, it is observed that the numbers which are found do not correspond with the analysis of dried wood. The following analyses by REGNAULT and MULDER show the centesimal contents of carbon, hydrogen, and oxygen:—

Locality.	Carbon.	Hydrogen.	Oxygen.
Vulcaire,.....	{ 59·57 5·96 34·47 Regnault.		
	{ 60·40 5·86 33·64 Mulder.		
	{ 60·06 6·21 33·73 Regnault.		
Long,.....	{ 60·89 6·21 32·90 Mulder.		
	{ 60·21 6·45 33·34 Regnault.		
Champ de Feu,...	{ 61·05 6·45 32·50 Mulder.		
Friesland,.....	59·42 5·87 34·71 "		
Friesland,.....	60·41 5·87 34·02 "		
Holland,.....	59·27 5·41 35·35 "		

In these samples, the numbers are calculated after deducting the ash. It is a well-ascertained fact that a greater or less quantity of nitrogen is invariably contained in peat, but this element appears to have been overlooked in the preceding. To show the average extent of the contents of nitrogen, the following analyses, selected from the *Dublin Journal of Industrial Progress*, so ably edited by Professor SULLIVAN, are submitted. The materials were taken from the same localities as mentioned in the foregoing table; but before subjecting them to analysis, they were thoroughly exsiccated at a temperature of 220° Fahrenheit:—

	Carbon.	Hydrogen.	Oxygen.	Nitrogen, mean.
Surface-peat, Phillipstown,.....	58·694	6·971	32·883	1·4514
Dense peat, Do.,	60·476	6·097	32·546	0·8806
Light surface-peat, Wood of Allen,...	59·920	6·614	32·207	1·2588
Dense peat, Do.,	61·022	5·771	32·400	0·8070
Surface-peat, Twickenin,.....	60·102	6·723	31·288	1·8866
Light surface-peat, Shannon,.....	60·018	5·875	33·152	0·9545
Dense peat, Do.,	61·247	5·616	31·446	1·6904

Kane and Sullivan.

intimately associated with heat, although the value of the charcoal which the substance affords as a calorific agent has been attested by practical skill and theoretical calculations. Attempts have long been made in Holland and some states of Germany, to render peat more profitable, as well in manufacturing operations as for domestic purposes; but it is remarkable that in a country such as Ireland, where, compared with other nations, the cost of labor is low, with one exception nothing has been done to convert her area of *two millions eight hundred and thirty thousand acres* of the finest bogs in the world to her advantage, although, if properly treated, they might prove a source of immense wealth. This neglect of the national interests seems still more inexplicable, when it is considered that the wealth requisite for successful manufacturing enterprise is already in the hands of the people, but lies a mere waste, useless to the possessor and to the universal interests of the community. It would appear, however, that something like an incipient spirit of enterprise is growing in the Irish mind, and, if this be fostered by the hand of science, doubtless, ere long, many of the hidden treasures which lie at the feet of the impoverished population, will be developed to the advantage of the parties immediately concerned, and the prosperity of the nation at large.

For domestic purposes, the peat is prepared by a very simple course of operations, differing sometimes according to its nature and thickness.

In every case the surface layer, which contains the living plants and their roots in the natural state, is stripped off to the depth of six to nine or twelve inches. The material is then cut with a kind of spade known as the *slane*, which has a wing bent at right angles to the blade of the instrument, so as to form with the latter two sides of a square. Sometimes two such wings or ears are added to the tool, and at the outer end these are united by a plate of iron which gives to it the appearance of a hollow rectangular cube, open at both ends. By this instrument the peat is cut in long square masses, and then spread upon the sward, where it spontaneously loses its water. After the bricks have acquired sufficient consistency, they are piled up on end so as to afford a more thorough exposure to the air; and finally, when desiccation has advanced, the turf, as it is then called, is piled together, being built round by a kind of clamp construction of the sods or bricks, and left till the material becomes as dry as it can be made by exposure to the air. Such is the mode adopted when the peat is sufficiently elastic to bear being so handled without breaking; when, however, the material is brittle and will not admit of being used in this way, it is dug out with ordinary spades, shovels, *et cetera*, and all roots, stones, and such like solid bodies picked out. It is then spread in a layer of from twelve to eighteen inches in thickness, watered, and brought to a homogeneous mixture, either by the tramping of men or beasts, where the latter can be employed. Afterwards the surface is smoothed and moulded in forms, either with the hand or a small mould which indents the surface. When the excess of water has drained off and the peat becomes consistent, the bricks are cut

out with a long knife, and dried in the manner already indicated. In many moors or fens the peat is so surcharged with water that it cannot be extracted even with the spade; in this case the workmen employ a kind of dredge, by which the material is collected. It is deposited on a sloping sward, and after the superabundance of water has drained off and the mass becomes more consistent, it is moulded into bricks. The latter processes are usually resorted to in France, Germany, and most other localities where peat abounds. In Holland a different course is pursued, which, though more circuitous, is notwithstanding more effectual in producing a denser fuel than can be obtained by the foregoing methods. The upper stratum, which is light and fibrous in its nature, is nearly always moulded with the *slane*, though sometimes it is subjected to the same operations as the under layer. Generally, this is scooped out with a kind of ladle when it is not too wet, and carried to the tempering ground; where, by sprinkling with water, tramping with the feet, and tempering with a rake, it is brought to a homogeneous consistence, and freed from stones, bits of wood, leaves, and the like. In case the matter is slimy, and so thin that it will not admit of adhering together in masses, another kind of tool is employed, enabling much more peat to be abstracted, with less water, than if the ordinary iron ladle dredge were used. It consists of a ring of iron, the edge of which is sharp, attached to a long handle; the side of this band is perforated for the purpose of affixing the body, which is a thick cloth, and the whole forms an instrument not unlike a fisherman's landing-net. Much more peat is taken up by this, and the excess of water filtering through the meshes of the tool, the peat is in a state which will admit of being immediately worked. This very slimy material is kneaded in a kind of trough or tub, till it becomes thoroughly blended together. In this state it appears like a kind of mortar. The next operation is to prepare the sward on which it is to be spread. This is done by laying upon it a covering of hay, which is trodden down to a level, whereon the peat is spread to the depth of a foot or more. The depth is regulated by means of planks or boards set in parallel lines, and placed, as circumstances may admit, from twelve to thirty feet apart. It is usual to beat down the surface of these beds to give the peat a uniform thickness. After a few days, when the excess of water has, partly by draining off, partly by infiltrating into the soil, and partly by evaporating, disappeared, and the layer of matter has acquired a certain consistence, it is rendered more compact by treading. This part of the work is performed by women and children, who attach flat boards, about six inches broad and twelve to fourteen long, to their feet. Before this treading is finished, the peat has acquired such solidity that it will bear a person's weight upon it without sinking. The surface is again brought to a level by beating it with oars, shovels, and the like; and after this is accomplished, the surface is divided into squares, the sides of which are about four to five inches. When the tracings thus made are cut, the bricks are about eight inches long by four to five inches square in the section. The drying is performed

by placing alternate rows crosswise upon one another, reversing this order in a few days, and continuing the exposure till the most of the moisture has disappeared. When this is the case, the turf is stored for use, but it is necessary that the moisture be sufficiently expelled before this part of the business is performed, as according to DUMAS, when this is not effected, the stacks are liable to a fermentative process which raises the temperature so high as often to cause spontaneous combustion. It has been already stated, that one essential quality of peat, in relation to its value as a fuel, is its density and freedom from large quantities of mineral matters; but another is also required, namely, that it contains as little water as possible. However well exposed or prepared, air-dried peat always retains from twenty to thirty per cent. of moisture, and this expends a considerable quantity of the heat of combustion in its evaporation. When intended for particular purposes, such as for charring in heaps, for lime-burning, and such like purposes where it is to be piled up in large masses, or has to resist much pressure, the value of the material is enhanced by the quality of strength or solidity, because, if it were very brittle, it would prove almost valueless for either of these uses.

COMPRESSION OF PEAT.—The relative heating power of dense peat well dried is about the same as wood, and half that of coal; the lighter kinds prove to be not more than one-third as effectual as coal for heating. Prepared according to the improved processes which have lately been introduced, it gains considerably in calorific power, as much more combustible material is contained in compressed peat, bulk for bulk, than in the ordinary sods or moulded turf. Much difficulty, however, stands in the way of effecting this condensation of the article, owing to the elastic nature of the fibre, which causes a distention after the force is removed. The system of pressing each sod or mould, as in the preparation of artificial fuels, would never answer with peat, as the labour would be too great in proportion to the value of the material; and, besides, the supply which could be so furnished would be inadequate to the demands of a large consumption. This led Mr. WILLIAMS, a gentleman who has contributed much to the development of the industrial uses of peat in Ireland, to the adoption of powerful hydraulic presses, which, while they are able to overcome the elasticity of the material, can supply it in considerable abundance. It is questionable, however, if his endeavors have been remunerative, as it is difficult to eradicate the preconceived prejudice of manufacturers and traders against this species of fuel. The manner of compressing, as conducted in the Cappoge works, was to break up the fibre of the peat as much as possible after cutting, and then to place it interlaid with coarse cloths or coco-matting under the machine. After the action had been exerted during the period allowed, the material was found to be reduced to one-third its original volume, and to have lost about two-fifths of its weight. In this state, the peat, when thoroughly dried, is not so hygroscopic as when the drying is conducted in the open air and no pressure exerted, and the lighter kinds yield by compression a substance denser than wood; the lower stratum affords a product

still more so. The elimination of the water by pressure improves the quality of the peat in other respects, not the least of which is the reduction of the relative amount of mineral matters contained in it, for considerable quantities are carried off in the water that would remain if it were exposed to spontaneous exsiccation. It would appear that the increased expense of this process is immaterial, when the relative volumes of product it affords, compared with ordinary peat, and the large percentage of water which the latter contains, are considered; for, whereas the latter costs three shillings and sixpence per ton at the bog, the prepared article can be had at five or six shillings. Mr. COBBOLD's method is to convert the peat into a magma, with the addition of water if necessary, and when by means of *centrifugal* power this is subsequently got rid of, a very dense product is obtained. The course recommended by Mr. STONE as described in his patent, sealed in March 1850, is the use of a box divided into a number of compartments suited to the size of the machine, and pressure to be exerted upon this, by rollers adapted to one another by means of leverages. Figs. 38 and 39 are vertical and side views of this arrangement, where the same letters indicate similar parts in each figure. A and B are cast-iron rollers, the latter of which is fixed in a stationary bearing, C. D is an adjusting screw, by means of which the roller may be raised or lowered at

Fig. 33.

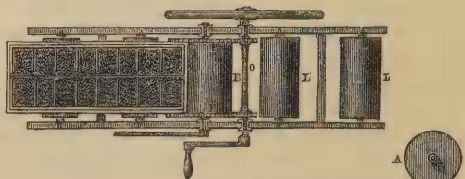
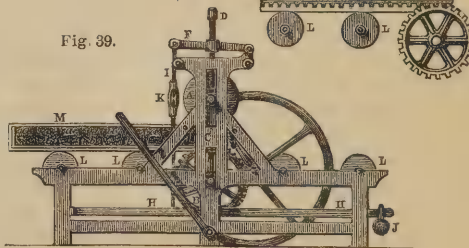


Fig. 39.



pleasure; this screw works in the lever, F, the fulcrum of which is at the top of the side frame, and the handle connected with the long one, H, by the rods, I, I, which are adjusted by the screw, K. Pressure is exerted upon the lever, H, by sliding the weight, J. The friction rollers are shown at L L L L, for supporting the pressure box, M, before or after it has passed the pressure rollers, A B. Upon the shaft of the latter, two toothed wheels, P P, are fixed, which are worked by two pinions, N N, upon the shaft, O; the wheels, P P, gear into two toothed racks at each side of the pressure box, and serve to carry it along under the pressure rollers already indicated.

The box is such that it contains another one, R, in

which the peat is condensed; this is divided into sixteen compartments by means of bevel-edged knives, *a a*, fixed transversely in the cover, and *b b* in the bottom, and so corresponding with one another that when pressure is exerted they are nearly in contact. The longitudinal knife in the middle separates the interior into two divisions.

Motion is given to the whole by means of a winch-handle and fly-wheel appended to the ends of the shaft, *o*; when the motive is steam, the handle is substituted by a drum on which a strap works. The lever, *h*, may be lifted by means of another lever shown in the figure, so as to remove all pressure. The method of operating with this machine is to fill the movable box with peat, after which it is placed inside the box, *m*; the lever, *h*, is raised, and the box is drawn forward by putting the shaft, *o*, in motion. When it has come under the roller, *h* is let down so as to bring *A* in contact with the lid of the box. From the time that the verge of the box has entered under the roller till it has passed the centre, the lid is in an inclined position, varying from an angle of 10° or 15° . At the time the roller is at the centre, the cover will have assumed a horizontal position, and a uniform pressure will be enforced upon the entire contents. When the box has passed through the roller, the lid is taken off, and the compressed material removed and exposed to thorough desiccation. The compartment is again filled, the cover fitted on, and, by reversing the motion of the handle, the box is made to pass the same way backwards. Thus the compressed material is discharged at each end of the machine.

These and a few others are the means hitherto proposed for improving the quality of peat fuel, so as to remove its characteristic fault, namely, want of density; but it seems that as yet the processes have not been conducted with sufficient spirit, or the outlay in machinery is too great in proportion to the value of the material operated upon. It appears that in Ireland the chief improvement in this process must, for some time to come, turn upon the system of drying under sheds, so as to protect the peat from the influence of the rain, a considerable quantity of which it is capable of absorbing, and yet will appear dry to the touch. The amount of water thus retained considerably diminishes the heating power of the turf. This will be seen more clearly from the following data:—When a pound of pure dry peat is burned, and the entire amount of caloric which it yields is conducted through water, it will be found that six times its weight of this liquid will be raised to 212° . In ordinary turf the fourth part of the weight is water, so that there is only three-fourths available as a heating medium. Were a pound of this consumed in the same manner as the foregoing, it is evident the caloric developed would raise only four pounds and a half to the boiling point. This quantity would, of course, evaporate the water contained in the peat, so that the visible effect would be as four and a quarter to six, or about thirty per cent. in favor of the dried material. Such a wide difference, it is needless to say, is sufficient cause for condemning the moist material even for domestic use, but especially in manufactories, where it is an object of

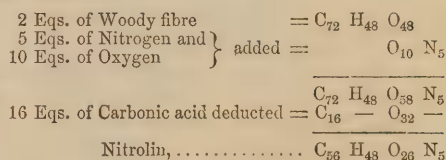
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the first importance that the fuel should exert the greatest possible effect in proportion to its bulk and value.

Before passing to the discussion of the action of heat upon peat, it will be well to devote a little attention to the consideration of the nature of those substances contained in it, as well as those which are artificially produced from it. It has been stated already—page 51—that by the action of alkalies upon peat, the greater part is dissolved, and that, when the liquor is further treated with acids, the *ulmin* is precipitated in flakes. This substance, which is the principal and most important component of peat in its ordinary state, is so analogous to woody fibre in its composition, that the changes which the material producing it has undergone, may be considered as sufficient to account for the difference. By the researches of BRACONNOT and others, it has been proved that in the fresh peat *ulmin* is combined with lime, and forms therewith a true chemical compound—ulminate of lime. Ulmin or humus, popularly termed vegetal mould, has the following composition when prepared from wood and sugar:

	From Wood.	From Sugar.
Carbon,.....	72.7	65.65
Hydrogen,.....	6.1	4.28
Oxygen,.....	21.2	30.07
	100.0	100.00

When peat is subjected to destructive distillation ammonia is invariably one of the products, a circumstance for which it is difficult to account, seeing that ulmin is entirely devoid of nitrogen, unless it be admitted that, during the progressive decomposition of that body, nitrogen is assimilated from the air, just in the same manner as decaying wood or vegetal matter takes up the same element. In the course of the decomposition of vegetal bodies, oxygen and nitrogen are absorbed and combined with the other elements, and the consequence is the formation of a new substance called by HERMANN *nitrolin*—a body that approximates closely in its composition to animal flesh. Such a metamorphosis may be explained by supposing that two equivalents of woody fibre take five equivalents of nitrogen and ten of oxygen from the atmosphere, and give off sixteen equivalents of carbonic acid; thus—



By a further change these elements are disturbed, and carbonic acid is produced together with ammonia. Besides these, several other new substances of a brown or black color remain, among which are ulmic acid, *et cetera*. DUMAS supposes that the ammonia results from the decomposition of animal remains embedded in the marshes; but the Editor is of opinion that it is mostly derived from the atmosphere.

When peat is exposed to the action of heat in close vessels, it affords a variety of substances, the principal being pyroligneous acid; a brown empyreumatic crystallizable oil, from which numerous products may be

H

extracted, and among them paraffin; carbonic oxide and carbonic acid, hydrocarbon gases, together with a variable quantity of ammonia. Industrial progress has invested several of these with a new value during the last few years, so much so that they have become special objects of manufacture. This has been shown under the heads ACETIC ACID, AMMONIA, ASPHALT, CANDLES, *et cetera*; and with regard to certain inflammable gases and other bodies, their importance will appear further on. The products of the distillation of peat are all useful in the arts, and consequently are in constant request. To provide them in sufficient quantity, or at least in some degree to supply the wants of the trades using them, a manufactory was erected a few years ago near the town of Athy, in Kildare, Ireland, for the purpose of distilling peat, and obtaining the useful products which it affords. This manufactory has now established itself, although it had many difficulties to contend against. It is worked on the principle of Mr. REES REECE's patent, sealed in 1849. The idea was derived from the application of inflammable gases to heating purposes by the late M. EBELMEN, for the utilization of inferior coals and other combustibles, by converting them into gases, the object being the production of those organic bodies already alluded to. These are produced in greater abundance from peat than from other combustibles, owing to the large amount of water in it, which keeps the temperature low during the distillation, and thus favors the formation of such products. The principle of the distillation is the introduction of a blast of air at the bottom of a furnace filled with the combustible. The heat developed in this part passing up with the gases through the mass, causes the destructive distillation of the latter, and the expulsion of the empyreumatic products with the combustible and other gases from the fire. By proper contrivances these are operated upon, in such a way that all the condensable substances are removed, and the inflammable products which cannot be liquefied are employed to heat boilers, stills, or evaporating pans required in the purification of the crude products. It is this application of all the products to economical purposes which renders the manufactory so novel in its nature, for the very substance operated upon is made to supply all the requisites for carrying out the manufacture, besides supplying the useful products.

For the following important details with reference to this manufactory, the Editor is indebted to the *Journal of Industrial Progress*, by Professor SULLIVAN:—

From repeated examinations of peat with reference to the amount of tar, oils, paraffin, and ammoniacal

salts which it yields, as well as from the researches of the patentee, most flattering results were anticipated from the development of this branch of industry. To carry it out, a company was organized, called the IRISH PEAT COMPANY, which stated in its prospectus that, by a manufactory capable of operating on one hundred tons daily, or thirty-six thousand five hundred tons annually, the following commercial results would be attained; namely,—

EXPENDITURE.

36,500 tons peat, at 2s. per ton,	£3,650
455 tons of sulphuric acid, at £7 per ton,	3,185
Wear and tear of apparatus, <i>et cetera</i> ,	700
Wages, labor, <i>et cetera</i> ,	2,000
Freight and incidental charges,	2,182

£11,717

PRODUCE.

365 tons of sulphate of ammonia, at £12 per ton, ..	£4,380
255 tons of acetate of lime, at £14,	3,570
19,000 gallons of naphtha, at 5s.,	4,750
109,500 pounds of paraffin, at 1s.,	5,475
73,000 gallons of volatile oil, at 1s.,	3,650
36,000 gallons of fixed oil, at 1s.,	1,800

23,625

leaving a net profit of £11,908, or a fraction more than a hundred per cent. The cost of the manufactory for working such a quantity was stated to be about ten thousand pounds. That peat, and other substances heretofore useless, should be productive of a trade so profitable, was more than could well be credited by the parties wishing to embark in the speculation; and to satisfy themselves on this point, a series of experiments was instituted in the laboratories of the Museum of Irish Industry, under the superintendence of Sir ROBERT KANE and Professor SULLIVAN. These were conducted upon specimens of peat from various peat deposits in Ireland in a twofold manner: firstly, by distilling the peat in close vessels, and secondly, by effecting the distillation by a combustion of a part of the material with a blast of air, as proposed in the manufactory.

In operating by the former method, a retort was used similar to that employed in the distillation of coal in the manufacture of gas. To the exit pipe from this retort a series of WOULDIE's bottles were adapted, wherein the greater portion of the tar and other aqueous products were deposited, the remainder being condensed in a worm fixed in a barrel of water, and the permanent gases collected. In each trial one hundred-weight of peat was worked off in eight to fourteen charges, according to the density of the substance. The annexed table represents the quantity of the gross products obtained:—

No of Experiments.	Locality whence obtained.	Water.	Tar.	Charcoal.	Gas.
1.	Surface peat, } A mixture of about equal parts of the two peats, from }	23·600	2·000	37·500	36·900
2.	Dense peat, } Mount Lucas Bog, near Phillipstown,	32·273	3·577	39·132	25·018
3.	Light surface peat, from Wood of Allen,	38·102	2·767	32·642	26·489
4.	Black compact peat, from do.,	38·628	2·916	31·110	32·346
5.	Surface peat, from Ticknevin,	32·098	2·344	23·437	42·121
6.	Do. distilled with the retort heated to a very bright redness,	38·127	4·417	21·873	35·693
7.	Surface peat, from Shannon,	21·189	1·462	18·973	57·746
	Dense peat, from do.,				
	Average,	31·378	2·787	29·222	36·616

The amount of ammonia, acetic acid, and naphtha, as well as that of the oil and paraffin in the tar; the following table contains the results obtained:—

TABLE REPRESENTING THE PER CENTAGE OF AMMONIA, NAPHTHA, ACETIC ACID, PARAFFIN, AND OILS, OBTAINED BY THE DISTILLATION OF PEAT.

Locality whence obtained.	Ammonia.		Acetic Acid.		Pyroxylic spirit or naphtha.	Paraffin.	Volatile oil.	Fixed oil.
	Ammonia as NH_3 .	Corresponding quantity of sulphate.	Acetic acid as $\text{C}_4\text{H}_3\text{O}_3, \text{H}_2\text{O}$.	Corresponding quantity of acetate of lime.				
1. Surface peat, { A mixture of equal parts 2. Dense peat, { of both peats from Mount { Lucas Bog, Phillipstown,.....	0.302	1.171	0.076	0.111	0.092	0.024	0.684	0.469
3. Light surface peat, Wood of Allen,.....	0.187	0.725	0.206	0.302	0.171	0.179	0.721	0.760
4. Black compact peat, do.,.....	0.393	1.524	0.286	0.419	0.197	0.075	0.571	0.565
5. { Surface peat, from Ticknevin,..... { Do. distilled with the retort heated to redness,.....	0.210	0.814	0.196	0.287	0.147	0.170	1.262	0.617
6. Surface peat, from Shannon,.....	0.195	0.756	0.208	0.305	0.161	0.196	0.816	0.493
7. Dense peat, do.	0.404	1.567	0.205	0.299	0.132	0.181	0.829	0.680
Average,.....	0.181	0.702	0.161	0.236	0.119	0.112	0.647	0.266
	0.268	1.037	0.191	0.280	0.146	0.134	0.790	0.550

In the second series of experiments, in which the peat was consumed by igniting it, and then supporting the combustion by a blast, the same peats were used as in the foregoing tables. The annexed table shows,

however, only the products obtained from those which in the former experiments exhibited the greatest dissimilarity, this being sufficient for the purpose of comparison:—

Character of Turf, and Locality whence obtained.	Water.	Tar.	Ash.	Gases.
Light surface peat, from Wood of Allen,.....	31.678	2.510	2.493	63.319
Dense peat, do.,.....	30.663	2.395	7.226	59.716
Dense peat, from the River Shannon,.....	29.818	2.270	2.871	65.041

The amount of ammonia, acetic acid, naphtha, paraffin, and oils, obtained in the same way, and expressed in the following numbers, affords a comparative view of the merits of both methods of working:—

TABLE REPRESENTING THE PER CENTAGE OF AMMONIA, ACETIC ACID, NAPHTHA, PARAFFIN, AND OILS, OBTAINED BY THE DISTILLATION OF PEAT IN A BLAST OF AIR.

	Ammonia.	Acetic acid.	Naphtha.	Paraffin.	Oils.
Light surface peat, Wood of Allen,.....	0.322	0.179	0.158	0.169	1.220
Dense peat, do.,.....	0.344	0.268	0.156	0.086	0.946
Dense peat, from the River Shannon,.....	0.194	0.174	0.106	0.119	1.012
Average,.....	0.287	0.207	0.140	0.125	1.059

The average results of both methods of operation gave for the distillation in close vessels—

	Average.	Maximum.	Minimum.
Aqueous products,.....	30.614	32.678	29.818
Tar,.....	2.392	2.510	2.270
Gases,.....	62.392	65.041	59.716
Ashes,.....	4.197	7.226	2.493

The watery products and tar afforded—

	Average.	Maximum.	Minimum.
Ammonia,.....	0.287	0.344	0.194
or as Sulphate of ammonia,.....	1.110	1.330	0.745
Acetic acid,.....	0.207	0.268	0.174
or as Acetate of lime,.....	0.305	0.393	0.256
Naphtha,.....	0.140	0.158	0.106
Volatile and fixed oils,.....	1.059	1.220	0.946
Paraffin,.....	0.125	0.169	0.086

Placing these numbers in apposition, the following will express the relative value of the two modes:—

	Average produce from close distillation.	Average produce from distillation in blast of air.
Ammonia,.....	0.268	0.287
or as Sulphate of ammonia,.....	1.037	1.110
Acetic acid,.....	0.191	0.207
or as Acetate of lime,.....	0.280	0.305
Naphtha,.....	0.146	0.140
Oils,.....	1.340	1.059
Paraffin,.....	0.134	0.125

The similarity of these numbers shows that very little difference exists between the results obtained from the distillation of the substance in close vessels, and from its decomposition in the fire by a blast of air. In the first case, however, there remains an average of twenty-nine parts of charcoal, which might determine a preference for that method, were it not that the greater part of this is consumed in carbonizing the matter in the retort.

A similar and independent series of experiments was conducted by Dr. HODGES, whose results are appended

below, and contrasted with those arrived at by Professors KANE and SULLIVAN, as well as with those form-

ing the basis upon which the company's prospectus was founded:—

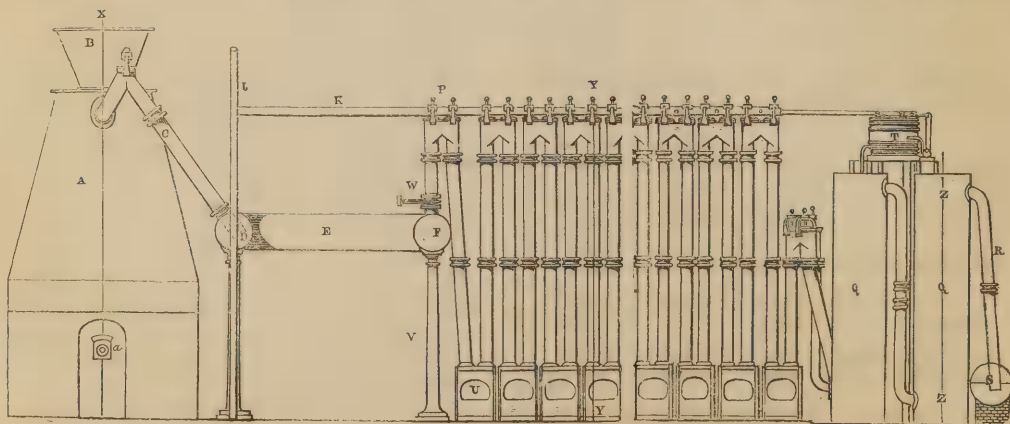
	Kane and Sullivan.		Hodges.		Statement in Company's Prospectus.	
	Per ton.	Per cent.	Per ton.	Per cent.	Per ton.	Per cent.
Sulphate of ammonia,.....	24 $\frac{3}{4}$ lbs.	1.110	22 $\frac{3}{4}$ lbs.	1.000	22 $\frac{3}{4}$ lbs.	1.000
Acetic acid—real hydrated,.....	4 $\frac{3}{4}$ “	0.207	7 $\frac{1}{4}$ “	0.328	— “	—
or as						
Acetate of lime,.....	6 $\frac{1}{4}$ “	0.305	— “	—	nearly 15 $\frac{7}{10}$ “	0.700
Wood naphtha, ..	50 $\frac{1}{4}$ ozs.	0.140	83 $\frac{1}{4}$ ozs.	0.232	66.3 ozs.	0.185
Tar,.....	53 $\frac{3}{4}$ lbs.	2.390	99 $\frac{1}{2}$ lbs.	4.440	—	—
Products of {Paraffin,.....	2 $\frac{1}{2}$ “	0.125	—	—	3 lbs.	0.104
the tar, {Oils,.....	nearly 2 $\frac{3}{4}$ galls.	0.159	—	—	2 $\frac{1}{2}$ galls.	0.071

If the difference of the peat in these experiments be taken into account, the results of the three columns will be nearly equal; for in HODGES' experiments the peat was of a black unctuous nature, weighing, per cubic yard, from five and a half to six and a half hundred-weight.

At first, the apparatus erected for the distillation, *et cetera*, was on a small scale, and not so much with the object of realizing an immediate profit, as with a view to the perfection of the process by which the operation might be conducted on a scale of greater magnitude. During this preliminary phase of the undertaking, very little advantage accrued beyond opening the eyes of the conductors to the necessity of having some more perfect medium for condensation, and turning the inflammable gases to useful purposes, as also for purifying the products, and bringing them into marketable condition. It was necessary, therefore, under these circumstances, to erect new works; and, as many things had to be invented, this occupied considerable time. The factory has now been in active operation for some few years. The arrangement for the combustion of the peat consists of four furnaces, constructed like ordinary blast furnaces, and without gratings, but furnished with three tuyeres through which the blast enters. Each furnace is thirty-two feet seven inches high, from the ground to the top of the hopper; the hearth is three feet two inches deep, three feet wide, and eighteen

inches to the top of the dam-plate; the tympanum is thirteen inches high, and has two inches of water space; the boshes are seven feet six inches high from the bottom of the crucible part, and twelve feet wide at the belly; the cone or body is sixteen feet high, and six feet wide at the tunnel head. The base of each furnace is square as high as the belly, and the whole of the cone or body is covered with boiler-plate firmly riveted. Such a protection is necessary, in order to prevent a leakage of the products of distillation, besides giving greater stability to the erection. The top of each furnace is completely closed by a conical valve three feet in diameter, and surmounted with a changing hopper provided with two tight-fitting lids. This hopper is five feet high from the valve-opening to the lid, and eight feet in diameter at the top. Two pipes, each twelve inches in diameter, convey the products of distillation into an hydraulic main, three feet in diameter, whence the condensed tar and other liquids flow into a tank, while the gases are made to pass through two double rows of upright condensing pipes, twelve inches in diameter, and twenty-five feet high, including two series of rectangular boxes upon which they are fixed. During the passage of the elastic vapors and gases through these pipes, an additional quantity of tar and aqueous products is liquefied and collected in rectangular boxes placed in connection with the pipes, by an arrangement which will be further explained in the drawings annexed. After

Fig. 40.



the gases traverse the condensers, they are conducted through a series of eight scrubbers, twenty feet high, and arranged in four rows. Each scrubber has three layers of small stones resting upon gratings, and is besides fur-

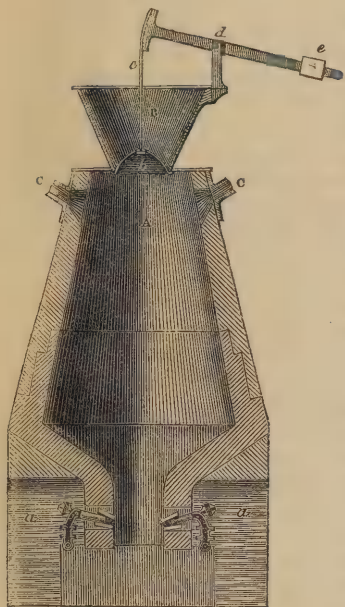
nished with a mill and tumbler, by which a dense shower is made to fall through the scrubber. By this contrivance the gases are washed of all traces of tar and condensable matters, such as naphtha, *et cetera*. From the

scrubbers the gas flows into a kind of main called the trunk, twenty-five feet three inches in length, and three feet eight inches in diameter, and from which it is distributed to the several fire-places to be consumed under evaporating pans or boilers, as required.

Fig. 40 is a side elevation of this arrangement, represented, for want of space, as broken off in the middle. *A* is one of the four furnaces, a section of which, along the line *x*, is shown in Fig. 41; and Fig. 42 is a plan of the platform, *G*, on the top of the furnaces, with part of the condensing apparatus attached. The same letters in each of the figures indicate corresponding parts.

Referring, in the first place, to the sectional view of the furnace—Fig. 41—*a* represents the arrangement of the tuyeres, with their nozzles, showing the water spaces and the plug valves for allowing the

Fig. 41.

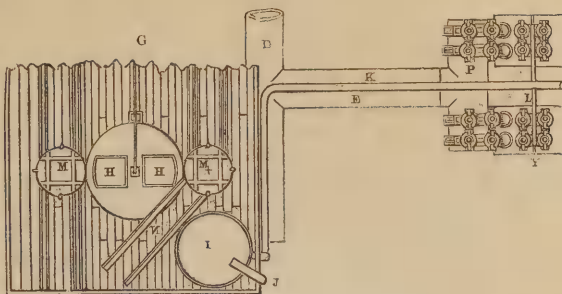


of cast-iron or other material to form the counterpoise.

The platform on the top of the four furnaces, part of which is represented at *G*, in Fig. 42, is constructed of planks of wood laid on the same plane as the covers of the hoppers. The dried peat or turf is elevated to this platform in iron waggons, each thirty cubic feet in capacity, by means of a water lift, consisting of a floor upon which four waggons fit, supported by a frame or cage with friction pulleys at the angles, for working against the four upright pillars of wood which support a framework at top, having a drum and brake. The flooring of the cage is attached to a chain which passes over the forementioned drum, and is counterpoised by a wrought-iron cistern, five feet square, and two feet six inches deep, provided with a valve in the bottom, with an externally projecting spindle. The peat is brought from the bog in flat-bottomed boats by the canal, which

terminates in a kind of basin, having a quay a few yards wide at the foot of the lift. Here the waggons are

Fig. 42.



filled with the turf, and they are then rolled in upon the floor of the cage previously let down to receive them. In this position of the cage, the counterpoise or cistern is at the top, and, while there, water is allowed to flow into it from the tank, *I*, which is in turn supplied by the feed-pipe, *J*, connected to a large pump worked by a steam-engine which drives the other smaller ones throughout the works. When the cistern is full, it more than counterbalances the weight of the cage and loaded waggons; and, accordingly, on letting go the brake, the former descends, and by means of the chain passing over the drum, draws up the cage and waggons to the level of the platform, *G*. When the cistern full of water reaches the ground, the projecting pin strikes against it, by which the valve is lifted, and the water allowed to flow out. The waggons full of turf are next rolled along tramways at each side of the hoppers, one of which is shown at *N*, to the furnace into which it is discharged. This part of the work is performed by rolling the waggon on to a turning table, *M*, situate at each side of the furnace, and there made to perform a fourth of a revolution, so as to bring the end of the waggon, which is provided with a hinge and latch, over one of the hopper lids, *H*; the latter is opened, and the turf discharged into the orifice. Three waggons full, or ninety cubic feet, fill the hopper, and this constitutes a charge. Whilst the hopper is being filled, the conical valve, *b*, is raised to the position in which it closes the furnace, as shown in Fig. 41, and none of the products of distillation can escape; but as soon as the hopper is filled, the lids, *H H*, are firmly closed, and the grooves into which the lid flanges are partly filled with turf dust and some of the blue clay marl underlying the peat bog, mixed up into a magma with water. This paste forms an excellent lute round the lid, which is kept tight by a latch.

The valve, *b*, Fig. 41, may now be lowered by the lever, *d*, which, while the valve is up, has its extremity bearing the counterpoise, *e*, hooked to the platform by means of the small aperture seen near the counterpoise; but when this is unhooked, the valve descends, and the turf falls into the furnace. This being effected, the lever is again hooked in the usual position, and the hopper recharged. In this method of working, the only loss sustained is merely the full

of the hopper of gases each time the furnace is charged. When light peat is burned, the charge weighs about seven hundredweight, so that it would require about a hundred and forty-three charges to burn fifty tons of material, and two hundred and eighty-six to burn one hundred tons, the work assigned to each furnace in twenty-four hours. Allowing one hundred cubic feet of gas to be lost at each charge, the total for each furnace during the day's working would amount to twenty-eight thousand six hundred cubic feet; but this is too high, for the average weight of a charge of the brown turf employed is about half a ton, and, therefore, only two hundred charges are required to perform the work, so that the loss is reduced in actual practice to twenty thousand cubic feet; and this quantity, compared to the total quantity produced, is very insignificant.

When the fire is lighted in the furnace, and the blast directed upon it, the part immediately ignited is resolved into the simplest and most permanent products of combustion; but as these ascend, the carbonic acid is resolved into carbonic oxide by the incandescent fuel overhead, and this gas, together with the nitrogen of the air, rises in a heated state through the mass. These superheated gases are the agents which effect the distillation of the great mass of peat in the body of the furnace, and carry the products off to the mains, as already intimated, by outlet pipes, C—Figs. 40 and 41—of which there are two to each furnace. These outlets are fixed near the top of the furnace; they consist of a short ascending and a long descending pipe, the angle where they meet being provided with a hand-hole for cleaning out, and which can be secured by a dog and screw. The long arm enters the hydraulic main, D, shown in section in Fig. 40, and represented as broken off in the plan, Fig. 42. This main is kept half full of liquid, below the surface of which the outlet pipes dip. Each furnace is thus isolated in the same way as the retorts in a gas factory. The hydraulic main consists, properly speaking, of two; the principal one running along the furnaces in front, and marked D; and, secondly, a cross piece, E, which connects the former to a shorter one, F. Both these are closed at the ends with plates of iron, which can be removed whenever they want cleaning. Overflow pipes, screwed to those plates, draw away all the tar and liquid which accumulate in the mains above the proper level; this excess is conveyed into a tank not marked on the drawings, but its place is indicated by x, in Fig. 42. Four ascending pipes convey the gas from the main into the condensers; each of these pipes is provided with a valve, w. As was already stated, there are two distinct series of condensers, each consisting of eighteen rectangular boxes, shown in section at U, Fig. 43. Upon the top of each of these are placed four upright pipes, and those of each series constitute two rows. The adjoining pipes in each row, belonging to different boxes, are connected by a breeches-piece, which has two openings in the top, closed by caps, dogs, and screws, p. The gas flowing through the valve, w, is thus enabled to ascend one pipe in a row and down the next, into the first rectangular box, thence up the next, and, by means of the breeches-pipe, into the adjoining condenser pipe and box, and so

on. A diaphragm, as seen in Fig. 43, separates the box into two compartments; this division is not perfect, however, for at the bottom a space is left, so that both form only one.

The four pipes open into one compartment, and as both are kept nearly half full of water, the gas entering into the side compartment cannot escape otherwise than by the pipes, unless the pressure is so very great as to force all the liquor out by v, into the next chamber. All the condensable matter that accumulates in the inner chamber soon finds its level in the outer one by the communication at the bottom of the box, and when it rises to a certain height in the latter, it flows out by a siphon pipe into a conduit in connection with the tank, x. All the boxes are in communication with one another by a short connecting pipe passing from one to the other near the bottom; the same level of liquid is thus insured in all. To prevent the condensing pipes ever getting too hot, a conduit, K—Fig. 42—in connection with the cistern, I, is carried along the top between the two rows, to each set of which it sends out an arm, L, pierced with small holes, which allow a fine stream of water to fall on the tops of the pipes, and to trickle down the sides, and thus cool them effectually.

Notwithstanding all the refrigerating surface afforded by the double line of condensers, a certain quantity of tar and ammonia, and the greater part of the naphtha, still remain uncondensed, and are carried forward mechanically by the force of the blast; and to guard against a loss being sustained, the scrubbers, Q—Fig. 40—have been appended. These are arranged in four rows, corresponding to the four rows of condensing pipes. Each scrubber consists of a cylinder of wrought-iron, four feet six inches in diameter, and twenty feet high, closed at both ends, and having three gratings in the interior, upon each of which is placed a layer of stones, shown at j, Fig. 44. The gas enters at M', and passes up through the layers of stones, while, at the same time, the mill, K', supplied with water from an inch pipe connected with K, Fig. 42, or with the tumbler, L', produces a dense rain by its revolution; and this shower meeting the gaseous bodies ascending through the layers of stones, completely removes all the considerable bodies remaining in it. The water which thus traverses the scrubber, and becomes partly saturated with tar, ammoniacal matter, and naphtha, flows off from the base by a pipe into a tank, not exhibited in the drawing, but which may be designated by z, Fig. 40. After passing through the first scrubbers,

Fig. 43.



Fig. 44.



the gas enters the second series by means of a pipe, and after it is washed in these, as described, it flows into a kind of gasometer, *s*, Fig. 40, consisting of a pipe twenty-five feet three inches long, and three feet eight inches wide, and kept full of water to the level of the line shown. By means of the valve, *w*, in the main, *r*, and the dip of the pipe, *r*, into the water of the gas-holder or trunk, *s*, each row of condensers, and each pair of scrubbers, may be isolated, and the gas shut off from them whenever they require cleaning.

As the whole of the water which passes through the scrubbers must be distilled in order to obtain the ammonia and naphtha which it has absorbed, it is found desirable to make the same liquid serve two or three times for washing the gas. This is done by placing barrels, *t*, on the tops of the scrubbers, *q q*, and pumping into them from time to time a portion of the liquor from the tank, *z*. Each barrel supplies liquor to four scrubbers, by means of branching pipes.

Owing to the retention of the tar by the layer of stones, the scrubbers would get clogged from it, were there no provision made for cleansing them. The means adopted is to inject steam into them once in the day, by which the tar is melted, and in this state flows out at the bottom of the tank. From *s* the combustible gases are carried off by a duct, from which, by other channels, it is taken to the several flame-beds, where it is consumed.

Such are the principal details of this manufactory, having in view the recovery of the volatile products of distillation only, the charcoal which the peat would afford being entirely burned.

The high heating power of peat-charcoal, as well as its disinfecting and other qualities, invest it with peculiar interest to the smelter, the sanitary reformer, and the agriculturist: for the former it has long been productive of great advantages, more especially in the manufacture of iron, and therefore its production, on the most economical scale, and in the largest quantity, has been a subject to which some attention has been paid. This is more particularly the case in Bohemia, Bavaria, France, Russia, and other countries, where it is used in the blast-furnaces of their iron-smelting establishments, and produces very satisfactory results. In the numerous other processes to which the metal is subjected, the charcoal is found quite as efficient, if not more so, than wood-charcoal. In England, however, where coal is so abundant, a material which is at her command in as great abundance as her coal, has been allowed hitherto to remain useless; but it is to be hoped, that the success which has attended its application in the particular instances alluded to, and the free discussion of its advantages which one now meets with, will remove any prejudices existing in the minds of manufacturers against its employment. At present, or at least till within a recent period, the cost of the product has been very high, in fact out of all proportion when compared to that of other kinds of fuel; and this, perhaps, has been one cause why it has not been extensively consumed in smelting and other works: but if, by the attention of manufacturers, the charring of peat had been understood, and conducted on such a scale as would bring its marketable value on a footing

with that of coke, there is little doubt of its very soon being introduced into several establishments from which it is at present excluded. When peat is acted upon by heat in close vessels, it yields a variable amount of charcoal, from twenty-five to forty per cent., according to its density and state of dryness; but, as it is rarely distilled in this way, the quantity obtained is from twenty-five to thirty per cent., and at best does not exceed thirty-five per cent. The methods followed for the charring of peat are, in some respects, similar to those already described as being pursued in carbonizing wood on the large scale; these are the meiler system, and that by the furnace. For operations by the first of these methods, the nature of the peat and the regular form of the sods or bricks offer advantages for constructing the heap more regularly, leaving less interstitial space than the logs of wood, and, being less combustible than the latter, the process does not exact that minute attention which the carbonization of wood requires. It is necessary that the peat should be thoroughly desiccated, otherwise the charring will proceed irregularly, and sometimes not at all. Large quantities of peat are carbonized in this way in the Vosges, in Bavaria, Saxony, and Bohemia. In these places, one or other of two forms of constructing the meiler is adopted—either the circular or bee-hive, so frequently resorted to in charring wood, or the rectangular one. At the Royal Iron Works of Weierhammer, in Bavaria, where the refining and puddling of iron has been carried on since 1838 by means of peat-charcoal, the peat is charred in the circular mound, prepared almost as in manufacturing wood-charcoal.

A level site being chosen, a stake or quandel is fixed in the middle of a circular space, and round it on the ground a quantity of brushwood is spread, and which in turn is covered with waste charcoal from a previous operation. The turf is then piled round to the extent of the base, and to the proper height, preserving the conical shape. Generally, the size of the heap is about two thousand five hundred cubic feet, or thirteen and a half tons of the peat of the locality. When the central stake is withdrawn, brushwood is introduced into the opening and ignited. This communicates fire to the surrounding mass, which, in turn, conveys the heat towards the exterior. Owing to the closeness with which the turf admits of being packed together, the carbonization would proceed but slowly, were it not that air-channels of the breadth of a single brick of the peat are constructed at regular distances, and radiating to the circumference of the meiler. A covering of moss and leaves is placed upon the body of the heap, and outside this another of sand and turf ashes, or charcoal dust, is thrown on, leaving the upper part open, as a kind of chimney for the passage of the gaseous products, till the mass has been thoroughly ignited. As soon as flame appears at the top of the heap, a covering is thrown on, and the contraction of the mass observed, so as to keep any breaks occasioned by the sinking renovated. The charring is conducted regularly in the whole meiler by closing the draught-holes at the base, where the combustion becomes too vivid, or boring a few about a foot asunder in the upper part, where the progress is slack. Twelve to fourteen

days are necessary to char and cool a meiler of the above size, so as to be fit for removal. About seven hundred cubic feet of charcoal are obtained, weighing about three tons eight hundredweight, or 27·7 per cent.; hence, somewhat less than four tons of the peat of the district yields one ton of charcoal.

In Saxony, the rick or rectangular system is adopted, and the results are good. The ground is levelled and covered with sand in the usual way, and afterwards the rectangular space marked out; this is about fifty feet long by five or six in breadth. The middle of this plot is hollowed out into a kind of basin, and from it two channels or drains are cut from the ends of the intended heap, but inclining towards the central cavity. Both channels and well are constructed of, or are lined with bricks, a layer of clay being laid beneath, so as to prevent any fluid products collecting therein from percolating through the soil. A small gutter leads from the cavity in the middle to a tank at a little distance, where the liquids are recovered. These necessary constructions being made, a number of quandels is fixed in the longitudinal channel, ten feet apart, and the peat heap constructed to the height of four feet, leaving transverse channels corresponding with the vertical one which the stake forms. When finished, the quandels are withdrawn, and the whole coated with a mixture of clay, sand, and chopped straw or grass, the latter being used to prevent the luting from cracking. This mixture is prepared in two boxes or pits, one at each side of the mound, and quantities of it are always at hand so as to be available for stopping any cracks which might present themselves during the charring. Ignition is commenced at each end of the rhomboid by a fire placed in the central channel; the brushwood with which this has been filled burns, and, in doing so, sets fire to the surrounding peat. When the turf is fully ignited throughout the whole mass, a thick black smoke issues from the chimneys; as the carbonization proceeds, this becomes lighter, assuming gradually a greyish-white color, and finally changes to a bluish shade as the moisture evaporates. At this state, sulphurous acid becomes disengaged. As soon as the whole of the moisture is dispelled—a fact ascertained by holding the hand in the vapor as it issues from the chimneys, and observing if condensation takes place—the fire is gradually smothered by closing the air channels and fire flues. Care is also required in the management of the draught, so as not to allow of a consumption of charcoal taking place; generally, the apertures on the windward side are kept closed, the opposite ones being sufficient to supply air. The charcoal prepared in this way is of excellent quality, and much used in the metallurgical establishments of Saxony and Bohemia.

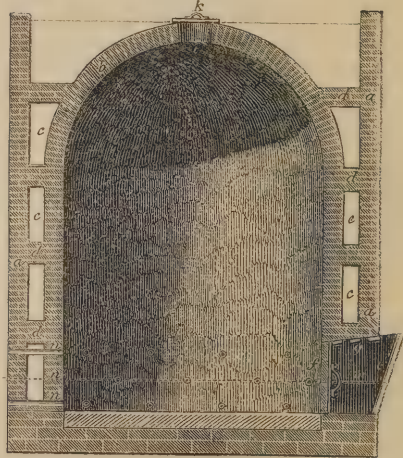
Both these systems of charring peat afford nearly the same yield of charcoal, when the operations have been properly attended to. It ranges from twenty-four per cent. by weight and twenty-seven by bulk when the peat is not thoroughly air-dried; but if this condition has been attained, the product is about twenty-seven per cent. by weight, or thirty-two and a half by bulk: a larger produce is occasionally obtained, but in those cases the exception must be attributed to the density and dry-

ness of the material before carbonization. The cost of a ton of charcoal at Weierhammer, manufactured by the process described, is about sixteen shillings and twopence, the peat from which it is produced having a marketable value of two shillings and elevenpence halfpenny per ton: allowing that four tons of peat are required for the production of one ton of charcoal, it appears that the charring expenses for one ton of charcoal are about four shillings and fourpence. In the neighborhood of Carolinen Hütte, near Achthal, in Styria, where some successful attempts have been made to smelt iron with peat in its raw state, mixed with wood, a ton of peat-charcoal costs twenty-two shillings and sixpence; but of this, eighteen shillings and twopence form the cost of the material, so that, practically, the charring expenses are the same as at Weierhammer. Such is also the cost of carbonizing by the meiler or rick system in Saxony.

Partly from the fact that less labor is required in managing the operation, whilst a regularity in the produce is, in some measure, insured, and partly from the circumstance that there always exists a supply of material at hand in every peat district, which would render the expense of removal of furnaces unnecessary when once erected, the system of charring in kilns has been resorted to with advantage. Furnaces or kilns are employed near Meaux in France, in East Friesland, and Bohemia, to a considerable extent.

The furnace or kiln employed for this purpose at Oberndorf, in Wurtemberg, is represented in Fig. 45. It is an upright cylinder, nine feet high and five and a half feet in diameter, having a capacity of about two

Fig. 45.



hundred cubic feet, and capable of distilling about four tons of average peat; the top is closed by an arch, with the exception of an opening, *i*, through which the peat is introduced; it also answers the purposes of a chimney till the charge is carbonized. A double line of construction is adopted in the erection of these kilns; an inner one, *b b*, of firebrick, and an outer one, *a a*, of more common material: both are about fifteen inches thick, and between them is an interstice, *c c*, of the same width, excepting where the brickwork extends the

whole breadth, as at *d d*, for giving greater firmness to the construction. The superior aperture, *i*, is closed by a tightly-fitting lid, *k*, when necessary; at the base is another door, closed by a cast-iron plate, *f*; and behind this is a space, *m*, formed by the door and the plate or board, *e*, and which is filled with sand through the aperture, *g*; thus the draught is effectually cut off at this orifice. There are three tiers of holes, *d d d*, formed at a short distance from the base of the furnace, through which air enters for supporting the combustion of the peat during the carbonization, as long as this takes place. In working this kiln, the peat is thrown in at the top and packed closely, with the exception of a few channels left free, corresponding to the lower draught holes, and also a vacant space in the centre; after being filled, fire is thrown in from the top, and the orifice in this part left open; when the fire has spread through the mass, so as to present a glowing appearance on being viewed through the lower apertures, these are closed with clay stoppers, and the combustion allowed to proceed till the same appearance is observed on looking through the second holes, when these are likewise stopped; and when the mass appears white hot at the third row of perforations, and no more smoke appears, all the apertures are secured, and the mass is allowed to remain till cold. Forty-eight hours are occupied in bringing the mass to incandescence, and after that seven or eight days are required for the cooling of the furnace. To avoid this delay, it is customary to have a damper plate situated in the bottom of the furnace, under which is a pit, so that, on withdrawing the damper, the red-hot charcoal falls into the pit, and the furnace is ready for a fresh charge. Sometimes the furnace is so constructed as to enable the manufacturer to recover some of the products of distillation, and use the combustible products for heating the mass of peat. In these, a pipe leads from the shoulder of the arch to a kind of condenser, where the ammoniacal and tarry matters are retained, and the gaseous bodies are reconducted by pipes to the bottom of the furnace, where they are burned under a grating, and serve to ignite the charge. No delay, or at most

only an inconsiderable one, takes place in the charring with the latter kind of furnace, and the product is satisfactory in relation to quality and yield.

Of this description are the kilns used at Crouy-sur-l'Ourcq, near Meaux, one of which is represented in Fig. 46. In this kiln the carbonization is effected in a cylinder, *a*, heated exteriorly by the flame and heat from the fires, *c c*, which circulate in the spiral flue, *b b*; *d d* is a chamber, encircling the walls of the flue, wherein air is

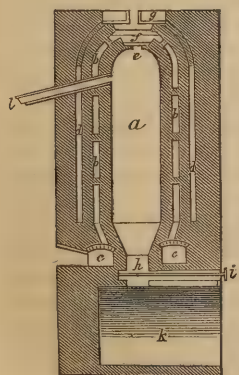
confined, with the view of retaining and equalizing the heat. The peat is introduced into the kiln by the aperture, *e*, at the top; this aperture is closed when

the charring is going on, by an iron plate, *f*; the products of the combustion going on in the fires, *c c*, issue by an opening, *g*, in the top, and those of the distillation of the charge by a pipe, *l*, connected with a condensing apparatus of the usual construction, and in which the liquid products are retained, the uncondensed gas being conveyed back to the fires, where by their combustion they serve, in part, to maintain the proper degree of heat. When the carbonization is completed, the charcoal is removed by the channel, *h*, by drawing the plate, *i*, which serves as the bottom of the kilns; it then falls into the chamber, where it is allowed to cool; from thirty-five to forty per cent. of charcoal is obtained, according to the density and state of dryness of the crude fuel. The cost of charring by this furnace is estimated at an average of four shillings per ton of charcoal.

Somewhat differing from the latter in construction, though worked upon the same principle, is the peat-charcoal furnace of East Friesland. It has a solid base sixteen feet long, thirteen wide, and two feet thick; upon this base an oblong furnace is erected, twelve feet long, five wide, and eight and a half high. The end walls of this construction are two feet thick, but the sides are only six inches; parallel with the side walls, and at a distance of eighteen inches, two others are built, each two feet thick, and the end ones are continued at both sides to meet them. By this arrangement a space is enclosed between the interior construction, or the retort, and the exterior wall, and this space serves for the fire channel, in which the products of combustion, from a fire lighted in a hearth, one foot high and eighteen inches wide, with grate and ashpit, made at one end of each of these chambers, circulate for the purpose of heating the retort. An arch or dome completely encloses the inner chamber destined to carbonize the peat; another similar arch is sprung from the outer walls, thus encasing the top of the retort as well as the sides. At the end where the fires are situated, a charging door, five feet high and three wide, is situated, and this, when the process of charring is going on, is kept tightly closed. The floor of the inner retort is hollowed in the middle along the whole length, and the channel thus formed walled by a glazed clay gutter, and covered over with perforated tiles, the whole slightly inclined towards one end. The tar and other fluids which accumulate here during the carbonization, are carried off by a pipe to a tank at a short distance from the retort, and the uncondensable gases conducted back by other pipes to the furnace, where they are burned. For the sake of economy, two or more of such furnaces are built close to each other, by which the time of charring is shortened, less heat being allowed to escape. Such a furnace is capable of producing one ton of charcoal at each operation, at an average expense of four to five shillings.

Another furnace employed in Bohemia is the following:—A circular excavation six feet deep and twenty in diameter, is made, and the base lined with brickwork nine inches deep. Upon this the walls of the furnace are constructed, so that when completed the whole forms a frustrum of a cone. For this end, the walls are five feet thick at the base, and tapering, till, at the height

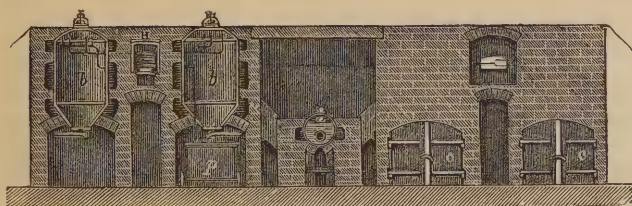
Fig. 46.



equal from seventeen to twenty-two shillings per ton. To prepare the peat, the patentee piles it, after being cut, upon wicker hurdles, one above another, and allows it to remain in this state till dry. The yield of charcoal is stated as from thirty-three to thirty-six per cent. —*Journal of Industrial Progress.*

VIGNOLES has taken out a patent for drying, compressing, and carbonizing peat, the latter being effected by means of steam heated to 450° or 460° Fahr., and the two former by a hydro-extractor, in which the centrifugal force expels the water, and renders the mass denser at the same time. With reference to the charring—the peat dried in the air, or by a current of heated gases forced through a chamber containing it, is thrown into cylindrical vessels, into which steam at a high temperature is forced, till the charring is effected. Fig. 49 shows a vertical section and partial elevation of the apparatus. In this, *a* represents a section of

Fig. 49.



the boiler employed for raising the steam; it is placed over a furnace, the flues of which, after passing under the boiler, branch off and circulate round the carbonizing cylinders, and finally enter the chimney. Two of the charring cylinders are shown at *bb*, of which there are six at each side of the boiler; they are ranged round a coil of piping, *h*, in which the steam from the boiler is heated to the required degree by a fire, previous to its passing into the cylinders where the peat is charred, by means of pipes connecting them. After the steam traverses one of these carbonizers, it escapes by a pipe, which conducts it over the furnace, to raise its temperature previous to its passage through the next carbonizer in the series. In this way, the steam being first heated is made to traverse a carbonizing vessel and the heating pipe successively, till it passes through the whole of the charring vessels. Ultimately, the waste steam is made to work a low-pressure engine, which turns a fan that forces air, heated by pipes placed in a furnace to 250°, into the drying chamber where the peat is desiccated.

The carbonizers, as may be inferred from the drawing, are conical towards the bottom, and are furnished with a valve or door which is rendered steam-tight, but may be opened when the charring is completed, so as to allow the charcoal to fall into a box, *p*, beneath it, and into which low pressure steam is passed for the purpose of cooling the charcoal. These boxes are constructed of iron, and are well covered, lest the charcoal might spontaneously ignite, to which it is liable, if exposed to air at this temperature; they move on tramways, and can be drawn out when required through the door-ways, *cc*. The top of the cylinder has a similar

opening secured by a screw; through this aperture the charge of peat is introduced.

Several other patents have, within the last few years, been secured by parties for economizing fuel, but to dwell further upon them would be out of place, as many of them come within the range of processes for the manufacture of artificial fuel, more than for preparing the peat alone in an improved state. That of Mr. P. M. CRANE, from its simplicity and its connection with the process already detailed, as pursued by the Irish Peat Company, will be briefly explained. The improvement to be noticed in this patent is the annexing of another furnace to that in which the combustion of the peat was effected in the above-mentioned Company's works. In this appended furnace, the peat is consumed by a blast of air in the ordinary way, and the torrefied gases are conducted by a flue to the second one, which is likewise filled with peat, and the heat thus communicated chars the matter.

In this way charcoal may be prepared without any loss of the products of distillation, as both furnaces may be closed down in the manner described in Fig. 41. The appended hearth or furnace may be modified, so as to enable the manufacturer to burn coal or coke, or even the waste gases formed in the distillation of the peat, turning the caloric and heated products which they yield to the use

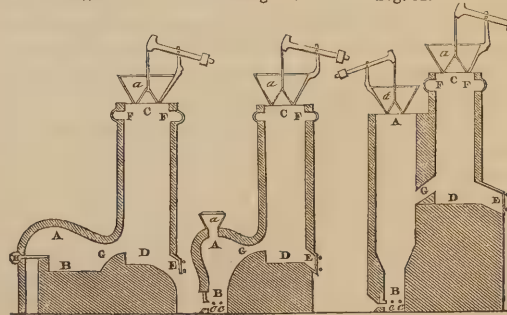
mentioned.

Fig. 52 is a sectional drawing of one of CRANE'S furnaces for preparing charcoal by the combustion of peat alone. In this drawing, *AB* is the furnace connected with another furnace or charring chamber, *CD*, by a flue, *G*. Both these are filled with peat, and closed down in the manner described at Vol. II., page 60. The furnace, *AB*, is lighted, and the blast of air thrown upon the ignited fuel through three tuyeres, *ccc*, at the bottom. The heated gases are forced over into the furnace, *CD*, and passing up through the peat, char it. All the products—as well those from the combustion as from the charring furnace—are carried

Fig. 50.

Fig. 51.

Fig. 52.



off by the exit pipes, *fff*, to the mains and condensers in the usual manner. When the peat in the charring furnace becomes carbonized, the charcoal is drawn out at *E*, into covered tanks, or cast-iron boxes, in which it is allowed to cool out of contact with air. According as the peat becomes consumed in the first, or the

charcoal is withdrawn from the second furnace, the space rendered vacant is filled by charging the hoppers, *a a'*, and letting this charge into the furnaces in the usual way. Figs. 50 and 51 show the construction of the furnaces intended to consume coal, or anthracite, and gas, for the purpose of generating heated products for distilling peat. Fig. 51, for coal, needs no explanation, as its operations are similar to the foregoing. When gas is employed, it is conducted to the hearth, *Δ B*, by the flue, *I*, Fig. 50, and, being ignited, a blast of air is introduced by pipes communicating with a blast-pipe, *H*. The pressure of this blast forces the heated products through the carbonizer, *C D*, producing the intended results.

Such are the methods in common use where the preparation of peat-charcoal has been industriously pursued, and some of them offer considerable advantages. Of the analyses of peat-charcoal little need be said here, as the analyses of peat already given will throw some light upon this part of the subject. As a generator of heat, good peat-charcoal is as efficient as bituminous coal; and some varieties are even above the average heating power of the latter kinds of fuel.

COAL.—This is by far the most valuable and extensively disseminated fuel, or source of heat, and is defined by REDFERN—*a compressed and chemically altered vegetal matter, associated with more or less earthy substances, and capable of being used as fuel.* This definition expresses all that is necessary; but its truth can only be established by the concurrence and aid of several branches of knowledge. For instance, *animal* matters may, by a process of decomposition, yield a mass of carbonaceous substances, which could not be distinguished from similar vegetal ones by the naked eye. In such cases, the microscope and chemical analysis lead to a certainty as to the nature of the originals; the former by revealing the texture of the fibrous matter of the plant, and the latter by the separation and estimation of those bodies into which it has been partly resolved. Before giving any detailed account of the process by which coal has been produced, it may be well to explain briefly the proofs which are cited in argument to show what coal is; and for much of what follows on this point, the Editor must acknowledge himself indebted to the treatise on *Fuel and its Applications*, by RICHARDSON and RONALDS.

Evidences of the origin and character of coal may be gathered from the geological position of the deposit, the mineral characteristics, the chemical nature, and the visual appearance of the substance under high magnifying power. It is the opinion of geologists that coal may be viewed as a stratified rock, in which layers of other geological formations—such as clays, sandstones, and limestones—are found. These, in themselves, form vast deposits, or strata; but, in this respect, there is no difference between them and the coal-beds, excepting in the nature of the substances. How the matter has become so stratified, is a question to be afterwards considered. The coal seams vary from a mere film, or a layer of less than a quarter of an inch in thickness, to three or four feet. It is not often, however, that the deposits are of the latter dimension. In mines, where the depth of the carbo-

naceous deposit averages from ten to twenty or thirty feet, seams of mineral matters interpose themselves at intervals, varying as to the distance between them, but rarely exceeding the limits above assigned. All coal-beds contain these foreign strata, or *partings*, to a greater or less extent; they seem to have been the result of the precipitation of matters held mechanically suspended in water. The thickness of these intervening deposits is found to vary considerably from a mere seam to a bed of several feet. In many cases the mineral matter, thus interstratified, has become so saturated with bodies emanating from the coal, or during its formation blending with the carbon, that it ignites and burns like coal, only that its bulk of earthy substances remains, often retaining the original form. Such matters are frequently observed in the burning of many varieties of coal, and in common language are called *slates*, *batts*, or *basses*. This blending of the two substances is often so unmistakable, that at a glance it may be ascertained whether the *shale*, as it is called, is argillaceous or calcareous; but when it is known that the coal-beds belong to the alluvial deposits, it will be evident that the intermixture of mineral and organic matters must have proceeded collaterally, even although the latter appears in such excess as completely to obliterate any traces of the former. In Great Britain, coal is principally in the carboniferous formations, occupying a posterior place in the series of stratified rocks; and where the same stratification of limestone rocks is met with in other countries, beds of coal are generally to be encountered. Still coal is not confined to this set of rocks; it is found in different parts of the strata, from the Devonian down to the most recent tertiary formations.

Mineralogical Characters.—Although here the subject under consideration is spoken of as a mineral, it ought to be remembered that, strictly speaking, it is not a pure one, but a mixture of various matters, of which carbon is the principal. It may, however, be regarded as organic matter *mineralized*; and, as it manifests some of the general properties of minerals, these will be noticed. The several known varieties of coal possess each some distinctive feature, differing from one another in hardness, fracture, *et cetera*. Several species break up into cubical and rhomboidal fragments; whilst others—such as the anthracite—are nearly devoid of crystalline structure. Generally, the fracture is conchoidal, uneven, fibrous, or slaty; in Boghead coal the fracture is conchoidal, perpendicular to the plane of stratification, but slaty when parallel. In color, it presents according to the variety every difference of hue, from jet-black to brownish-yellow; many kinds have a glossy brilliancy; others—such as the varieties of anthracites—a beautiful semi-metallic iridescent lustre; whilst some—such as the Wemyss, Methil, and other varieties of cannels—have a dull appearance. Coal exhibits great differences in point of hardness, although none of the varieties possesses it in an eminent degree. Anthracite has a specific hardness of two to two and a half. The gravity of several kinds of coal differs according to the texture and age; the lightest kinds have a density bordering on 1·00, whilst the heaviest range from 1·75 to 2·00.

Chemical Characteristics.—From what has been stated, it is evident that a chemical examination of coal would, in the simplest manner, lead to its division into inorganic and organic substances, and that these are contained in it in variable proportions: and, further, that each of these classes can be resolved into other substances, the most characteristic of coal being those generated by the vegetal portion. This arises from the large proportion of the elements always found in it—namely, carbon, hydrogen, and oxygen; and which, by the action of heat out of contact with air, are converted into numerous and peculiar substances.

Distillation in close vessels resolves coal into solids, liquids, and gaseous bodies, consisting of carbon or coke, tar, ammoniacal liquor, benzol, naphtha, naphthalin, paraffin, paraffin oil, and illuminating and other gases, in various quantities. By the detection of these, and the proportion in which some are contained in the substance, a good inference may be drawn as to whether the body be coal or otherwise: nevertheless, the evidence is not so conclusive as when the investigation is conducted microscopically.

Microscopic Characters.—By the use of the microscope, the most conclusive proof of the origin of the coal is attained. Dr. AITKEN of Glasgow has carefully investigated the structure of coal, and found that, even in the most altered specimens, traces remain sufficiently characteristic to prove that the material is of vegetal origin.

In the variety of bitumens, whether pure mineral tar, or asphaltum, no such structure is observable, and consequently, in the hands of a chemico-microscopist there is nothing to render the detection of real coal a matter of uncertainty.

Origin of Coal.—Such being the principal or more marked characters by which a substance submitted to examination may be affirmed to be *coal*, it will now be desirable to enter more fully upon the origin and nature of this product, in reference to its value as a fuel. Allusion has already been made to the analogy which exists between peat and coal, and the reader will have inferred that coal, like peat, has been produced by the decomposition of species of organic growth. All who have given attention to the composition of coal, and the geological position it occupies, concur in this view of the subject; and the Editor will now explain briefly the different opinions advanced as to the manner in which the change and disintegration of the vegetal products have been produced.

It may be said that the process which has operated to convert countless reproductions of plants into peat bogs, has been similar in the case of coals to some extent; but, geologically considered, it is evident that the oldest peat deposits are of modern formation, when compared to the most recent beds of coal. Of the vegetal origin of the latter, no doubt can be entertained, even if the microscope had not revealed the fact in the more compact varieties, since among other indications, even the trees have been found in their natural position converted into coal. The character, the variety, and the immense mass of vegetal matter thus converted, have led to the conclusion that the several species of plants whence coal has resulted were indigenous to a

southern or equatorial climate, as it is certain they could not flourish so luxuriantly in the existing temperature of northern latitudes. The varieties most commonly distinguished in the different strata are ferns, calamites, sigillariæ, stigmaria, and others; in fact, no less than three hundred distinct kinds have been detected.

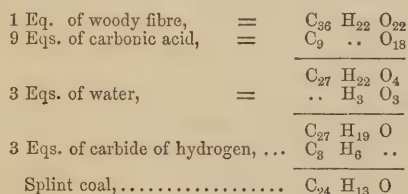
As to the manner, however, in which the strata of the coal deposits have been formed, there is much difference of opinion. Some geologists suppose that they were originally peat, the several successive layers being occasioned by successive subsidences of the land; whilst others assert that the various constituents were originally conveyed by currents to estuaries and deltas, where, being buried under the sand, mud, and debris brought down by the current, they were subsequently submitted to agencies which effected their carbonization. It is certain that the surface of the globe was at one time nearly submerged in an ocean, in which state it remained till, by the effects of volcanic eruptions, portions were uplifted, causing a corresponding depression in other places, and thus forming valleys, the forests and vegetation of which were buried under layers of loose earth and mud. At the same time, it would require many such forests to constitute a layer of the thickness of some of the coal seams, and these can scarcely be imagined to have been produced otherwise than by the drifting of vast accumulations of trees and plants into the basins in which coal is now found.

But leaving geologists to discuss and settle these questions, it is more in accordance with the plan of this work to attend to the chemical changes which have contributed to the conversion of the organic fibre into the carbonaceous matter in question. Whether the organic products on the surface of the earth were collected by changes in the relative position of the earth's solid crust, or by the force of violent currents, such as the large American rivers of the present day, it may be admitted and assumed as a fact that they were embedded with other matters saturated with moisture. The first natural change under such circumstances would be a fermentation of the albuminous matter and the gum, by which their molecular constitution would be broken up, and bodies of a simpler composition formed. The exclusion of the air after a short time would suppress the *eremacausis* or decay of the substance of the wood and fibrous matter, but the equilibrium of the affinities of the elements in the plants being broken, and considerable pressure being exerted, coupled with a certain rise of temperature, the change of elements arising from the new elective affinities would contribute to remove the hydrogen and oxygen to that extent which is observed in the composition of coal. The oxygen and hydrogen being most subject to the effect of this metamorphosis, these elements, leaving the carbon, would more readily assume their simplest and most permanent state of combination; but, as in the process of destructive distillation already alluded to, the conditions supplied are capable of inducing the water thus constituted to react upon a portion of the carbon, so in the coal formations, where the enormous pressure must have operated with an effect

in some degree equivalent to an increased temperature, the moisture and excess of hydrogen would convert the remaining substance into carbonic acid and carbides of hydrogen respectively. The actual facts, as determined in coal mines, seem to bear out this view.

From such considerations it will be readily concluded that the elementary composition of coals must be different from ligneous fibre; but following up the assumed alteration by a symbolical representation, the composition of coal offers very conclusive grounds to warrant the opinion that the former has resulted from the latter in the manner indicated. For instance, the composition of woody fibre may, as already stated, be represented by the equation $C_{36} H_{22} O_{22}$; and if, by the change above indicated, three equivalents of carbonic acid be extracted, represented by $C_3 O_6$, there results $C_{33} H_{22} O_{16}$; and if from this one equivalent of hydrogen be taken away, represented by H, there is left a formula— $C_{33} H_{21} O_{16}$ —corresponding with the composition of a variety of coal worked in Laubach.

In like manner the formula of splint coal may be deduced from the elements representing woody fibre, by supposing that the combined agency of heat and pressure removed nine equivalents of carbonic acid, three equivalents of water, and three of carbide of hydrogen, thus:—



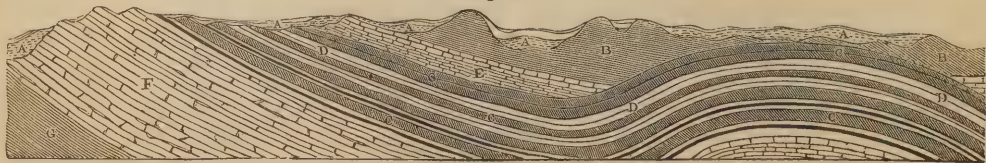
According to the degree of force exerted upon the decomposing substance, and the period of time in which this change was taking place, it is evident that the substances would be more or less removed from one another in composition. In the first example stated above, the formation bears every indication of recent production, when compared with the second; and this accounts for the close analogy between the two formulæ of wood and that species of coal. In other kinds, such as many of the anthracites, the alteration is much greater than even in the splint already referred to, and it is much more difficult to recognize the analogy between them and wood, for often all the oxygen and hydrogen are removed, so that nothing is left but carbon and the mineral matters intermixed with it.

Coal Measures.—The region of the coal formations is very extensive, and includes many strata, all of which are known as the *coal-measures*, or carboniferous group. Properly speaking the first of these is what is termed the *under-lay*; this is, a tough argillaceous substance, which, upon drying, turns grey and becomes friable. It retains considerable traces of carbonaceous matters. Two other strata beneath this are, however, included in the group; these are the mountain limestone, which varies very much in thickness, being sometimes nine hundred feet, and the old red sandstone upon which it rests; the latter stratum ranges from two hundred to two thousand feet in thickness. Next to the underlay in the ascending scale comes the seam of coal, or modified organic matter, varying from less than a quarter of an inch to several feet. Above these the upper layer or roof, as it is termed, rests. It is composed of slaty clay abounding in vegetal remains, as well as with crustaceæ, and several other matters. Interstratified with the latter are found various other substances, which seem to have been accumulations drifted by currents, such as laminated clay, grit, limestone, granite, sandstone, and other rocks.

All these deposits at one time, doubtless, formed regular horizontal layers, but through the effects of expansion in the depths of the earth, they have been distorted and thrown into undulated positions, and where the internal force has been very great, they have, by the upheaval of the subordinate strata, been formed into large valleys or basins. From the position of these layers, previous to such convulsions occurring, it is obvious that as the older deposits of mountain limestone, old red sandstone, *et cetera*, emerged in succession, so the more modern layers, including the carboniferous, would appear at the surface. This appearance is termed the cropping out of the strata, and serves to indicate the side of the basin. Considerable irregularity is occasioned by further subterranean disturbances which tend to alter the position of the strata subsequently to the first upheaval of the older formations. These generally render the deposits somewhat irregular in shape, so that they seldom form a true basin. In some localities, as in the Leicester and Warwickshire coal-field, none of the characters of a basin are observed; in the latter instance, the seams are surrounded on all sides by overlying deposits, under which they dip or incline to a considerable depth, and extend to an area unknown.

Fig. 53 represents this field in section, showing the alluvial deposits at A A; the new red sandstone, or marls,

Fig. 53.



at B B; the carboniferous shale and coal at C C, interlaid with carboniferous grit, or sandstones, D D; E, beds of magnesian; and F the stratum of mountain limestone, resting on the old red sandstone, G. Fig. 54 gives a

faint idea of the disturbances which are occasioned in the various beds by fissures filled with other materials. These veins are, in the language of the miner, called *dykes*, as they are the means of separating the strata

into compartments, which are designated *fields*. Besides this term, another is applied significant of the displace-

ment of the bands of coal from their original position—namely, *shifts*. Where these occur, the seam is

Fig. 54.



thrown out of its level, and, according as it is removed to a higher or lower one, the fault is called an *up-throw* or a *down-throw*. The displacement occurring at many of these shifts is considerable, and gives no small trouble to the miners. The largest known is that which runs through the Northumberland and Durham coal-field, and is termed the Ninety-fathom dyke, from the fact that the seams of coal are ninety fathoms lower at one side of the slip than at the other. Various matters fill these intersecting veins; hard and soft sandstone is contained in the one in question, which in some parts, especially at the Montague Colliery, attains a width of twenty-two yards. Two other dykes spring from this at the Southern side; one of which takes a South-eastern direction, and is about twenty yards in breadth; the other a South-western one, and attains a breadth of seventy yards. Both branches are filled with the same material as the primary one, but do not appear to have caused so great a disturbance at their point of intersection. These are represented in the foregoing drawing at F F, S S; but the others, although they partake of the nature of a dyke, are not recognised as such. For instance, those shown at D D' are of a different character, and are called *whin-dykes*, containing products of igneous origin, such as basalt, toadstone, *et cetera*; these do not always cause a removal of the strata from the ordinary level. Evidence of their eruption in a state of fusion exists in the fact, that the coal in their vicinity is more or less charred and converted into a true coke; besides, many substances of a fusible nature are acted upon, and indicate the powerful temperature which has pervaded the place, and which is often productive of great loss by consuming or changing the coal into anthracite, as shown at D' in the figure, where the basalt and other products accumulate. The *hitch* is another of those dykes, and is so called when its thickness is less than that of the

seams of coal which it intersects: this is represented at H H in the drawing. Smaller veins of foreign matters lying in any direction contrary to that of the strata are designated *faults* or *troubles*, from the annoyance the miners experience by the interruption of their work. Several of these are seen at T T; and although in working they cause much trouble, yet sometimes they contribute to render a field more valuable, since, by the depression which they occasion, seams of coal are brought in which might otherwise be lost. An example of this is given in the drawing referred to, where, by the down-throw of the strata between F F and T T, two seams of coal are brought in which would not otherwise be contained in it. Other interruptions or irregularities in the coal seams are designated *bands* and *nips*; the former, shown at B, are thin deposits or beds of grit or shale occurring in the middle of a seam of coal, and which, from being very thin, gradually acquire greater thickness, till ultimately they reduce the seam so much as to render it valueless; the second, shown at N, is a sudden local thinning of the seam, from an excrescence of the roof or floor.

The distribution of coal is very extensive; it is found in almost every country, although to a very unequal extent. The United States may be considered as the most highly favored in this respect, if the area of their coal deposits be taken into account, irrespective of the extent to which they are worked. It happens, however, that, from the abundance of wood, the home consumption of the article is limited, while the conveyance is costly, so that the benefits which result from valuable coal seams in other nations, remain to be developed in America. According to the statistical calculations of MITCHELL, the annexed table represents the amount and varieties of the mineral coal treasures in the United States:—

TABLE SHOWING THE AREA OF COAL IN THE UNITED STATES OF AMERICA.

	Area of the State. Square Miles.	Coal Areas. Square Miles.	Proportion of Coal.	Species.
1. Alabama,	50,875	3,400	1-14th	Bituminous coal.
2. Georgia,	58,200	150	1-386th	"
3. Tennessee,	44,720	4,300	1-10th	"
4. Kentucky,	39,015	13,500	1-3rd	"
5. Virginia,	64,000	21,195	1-3rd	"
6. Maryland,	10,829	550	1-20th	"
7. Ohio,	38,850	11,900	1-3rd	"
8. Indiana,	34,800	7,700	1-5th	"
9. Illinois,	59,130	44,000	3-4ths	"
10. Pennsylvania,	43,960	15,437	1-3rd	{ Bituminous and Anthracite.
11. Michigan,	60,520	5,000	1-12th	"
12. Missouri,	60,384	6,000	1-10th	"
	565,283	133,132	.... nearly 1-4th the area of the twelve States.	

It is certain that this vast tract of carboniferous deposit is not in its whole extent calculated to yield workable coal; still, making every allowance for those parts which, from their thinness or depth, cannot be profitably worked, it is evident that the area is sufficient to insure, for an almost indefinite period, a superabundant supply. Although within the last thirty years the coal trade of the United States has increased from an annual produce of three hundred and sixty-

five tons to five millions of tons, yet it must be evident at a glance that this enormous source of wealth is permitted to lie comparatively dormant at the present day. In British America the coal measures are not so extensive as in the States; it is doubtful, indeed, whether any workable seams exist in Canada, but fields of considerable area are known in New Brunswick and Nova Scotia, making about two-ninths of the whole area; and Newfoundland is said to be rich in this mineral.

TABLE OF THE PRINCIPAL COAL FIELDS IN THE BRITISH ISLES.

	Estimated workable area in acres.	Number of workable seams.	Estimated total thickness of workable coal in feet.	Thickest bed in feet.	Thickness of coal-bearing measures.
1. NORTHUMBERLAND AND DURHAM DISTRICT:—					
Newcastle coal field,.....	500,000	18	80	7	..
2. CUMBERLAND AND WESTMORELAND, AND WEST RIDING OF YORKSHIRE:—					
Whitehaven and Akerton,.....	80,000	7	..	8	2,000
Appleby—three basins,.....	17,000	..	..	..	..
Sebergham—Cumberland,.....	?	1	3	3	..
Kirkby-Lonsdale,.....	2,500	4	17	9	..
3. LANCASHIRE, FLINTSHIRE, AND NORTH STAFFORDSHIRE:—					
Lancashire coal field,.....	380,000	75	150	10	6,000
Flintshire,.....	120,000	5	39	9	200
Pottery—North Staffordshire,.....	40,000	24	38	10	..
Cheadle, do.,.....	10,000	..	..	..	..
4. YORKSHIRE, NOTTINGHAMSHIRE, AND DERBYSHIRE:—					
Great Yorkshire coal field,.....	650,000	12	32	10	..
Darley Moor, Derbyshire,.....	1,500	..	..	..	..
Shirley Moor, do.,.....					
5. SHROPSHIRE AND WORCESTERSHIRE:—					
Coalbrook Dale, Shropshire,.....	21,000	17	40	..	..
Shrewsbury, do.,.....	16,000	3	..	..	..
Brown Clec-hill, do.,.....	1,300	3	..	..	..
Tillerstone Clec-hill, do.,.....	5,000	..	..	..	..
Leekey-hill, Worcestershire,.....	650	?	..	..	..
Bewdley, do.,.....	45,000	?	..	..	..
6. SOUTH STAFFORDSHIRE:—					
Dudley and Wolverhampton,.....	65,000	11	67	40	1,000
7. WARWICKSHIRE AND LEICESTERSHIRE:—					
Nuneaton,.....	40,000	9	30	15	..
Ashby-de-la-Zouch,.....	40,000	5	33	21	..
8. SOMERSETSHIRE AND GLOUCESTERSHIRE:—					
Bristol,.....	130,000	50	90	..	..
Forest of Dean,.....	36,000	17	37	..	..
Newent, Gloucestershire,.....	1,500	4	15	7	..
9. SOUTH WELSH COAL FIELD,.....	600,000	30	100	9	12,000
10. SCOTTISH COAL FIELDS:—					
Clyde Valley,.....	1,000,000	84	200?	13	6,000
Lanarkshire,.....					
South of Scotland—several areas,.....					
Mid-Lothian,.....	?	24	94	..	4,400
East-Lothian,.....	?	60	180	13	6,000
Kilmarnock,.....	?	3	40	30	..
Ayrshire,.....					
Fifeshire,.....	?	?	?	21	..
Dumfries coal region,.....	45,000	10	55	6	..
11. IRISH COAL FIELDS:—					
Ulster,.....	500,000	9	40?	6	..
Connaught,.....	200,000	..	..	..	..
Leinster—Kilkenny,.....	150,000	8	23	..	..
Munster—several,.....	1,000,000	..	..	..	..

In the area of her coal deposits, Britain ranks next to the United States, and greatly exceeds the latter in the extent and value of her workable mines. The total extent of coal in England is estimated at about six thousand and thirty-nine square miles, or one-eighth of the whole area; in Scotland, one thousand seven hundred and twenty square miles, or one-eighteenth of the whole; and in Wales, one thousand one hundred and sixty square miles, or about one-sixth of its entire extent.

The principal deposit is that known as the great central coal-field, lying in South Yorkshire, Nottingham, and Derby; it is no less than sixty-five miles in length, and averages in some parts a breadth of twenty-five, making on the whole an area of about six hundred and fifty thousand acres. Next to this may be classed the Lancashire and Cheshire field, including the Wigan district; this deposit is about fifty miles in length, with an average breadth of ten miles, and is, therefore, no less than four

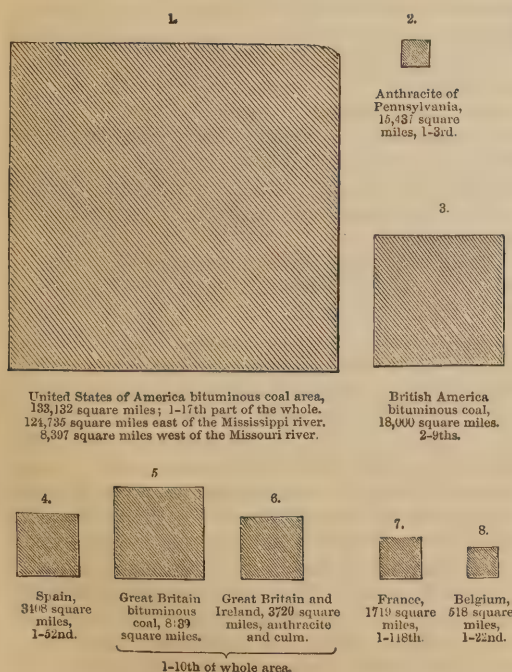
hundred thousand acres in area. Another field, which seems an extension of the latter, runs from its south-eastern extremity through Cheshire into Staffordshire, in which are the Cheadle, Macclesfield, and Pottery coal-fields. The third great deposit is that of Durham and Northumberland, which stands probably first in the list as to the quantity of fuel that is obtained from it. This vast deposit—called also the Newcastle coal-field—is estimated at thirty-six thousand acres situated in Durham, and about one hundred and fifty thousand acres in Northumberland. Of this extent about sixty-seven thousand acres are already worked. Estimating the content of this field at a thickness of twelve feet, each acre of four thousand eight hundred and forty square yards is supposed to yield a ton of coal per cubic yard, thus making the total weight of coals in this field about ten million tons, including the quantity destroyed and rendered unserviceable.

Besides the above, there are several other mines of secondary importance, from which a considerable quantity of coal is annually extracted. These, with their area, thickness, the number of workable seams, *et cetera*, are exhibited in the table in previous page, which is extended to embrace Great Britain and Ireland.

On the Continent the chief coal-producing countries are Spain, France, Belgium, and Prussia, although several others possess many valuable coal basins which hitherto have been little worked. The following diagram—Fig. 55—taken from TAYLOR'S work, gives a moderately comprehensive view of the comparative area of coal in the various countries that have been mentioned. It includes not only the workable seams, but the entire carboniferous area:—

DIAGRAM OF THE SUPERFICIAL COAL AREAS OF VARIOUS COUNTRIES.

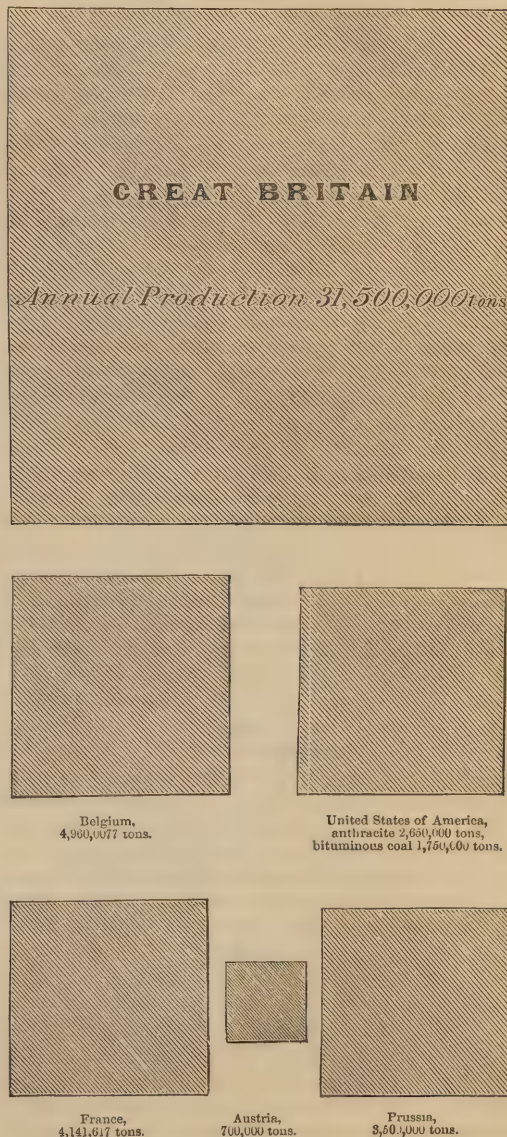
Fig. 55.



It is evident, however, that this diagram, with its numbers, does not exhibit the relative value of the coal-fields in the different countries. This must depend on many circumstances, apart from the mere consideration of superficial extent; but their productiveness at the present day is shown in the next diagram—Fig. 56.

DIAGRAM OF THE RELATIVE AMOUNTS OF PRODUCTION OF MINERAL COMBUSTIBLES IN THE SIX PRINCIPAL COAL-PRODUCING COUNTRIES OF THE WORLD, IN THE YEAR 1845.

Fig. 56.



A summary of the whole, exhibiting at one view the extent of coal area, the quantity raised in 1845, with its relative proportion to the area, and, finally, the official estimated value of the places of production, is added in the annexed table:—

Countries	Square miles of coal formation.	Tons of fuel raised in 1845.	Relative parts of 1000.	Official estimated value of the places of production.
Great Britain, . . .	11,859	31,500,000	642	9,450,000
Belgium,	518	4,960,077	101	1,660,000
United States, . . .	133,132	4,400,000	89	1,373,000
France,	1,719	4,141,617	84	1,603,106
Prussian States, . .	not	3,500,000	70	856,370
Austrian States, . .	defined.	659,340	14	165,290
Total,		49,161,034	1000	15,108,729

It may be added, as the result of recent researches, that Asia and even Africa have been found to be very well stocked with fossil fuel; and, indeed, there can be little doubt that the East Indies and China will yet become coal-producing countries. The same may be said of Australia, and other British colonies.

DIFFERENT KINDS OF COAL.—From the acknowledged transformation which the substance of the coal has undergone, and from its progressive nature, it is natural to expect that the material so produced should have very different properties, according to its more or less advanced state of decomposition. Such is really the case, and various species of coal exist differing by slight and regular gradations from the most recent lignite or brown coal, in which the outline of the wood may be easily traced, up to the most perfect anthracite, in which every vestige of the original is lost, and nothing remains but a conglomerated charcoal. Many of them, indeed, have so close a resemblance to one another, and pass so imperceptibly from one stage to the other, that it is almost impossible to mark the distinction between them. Several species, however, may be classified on broader data, grounded partly upon age, partly on their physical appearance, and partly on their composition. It is by these criteria that the classification of the fossil into brown and black coal, or into the bituminous and non-bituminous varieties, is effected. Several members are contained in each of these groups, but many kinds blend with each other in such a manner that it is difficult to draw a line of demarcation between them. Classifying the chief varieties according to their supposed age, the whole of the coal measures may be included under three heads; namely, the younger coal of the *tertiary* deposits, the older bituminous kind of the secondary formations, and the anthracites of the older transition series of rocks.

Lignite.—The coal of the tertiary formation, which includes several varieties, has been designated *brown coal* or *lignite*, from its characteristic appearance. This species, termed also bituminous wood, is the most interesting, as clearly exhibiting the ligneous structure of the matter from which it derives its name, in such perfection as to furnish sufficient data for instituting a diagnosis of the plants of very remote eras. It has a brown color; but this varies with the depth of the bed. The Bovey coal of Devonshire is a member of this class; it presents a distinct woody structure, and very rarely a conchoidal fracture; it is devoid of lustre, is brittle, and burns readily, leaving a white ash. Some others, however, such as the more compact kinds, exhibit a more or less conchoidal fracture and slightly resinous lustre. In the latter case, the color is brownish-black; it has been

called earthy-brown coal, to distinguish it from another kind of the same species, designated *pitch-coal*, the structure of which is more dense, as shown by its distinct conchoidal appearance when broken. Between these extremes may be found the *brown earthy coal*, so named from its argillaceous fracture, crumbling into loose friable particles; and *moor coal*, in which the structure of the plants is obliterated, and which exhibits in its fracture more or less lustre.

The species of coal embracing these varieties is encountered in several of the formations on the Continent; at Bovey Tracey in Devonshire, near Lancaster, and at Lough Neagh in Ireland, where it constitutes three beds, averaging in some parts a thickness of sixty feet. It is very inferior as a fuel to the other varieties of coal which will be presently described. As dug from the mine it is more or less impregnated with moisture, which it persistently retains, and which, even if entirely expelled, is reabsorbed with great avidity. Thus REINSCH determined in a sample of wood coal from the Upper Pfalz, in Bavaria, forty-three per cent. of moisture, and in an earthy-brown coal, thirty. VARENTRAPPE found no less than forty-eight per cent. of moisture in fresh lignite from Helmstadt, and further ascertained that, after thorough desiccation and re-exposure to air, about eight per cent. of water was again absorbed. By stacking this coal for some time, much of the water evaporates, so that the moisture averages about thirty per cent.; but if the exposure be made in summer, the quantity is lessened to twenty per cent., the bulk of the coal undergoing a corresponding reduction.

Distinct from the foregoing in physical appearance, though to some degree analogous in chemical composition, are those non-compact bodies, termed bituminous coal, in which the structure of the plants is entirely effaced, and the color and appearance are indicative of a pretty advanced stage of decomposition. Of this kind there are several varieties, distinguished by characteristic properties. When treated with ether they all yield more or less bitumen, and hence the general designation, *bituminous*, to distinguish them from the anthracites proper, which afford none of that substance. The following most marked varieties of this description are *caking coal*, *splint coal*, *cherry coal*, and *cannel* or *parrot coal*.

Caking coal is a moderately compact fuel; its fracture is uneven, and its lustre varies from a resinous to a velvety or greyish-black appearance. When heated, it breaks into small pieces, if the amount of bitumen be not more than the average, but afterwards the fragments agglomerate, and form a hard compact body; when the per centage of bitumen is high, it fuses at once into a pasty mass, and during the application of the heat bubbles of gaseous matter escape, leaving ultimately a carbonaceous substance, in which all traces of the original are effaced. Ignited in air, it burns with a yellowish flame, which is intermittent, unless the fuel be kept repeatedly stirred, so as to prevent its caking. The latter tendency renders this coal unsuitable for many operations where great heat is required, as the draught is impeded by its caking properties. It is, however, a valuable fuel, especially

as it is very often possessed of qualities which render it applicable for the manufacture of gas and coke, the latter being most eligible as a heating agent where the coal itself cannot be employed.

Caking coal is very general, being met with in almost all the coal-fields of Great Britain, but more especially in the Newcastle and Wigan districts.

Splint or Hard Coal.—This variety occurs most abundantly in the Glasgow coal deposits, where, for general application, it is highly prized. Its color is black or brownish-black, and its lustre resinous and glistening. When broken, the principal fracture appears imperfect and slaty, but the transverse one shows it to be fine-grained, uneven, and splintery; hence, as well as from its hardness, the term *splint*. It kindles with greater difficulty than the preceding variety, but when once ignition has taken place, it produces a fine clear fire, and throws out much heat.

Cherry or Soft Coal.—The similarity in physical appearance between this and the caking coal is very great, though for the most part the lustre of cherry coal is much more splendid, and hence the name given it by the miners. It differs from caking coal in not undergoing fusion when heated. Owing to its great brittleness, it is not economical in the working. It readily ignites, and makes a lively fire, yielding a clear yellow flame, but is consumed rapidly. This species is likewise met with in the upper strata of the Glasgow beds, as also in Staffordshire, in the Lancashire district, *et cetera*.

Cannel, Candle, or Parrot Coal.—This variety has a very compact and even texture; a shining resinous lustre, and a color varying between a jet and a greyish or brownish black. The lustre of cannel coal is sometimes not so very distinct as that of *pitch coal*, which is a species of the caking kind; its compact texture and gravity are sufficiently characteristic to distinguish it from the other sorts. The fracture of cannel is flat, conchoidal in every direction, and sometimes slaty. It takes a good polish, and on this account is manufactured into numerous articles, such as inkstands, snuff-boxes, beads, *et cetera*.

Cannel is found in several coal basins, but most abundantly in the Wigan district, at Lesmahagow, near Glasgow, and at Coventry. It is so named from its property of burning and yielding a bright flame like a candle. The other name, *parrot coal*, which is of Scottish origin, is derived from its decrepitation when thrown on the fire, owing to pieces of the coal flying off when heated.

Many other local appellations are given to the coal even from the same field, if it includes many seams, but these are of little interest to the consumer.

Anthracite.—In speaking of the origin of coal, allusion has been made to this variety as being the oldest, and, consequently, the furthest removed from its vegetal source in composition and physical characters. This fossil, which is sometimes known as *glance* or *stone coal*, is a hard compact substance possessing much lustre, often iridescent; the more perfect variety is entirely free from bituminous matter, and hence it constitutes a class of the coal formation in itself. These characters are not observed in all the anthracites, which

generally retain more or less bituminous coal interstratified or otherwise mixed with portions reduced to the state of true anthracite. The mixed varieties, or semi-anthracites, admit of being employed as a substitute for caking coals in many cases where a true anthracite would not answer the purpose.

This is the densest of all the coals known, excepting such as are very earthy or otherwise mineralized. It contains, when a true anthracite, only carbon, water, and inorganic salts, but generally more or less hydrogen and oxygen, besides the proportion of the latter elements in the form of water. Anthracite is ignited with great difficulty, and being dense, and having a tendency to break up into fragments when heated, in consequence of the expulsion of the water contained in it, it is not calculated to produce a strong fire in the ordinary grate or furnace, although, when once thoroughly ignited, its calorific power is very great. By a suitable modification of the grate or furnace, and proper management, it may in numerous instances—not the least of which is its application to smelting—be employed with advantage.

Anthracite is found most extensively in America, where it constitutes immense deposits. In England, it is chiefly worked in the South Wales coal-field, although it may be met with in large quantities in other basins. The total area of this description of fuel in Great Britain and Ireland is about three thousand seven hundred and twenty acres.

CHEMICAL COMPOSITION OF COAL.—The localities and general characteristics of the principal varieties of coal having been noticed, the Editor will proceed to a more minute examination of its composition. It has been already laid down as a general principle, that the value of a fuel is proportional to the amount of carbon which it contains. Like other rules, however, this admits of exceptions, and, for some purposes, the coal is valued according to its per centage of hydrogen. This is especially the case with coal intended for gas manufacture, and also when employed as a fuel in such arts as require the heat to exert its power at some distance from the fire. Moreover, other ingredients may be contained in the coal in proportions very insignificant when compared with the carbon and other inflammable portion, but still so injurious in their effects as to render the fuel unadapted for many purposes to which it might otherwise be applied with good results. Among these are found sulphur, arsenical and other kinds of pyrites; and similar prejudicial effects are produced by the presence of considerable portions of sulphates, or, in fact, of any mineral matters which undergo no change during the combustion. The pyritous ingredients are, however, the most deleterious, as during combustion they evolve sulphurous acid, and if arsenic be contained in the coal—which is fortunately a rare occurrence—arsenious acid will be eliminated. Now, both the sulphurous and arsenious acids are highly obnoxious and dangerous, and ought to be avoided as much as possible. From all these considerations, it is evident that, to determine the quality of any species of coal, with a view to ascertain its fitness for a given purpose, nothing short of a knowledge of its ultimate composition can be relied on; and

Description of coal.	Locality.	Specific gravity.	Per centage of ash.	Observers.
Coal Measures,	Blanz—dry coal, long flame,	1.362	2.28	Regnault.
	Rive de Gier, Grand Croix,	1.298	1.78	
	“ “ “ “ { fat and } “ “ “ “ { hard coal }	1.302	1.44	
Secondary Formation,	Anthracite, Lamure, Dep. de l'Isère,	1.362	4.57	
	“ Macot,	1.919	26.47	
	Common coal, Obernkirchen Lippe-Sch.	1.279	1.00	
	Ceral, Dep. Aveyron,	1.294	11.86	
	Noroy Vogesen,	1.410	19.20	
	St. Girons,	1.316	4.08	
	Belestet,	1.305	0.89	
	Czernitz, Upper Silesia,	1.362	5.80	
	Gnade Gattes, Lower Silesia,	1.285	4.65	
	Glück hülf,	1.276	0.80	
	Sulzbach, Duttweiler Saarbrücken,	1.258	0.15	
	Wettin, Saalkreis,	1.466	24.40	
	Sälzer and Neuack, Westphalia,	1.288	0.70	Karsten.
	Pottschappel, Saxony,	1.454	27.7	
	Königen Louise, Upper Silesia,	1.280	0.2	
	Königsgrubbs,	1.285	0.6	
	Merchweiler Saarbrücken,	1.282	0.9	
	Freschanf, Lower Silesia,	1.518	23.4	Lampadius.
	Brazils,	1.483	28.4	
	Coarse coal, mixed with pitch coal,	1.48	20.9	
	Slate coal,	1.24	22.7	
	“ “ with fibre coal,	1.20	26.3	
	Anthracite,	1.37	22.5	
	Slate coal, with a little fibre coal,	1.25	20.2	
	Hard slate coal, with layers of pitch coal,	1.42	24.0	
	Slate coal, with predominating layers of anthracite and fibre coal,	1.35	23.4	

From this table it may be seen that the specific gravity of coal ranges from 1.2 to 1.5, rarely exceeding the latter; and further, by rejecting those samples which yield very large per centages of ash, the mean gravity will be about 1.30. It will also be observed, that the relation existing between the mineral constituents of the coal and the density is quite irregular, and, consequently, offers no trustworthy grounds for inferring the per centage of ash which a coal may contain merely by determining the density, or inversely. It is true, however, that in numerous instances, samples with a larger proportion of ash will be found to have a higher density than those which contain less inorganic matter. This is more especially the case with different samples of coal from the same mine, which led JOHNSON to infer that the specific gravity and mineral constituents of the coal from the same bed have a constant relation to one another. The basis on which he erected this theory, is found in the following results of the analyses of four samples of coal from Beaver Creek, Lucerne County:—

No.	Specific gravity.	Per centage of ash.
1,	1.560	1.28
2,	1.594	4.00
3,	1.613	5.01
4,	1.630	5.063

The same increase was observed with four other

samples from the coal field of Maryland, bordering on Pennsylvania, thus:—

Mean specific gravity of two specimens.	Mean per centage of earthy matters in two specimens.
1.320	7.52
1.350	9.58
1.365	10.35
1.385	11.75
1.485	14.41

Admitting that a high density is to some extent an indication of the presence of mineral matters in greater abundance, yet it is impossible, even approximately, to estimate the per centage of these by this test, since no fixed and constant relation can be established between the two. Besides, it is well known that a great difference in the amount of mineral matters is sometimes detected in coal from the same working.

The nature of the inorganic matters in coal affects, in a great degree, not only the gravity of the substance, but its quality as a fuel, although the components found are generally the same in all. From the tables already given, it will be seen that the total quantity of ashes fluctuates between one and twenty-five per cent., the average being about ten per cent. or under. The following table of the analyses of the ashes of coal by PHILLIPS, shows the nature and extent of the components, which, strange to say, contain no alkalis:—

	NAME.	Silica.	Alumina and oxide of iron.	Lime.	Magnesia.	Sulphuric acid.	Phosphoric acid.	Total per centage.	Per centage of ash in coals.	Per centage of coke in coals.
Welsh.	Pontypool,	40.00	44.78	12.00	trace.	2.22	0.75	99.75	5.52	64.8
	Bedwas,	26.87	56.95	5.10	1.19	7.23	0.74	98.08	6.94	71.7
	Porthmawr,	34.21	52.00	6.199	0.659	4.12	6.633	97.821	2.91	63.1
	Ebbw Vale,	53.00	35.01	3.94	2.20	4.89	0.88	99.92	14.72	77.5
	Coleshill,	59.27	29.09	6.02	1.35	3.84	0.40	99.97	10.70	—
Scotch.	Fordell,	37.60	52.00	3.73	1.10	4.14	0.88	99.45	1.50	52.03
	Splint,									
	Wallsend,									
	Elgin,	61.66	24.42	2.62	1.73	8.38	1.18	99.99	4.0	58.45

The annexed table exhibits the composition of American coals according to Professor JOHNSTON:—

Character and Composition of the Ashes.	Sugarloaf Company's Anthracite, 1st speci- men, specific gra- vity 1.391.	Sugarloaf Anthracite, 2d specimen, specific gra- vity 1.374.	Sugarloaf Anthracite, 3d specimen, specific gra- vity 1.36.	Buck Mountain Anthra- cite, specific gravity 1.369.	Summit Coal Company's Anthracite, head of Beaver Creek, 1st speci- men, specific gravity 1.313.	Summit Company's An- thracite, 2d speci- men, specific gravity 1.344.	Stephenson's Bluff An- thracite, Beaver Creek, specific gravity 1.312.	Shom-vein Anthracite, Pottsville, specific gra- vity 1.539.	Quin's Run Bituminous Coal, specific gravity 1.372.
Per centage of ashes in the coals,....	4.83	8.73	2.242	3.079	5.01	4.00	3.71	6.75	6.80
Color of ashes,.....	Light- buff.	Reddish- white.	White.	Reddish- buff.	Fawn.	Reddish- grey.	Fawn.	Brick- red.	Grey.
Silica,.....	53.603	45.105	43.68	45.60	54.50	50.25	50.05	50.00	76.00
Alumina,.....	36.687	37.000	39.34	42.75	34.45	38.90	39.04	38.90	21.00
Sesquioxide of iron,.....	5.590	13.000	8.22	9.43	7.50	8.75	8.75	8.00	2.60
Lime,.....	2.857	1.380	5.76	1.41	2.25	0.85	1.56	2.10	..
Magnesia,.....	1.076	2.430	3.00	0.33	1.30	1.25	1.30	0.90	..
Oxide of manganese,.....	0.186	..	..	..	..	..	..	..	..
Loss per cent.,.....	0.001	1.085	..	0.48	..	..	..	0.10	0.40
	100.000	100.000	100.00	100.00	100.00	100.00	100.00	100.00	100.00

The same elements are contained in the ashes of brown coal, though in different proportions, as will be seen from the subjoined analysis by VARRENTAPP:—

Analyses of ashes of brown coal from Brunswick, repre- sented centesimally.	
Lime,.....	23.67
Magnesia,.....	2.58
Alumina,.....	11.57
Oxide of iron,.....	5.78
Carbonate of potassa,.....	2.64
Silica and clay,.....	19.27
Sulphuric acid,.....	33.83
Loss,.....	0.66
	100.00

Lead, copper, iron pyrites, and traces of iodine, *et cetera*, are also found in coal, but are by no means general. In fact, the traces of lead and copper are sometimes so minute as not to admit of estimation; but this is not the case with the iron pyrites. In some varieties this compound may be readily distinguished in clusters of cubic crystals, or in seams running through the mass; and, from its characteristic yellow appearance, the coals in which it is thus found are named *brassy coals*. It operates more injuriously than any of the other mineral compounds, as, during the combustion, the sulphur is transformed into sulphurous acid, which in itself is poisonous; and although it passes off considerably diluted by the other gases produced, yet it is hurtful, not only to animal life, but to many manufacturing processes, as well as to the boilers and furnaces of locomotives. When sulphurous coals are distilled, one-half or a certain portion of the sulphur is eliminated in the form of sulphide of hydrogen and sulphide of carbon, whilst the remainder is left united with the metallic base in the coke. In both cases it is the cause of much trouble and injury, as every gas manufacturer and smelter well knows. But these are not the only evils resulting from the iron pyrites. When coals containing it in large quantities are stored, and are affected with moisture, it not unfrequently happens that spontaneous ignition sets in, in consequence of the bisulphide being converted by

its oxidation into sulphate of iron, and generating at the same time as much caloric as determines the combustion of the carbonaceous matter, which ultimately may reach to a red heat. To guard against this danger, it is well to expose the heap as much as possible to a current of air, in order that the moisture may spontaneously pass off, and the entire mass be kept cool; or, if incipient combustion has already set in, it may be arrested by loosening and turning over the heap, so that the air may pass through it freely. This spontaneous combustion is more apt to take place in mines than in the coals even when stored, unless, indeed, they are accumulated in confined places where the temperature is somewhat elevated. Under such circumstances, aided by the presence of moisture, the coals are very liable to burn voluntarily. Although the combustion which has been going on in some mines for considerable periods, cannot be attributed to the oxidation of the pyrites, but rather to the large volumes of inflammable gases which are generated in crevices in the mass, and which are accidentally ignited, yet it cannot be doubted that, through the combined action of water and a limited supply of air, the mineral assists in developing the heat throughout. When a mine takes fire, it resists every effort to extinguish it, unless the whole working be so regulated as to admit of being flooded with water. This, however, is rarely the case, nor is it ever thought of as a provision for such an emergency; and yet it is the only effective precaution that can be adopted, for the numerous fissures in the coal, which often extend to the surface, serve the purpose of powerful chimneys, whilst other chinks co-operate with the shafts, in conveying air to the seat of the fire. Every exertion has been made to check the combustion going on in some of the British mines by the erection of dams; but, although it is believed that in some of them the rate of consumption is much reduced, it still continues.

Although the specific gravity of coals and the per centage of ash which they contain are very insufficient tests of their value as fuel, yet it is evidently important to know the amount of the combustible constituents

in different kinds. Fortunately, numerous analyses of coals have been made; and the Editor feels assured that a summary and compendious view of the most important of these cannot fail to be deeply interesting to all who are concerned in those arts and manufactures in which fuel is an object of primary considera-

tion, as well as to the scientific analyst. Accordingly, the following tables exhibit the results so elaborately worked out for the Admiralty by Dr. LYON PLAYFAIR, and others, in their examination of nearly all the products of the British coal mines:—

MEAN COMPOSITION OF AVERAGE SAMPLES OF WELSH COALS.

Locality, or Name of Coal.	Specific Gravity of Coals.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Percentage of Coke left by each Coal.
	A.	B.	C.	D.	E.	F.	G.	H.
Aberaman Merthyr,	1·305	90·94	4·28	1·21	1·18	0·94	1·45	85·0
Ebbw Vale,	1·275	89·78	5·15	2·16	1·02	0·39	1·50	77·5
Thomas's Merthyr,	1·30	90·12	4·33	1·00	0·85	2·02	1·68	86·53
Duffryn,	1·326	88·26	4·66	1·45	1·77	0·60	3·26	84·3
Nixon's Merthyr,	1·31	90·27	4·12	0·63	1·20	2·53	1·25	79·11
Binea,	1·304	88·66	4·63	1·43	0·33	1·03	3·96	88·10
Bedwas,	1·32	80·61	6·01	1·44	3·50	1·50	6·94	71·7
Hill's Plymouth Work,	1·35	88·49	4·00	0·46	0·84	3·82	2·39	82·25
Aberdare Co.'s Merthyr,	1·31	88·28	4·24	1·66	0·91	1·65	3·26	85·83
Gadly Nine-feet Seam,	1·33	86·18	4·31	1·09	0·87	2·21	5·34	86·54
Resolven,	1·32	79·33	4·75	1·38	5·07	included in ash.	9·41	83·9
Mynydd Newydd,	1·31	84·71	5·76	1·56	1·21	3·52	3·24	74·8
Abercarn,	1·334	81·26	6·31	0·77	1·86	9·76	2·04	68·4
Anthracite, Jones and Co.,	1·375	91·44	3·46	0·21	0·79	2·58	1·52	92·9
Ward's Fiery Vein,	1·344	87·87	3·93	2·02	0·83	included in ash.	7·04	—
Neath Abbey,	1·31	89·04	5·05	1·07	1·60	—	3·55	61·42
Graigola,	1·30	84·87	3·84	0·41	0·45	7·19	3·24	85·5
Gadly Four-feet Seam,	1·32	88·56	4·79	0·88	1·21	—	4·88	88·23
Machen Rock Vein,	1·297	71·08	4·88	0·95	1·37	17·87	3·85	65·2
Birch Grove, Graigola,	1·360	84·25	4·15	0·73	0·86	5·58	4·43	85·1
Llynvi,	1·28	87·18	5·06	0·86	1·33	2·53	3·04	72·94
Cadoxton,	1·378	87·71	4·34	1·05	1·75	1·58	3·57	82·0
Oldcastle Fiery Vein,	1·289	87·68	4·89	1·31	0·09	3·39	2·64	79·8
Vivian and Sons' Merthyr,	1·299	82·75	5·31	1·04	0·95	4·64	5·31	67·1
Llangennech,	1·312	85·46	4·20	1·07	0·29	2·44	6·54	83·69
Three-quarter Rock Vein,	1·34	75·15	4·93	1·07	2·85	5·04	10·96	62·5
Pentreporth,	1·31	88·72	4·50	0·18	—	3·24	3·36	82·5
Cwm Frood Rock Vein,	1·255	82·25	5·84	1·11	1·22	3·58	6·00	68·8
Cwm Nanty Gros,	1·28	78·36	5·59	1·86	3·01	5·58	5·60	65·6
Brymbo Main,	1·300	77·87	5·09	0·57	2·73	9·82	4·22	55·4
Tivian and Sons' Rock Vawr,	1·301	79·09	5·20	0·66	2·41	8·34	4·30	58·6
Coleshill,	1·29	73·84	5·14	1·47	2·34	8·29	8·92	56·0
Brymbo Two-yard,	1·283	78·13	5·53	0·54	1·88	8·02	5·90	56·2
Rock Vawr,	1·29	77·98	4·39	0·57	0·96	8·55	7·55	62·50
Porth-mawr,	1·39	74·70	4·79	1·28	0·91	3·60	14·72	63·1
Pontypool,	1·32	80·70	5·66	1·35	2·39	4·38	5·52	64·8
Pentrefelin,	1·358	85·52	3·72	trace	0·12	4·55	6·09	85·0

MEAN COMPOSITION OF AVERAGE SAMPLES OF NEWCASTLE COALS.

Locality, or Name of Coal.	Specific Gravity of Coals.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Percentage of Coke left by each Coal.
	A.	B.	C.	D.	E.	F.	G.	H.
Willington,	—	86·81	4·96	1·05	0·88	5·22	1·08	72·19
Andrew's House, Tanfield,	1·26	85·58	5·31	1·26	1·32	4·39	2·14	65·13
Bowden Close,	—	84·92	4·53	0·96	0·65	6·66	2·28	69·69
Haswell Wallsend,	1·286	83·47	6·68	1·42	0·06	8·17	0·20	62·70
Newcastle Hartley,	1·29	81·81	5·50	1·28	1·69	2·58	7·14	64·61
Hedley's Hartley,	1·31	80·26	5·28	1·16	1·78	2·40	9·12	72·31
Bates' West Hartley,	1·25	80·61	5·26	1·52	1·85	6·51	4·25	—
West Hartley Main,	1·264	81·85	5·29	1·69	1·13	7·53	2·51	59·20
Buddle's West Hartley,	1·23	80·75	5·04	1·46	1·04	7·86	3·85	—
Hastings' Hartley,	1·25	82·24	5·42	1·61	1·35	6·44	2·94	35·60
Carr's Hartley,	1·25	79·83	5·11	1·17	0·82	7·86	5·21	60·63
Davison's West Hartley,	1·25	83·26	5·31	1·72	1·38	2·50	5·84	59·49
North Percy Hartley,	1·25	80·03	5·08	0·98	0·78	9·91	3·22	57·18
Haswell Coal Co.'s Steamboat Wallsend,	1·27	83·71	5·30	1·06	1·21	2·79	5·93	61·38
Derwentwater Hartley,	1·26	78·01	4·74	1·84	1·37	10·31	3·73	54·83
Broomhill,	1·25	81·70	6·17	1·84	2·85	4·37	3·07	59·20
Original Hartley,	1·25	81·18	5·56	0·72	1·44	8·03	3·07	58·22
Cowpen & Sidney's Hartley,	1·26	82·20	5·10	1·69	0·71	7·97	2·33	58·59

MEAN COMPOSITION OF AVERAGE SAMPLES OF DERBYSHIRE COALS.

Locality, or Name of Coal.	Specific Gravity of Coals.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Percentage of Coke left by each Coal.
	A.	B.	C.	D.	E.	F.	G.	H.
Earl Fitzwilliam's Elsecar,.....	1.296	81.93	4.85	1.27	0.91	8.58	2.46	61.6
Holyland and Co.'s Elsecar,.....	1.317	80.05	4.93	1.24	1.06	8.99	3.73	62.5
Earl Fitzwilliam's Park Gate,.....	1.311	80.07	4.92	2.15	1.11	9.95	1.80	61.7
Butterly Co.'s Portland,.....	1.301	80.41	4.65	1.59	0.86	11.26	1.23	60.9
Butterly Co.'s Langley,.....	1.264	77.97	5.58	0.80	1.14	9.86	4.65	54.9
Stavelly,.....	1.27	79.85	4.84	1.23	0.72	10.96	2.40	57.86
Loscoe Soft,.....	1.285	77.49	4.86	1.64	1.30	12.41	2.30	52.8

MEAN COMPOSITION OF AVERAGE SAMPLES OF LANCASHIRE COALS.

Locality, or Name of Coal.	Specific Gravity of Coals.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Percentage of Coke left by each Coal.
	A.	B.	C.	D.	E.	F.	G.	H.
Inch Hall Co.'s Arley,.....	1.272	82.61	5.86	1.76	0.80	7.44	1.53	64.0
Haydock Little Delf,.....	1.257	79.71	5.16	0.54	0.52	10.65	3.42	58.1
Balcarres Arley,.....	1.26	83.54	5.24	0.98	1.05	5.87	3.32	62.89
Blackley Hurst,.....	1.26	82.01	5.55	1.68	1.43	5.28	4.05	57.84
Ince Hall, Pemberton Yard,.....	1.348	80.78	6.23	1.30	1.82	7.53	2.34	60.6
Haydock, Rushy Park,.....	1.323	77.65	5.53	0.50	1.73	10.91	3.68	59.4
Moss Hall, Pemberton, Four-feet,.....	1.258	75.53	4.82	2.05	3.04	7.98	6.58	55.7
Haydock Higher, Florida,.....	1.218	77.33	5.56	1.01	1.03	12.02	3.05	51.1
Ince Hall, Pemberton, Four-feet,.....	1.276	77.01	3.93	1.40	1.05	5.52	1.09	57.1
Blackbrook Little Delf,.....	1.26	82.70	5.55	1.48	1.07	4.89	4.31	58.48
King,.....	1.300	73.66	5.30	1.68	1.58	9.06	8.72	62.4
Rushy Park Mine,.....	1.28	77.76	5.23	1.32	1.01	8.99	5.69	56.66
Blackbrook, Rushy Park,.....	1.27	81.16	5.99	1.35	1.62	7.20	2.68	58.10
Johnson and Wirthington's, Rushy Park,.....	1.28	79.50	5.15	1.21	2.71	9.24	2.19	57.52
Laffak, Rushy Park,.....	1.35	80.47	5.72	1.27	1.39	8.33	2.82	56.26
Balcarres, Haigh Yard,.....	1.28	82.26	5.47	1.25	1.48	5.64	3.90	66.09
Haydock, Florida Main,.....	1.267	77.49	5.50	1.27	0.88	12.84	2.02	54.4
Wigan, Four-feet,.....	1.209	78.86	5.29	0.86	1.19	9.57	4.23	60.0
Ince Hall, Pemberton, Five-feet,.....	1.269	68.72	4.76	2.20	1.35	18.63	14.34	56.5
Cannel—Wigan,.....	1.23	79.23	6.08	1.18	1.43	7.24	4.84	60.33
Ince Hall Co.'s Furnace Vein,.....	1.314	74.74	5.71	1.53	0.96	13.52	4.04	58.4
Balcarres, Lindsay,.....	1.26	83.90	5.66	1.40	1.51	5.53	2.00	57.84
Caldwell and Thompson's, Rushy Park,.....	1.271	76.17	5.46	1.09	0.91	14.87	1.50	58.7
Barcarres, Five-feet,.....	1.26	74.21	5.03	0.77	2.09	8.69	9.21	55.90
Moss Hall, Pemberton, Five-feet,.....	1.283	76.16	5.35	1.29	1.05	10.13	6.02	56.1
Moss Hall Co.'s New Mine,.....	1.278	77.50	5.84	0.98	1.36	12.16	3.16	57.7
Caldwell and Thompson's Higher Delf,.....	1.274	75.40	4.83	1.41	2.43	19.98	5.95	54.2
Johnson and Wirthington's Sir John,.....	1.31	72.86	4.98	1.07	1.54	8.15	11.40	56.15

MEAN COMPOSITION OF AVERAGE SAMPLES OF SCOTCH AND VARIOUS OTHER COALS.

Locality, or Name of Coal.	Specific Gravity of Coals.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Percentage of Coke left by each Coal.
	A.	B.	C.	D.	E.	F.	G.	H.
Various, Scotch Coals. { Wallsend Elgin,.....	1.20	76.09	5.22	1.41	1.53	5.05	10.70	58.45
{ Wellewood,.....	1.27	81.36	6.28	1.53	1.57	6.37	2.89	59.15
{ Dalkeith Coronation Seam,.....	1.316	76.94	5.20	trace.	0.38	14.37	3.10	53.5
{ Kilmarnock Skerrington,.....	1.241	79.82	5.82	0.94	0.86	11.31	1.25	49.3
{ Fordel Splint,.....	1.23	79.58	5.50	1.13	1.46	8.33	4.00	52.03
{ Grangemouth,.....	1.29	79.85	5.28	1.35	1.42	8.58	3.52	56.6
{ Eglinton,.....	1.25	80.08	6.50	1.55	1.38	8.05	2.44	54.94
{ Dalkeith Jewel Seam,.....	1.277	74.55	5.14	0.10	0.33	15.51	4.37	49.8
{ Coleshill Co.'s Bagilt Main,.....	1.269	88.48	5.62	2.02	1.36	0.86	1.62	55.8
{ Ewlowe,.....	1.275	80.97	4.96	1.10	1.40	8.20	3.37	54.5
{ Ibstock,.....	1.291	74.97	4.83	0.88	1.45	11.88	5.99	50.8

AVERAGE COMPOSITION OF COALS FROM DIFFERENT LOCALITIES.

Locality.	Specific Gravity of Coals.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Percentage of Coke left by each Coal.
	A.	B.	C.	D.	E.	F.	G.	H.
Average of 36 samples from Wales,.....	1.315	83.78	4.79	0.98	1.43	4.15	4.91	72.60
" 18 " Newcastle,.....	1.256	82.12	5.31	1.35	1.24	5.69	3.77	60.67
" 28 " Lancashire,.....	1.273	77.90	5.32	1.30	1.44	9.53	4.88	60.22
" 8 " Scotland,.....	1.259	78.53	5.61	1.00	1.11	9.69	4.03	54.22
" 7 " Derbyshire,.....	1.292	79.68	4.94	1.41	1.01	10.28	2.65	59.32

AVERAGE COMPOSITION OF FOREIGN COALS.

Locality.		Specific Gravity of Coal.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen	Ash.
		A.	B.	C.	D.	E.	F.	G.
Van Diemen's Land Coals.	South Cape,.....	—	63.40	2.89	1.27	0.98	1.01	30.45
	Mount Nicholas Break o' Day,.....	—	57.37	3.91	1.15	0.90	9.10	27.55
	Tingal,.....	—	57.21	3.38	1.20	1.32	7.80	29.09
	Jerusalem,.....	—	68.18	3.99	1.62	1.12	5.89	19.20
	Douglas River, East Coast,.....	—	70.44	4.20	1.11	0.70	9.27	14.38
	Tasman's Peninsula,.....	—	65.54	3.36	1.91	1.03	1.75	26.41
	Schonten Island,.....	—	64.01	3.55	0.94	0.85	3.38	27.17
	Whale's Head, South Cape,.....	—	65.86	3.18	1.12	1.14	7.20	21.50
	Adventure Bay,.....	—	80.22	3.05	1.36	1.90	4.80	8.67
	Sydney, New South Wales,.....	—	82.39	5.32	1.23	0.70	8.32	2.04
	Borneo—Lahman Kind,.....	1.28	64.52	4.74	0.80	1.45	20.75	7.74
	“ Three-feet Seam,.....	1.37	54.31	5.03	0.98	1.14	24.22	14.32
	“ Eleven-feet Seam,.....	1.21	70.33	5.41	0.67	1.17	19.19	3.23
	Formosa Island,.....	1.24	78.26	5.70	0.64	0.49	10.95	3.96
	Vancouver's,.....	—	66.93	5.32	1.02	2.20	8.70	15.83
Chili Coals.	Lignite, Trinidad,.....	—	65.20	4.25	1.33	0.69	21.69	6.84
	Conception Bay,.....	1.29	70.55	5.76	0.95	1.98	13.24	7.52
	Port Famine,.....	—	64.18	5.33	0.50	1.03	22.75	6.21
	Chirique,.....	—	38.98	4.01	0.58	6.14	13.38	36.91
	Laredo Bay,.....	—	58.67	5.52	0.71	1.14	17.33	16.63
Patagonia Coals.	Talcabano Bay,.....	—	70.71	6.44	1.08	0.94	13.95	6.92
	Colcurra Bay,.....	—	78.30	5.50	1.09	1.06	8.37	5.68
	Sandy Bay, No. 1,.....	—	62.25	5.05	0.63	1.13	17.54	13.40
	“ No. 2,.....	—	59.63	5.68	0.64	0.96	17.45	15.64

Having seen in the foregoing the ultimate constituents of the several varieties examined, and also the amount of coke which they afford when heated in close vessels, the next point that demands inquiry is the state or condition in which those elements are contained in the coal. It is the belief of many, that common coal is compounded of a carbonaceous substance like anthracite, and a bituminous one; and it would appear, from the microscopical researches which have been made, that such is usually the case. When, however, the fusibility of good coal is considered, and the homogeneous mass which it yields upon exposure to heat is closely examined, one is led to infer that the carbon is not isolated, but combined with the other constituents in such a manner as to form a definite body. Doubtless, in some species of lignite, the bituminous matter is partly distinct from the carbonaceous; this may be deduced from the considerable quantity of tar which they yield, and the friable porous nature of their coke. From many facts connected with the manufacture of gas and other products from coal, it must be evident that this substance is chiefly composed of various carbides of hydrogen, which suffer decomposition by heat, and which, from the circumstance that suitable solvents have not yet been discovered, remain unisolated. It is an authenticated fact, that the more the amount of hydrogen in a coal exceeds that of the oxygen, the more fusible is the substance, and *vice versa*; but this surplus is not sufficient to account for its fusibility; the entire quantity is concerned in producing the effect. When the amount of hydrogen is small, the coal will not be so fusible as when the proportion is larger, although, in the first case, the ratio in which it stands to the oxygen may be much greater than in the second. If the absolute per centage of hydrogen is only about two, there is little reason to expect that such a coal will undergo fusion when submitted to heat. Experiments have shown that it requires at least three per cent. of hydrogen in

the substance, with as much oxygen as will combine with half of this to form water, to render it fusible under the influence of caloric. Such a coal affords a very intumescent coke. Coals less inclined to melt than one so constituted, may contain a variable amount of hydrogen; but when the proportion exceeds one-and-a-half per cent., the oxygen will be required in quantities capable of transforming at least two-thirds of this into water. On the other hand, if the hydrogen and oxygen be exactly so proportioned in the coal as to form water, the coal will be infusible, and the coke which is left will be pulverulent. It is remarkable that many substances constituted of carbon, hydrogen, and oxygen, differ in this particular from coals; thus sugar, gums, starch, when submitted to heat, fuse, and yield a compact coke. Hence it may be inferred that whether an organic matter containing about forty-eight per cent. of carbon, with oxygen and hydrogen to constitute water, shall be fusible or not depends on circumstances still requiring explanation. When the quantity of carbon exceeds fifty per cent., the substance is or is not fusible, according as the amount of hydrogen is or is not in excess above that which is necessary to convert the oxygen into water. All woody and fibrous matters are infusible, owing to their content of carbon being more than fifty per cent., whilst the oxygen and hydrogen making up the remainder are so proportioned as to compose water; there are, however, other bodies in which the carbon constitutes from half to nine-tenths of their weight, and yet they are fusible and even volatile under the influence of heat. Such is the case with some of the resins, wax, *et cetera*, which contain a large quantity of hydrogen that assimilates itself with the carbon, giving rise either to gaseous bodies, or liquids, into which the latter largely enters. It is upon these grounds also that the explanation of the fusion of coals so rich in carbon as eighty per cent. rests.

In many branches of trade, experience has pointed out the advantages which some varieties of coals afford,

from the circumstance that the nature of their combustion is adapted to the special work assigned them. Hence the selection of gas coal, steam coal, and such like, on account of the respective qualities they possess; the former of producing large quantities of gas, the latter of yielding a high temperature, at the same time that its combustion is tardy and gradual. The first are evidently such as, when heated, enter more into fusion, as is obvious from the adoption of cannel in gas-works whenever it can be found. For generating steam, coals which are only slightly fusible, and bordering upon the nature of anthracite, are found from experience to be the best. For various other manufacturing purposes, the particular requirements of each must decide the fittest quality of fuel. In reverberatory furnaces, and such others as are constructed with the view of producing an effect at a distance from the fire, flaming coals will be found best adapted for the purpose, but not those which are apt to form a coherent cake in the grate, whereby the draught would be impeded, and the combustion be inadequate to the effect required. On the other hand, where the heat must be very intense, those coals are found to be the best which contain a large percentage of carbon, with enough hydrogen and oxygen as will generate sufficient quantities of inflammable gases to promote its rapid ignition, but at the same time not so much as will effect fusion to any considerable extent. Such is the kind required in the smelting of metals, for the working of iron, *et cetera*. This subject will be further explained when the values of fuel come under consideration.

Torbanehill, or Boghead Coal.—The peculiar characters of this substance, on the nature of which geologists and chemists were much divided, attracted very great attention several years ago, and led to important legal proceedings, arising out of the following circumstances. In the beginning of the year 1850, a contract of lease was entered into between the proprietor of the estate of Torbanehill, near Bathgate, Linlithgowshire, and the Messrs. RUSSEL, Falkirk, conveying to the latter, in consideration of a fixed rent, a right to the whole coal, ironstone, iron ore, limestone, and fire-clay, on the lands of Torbanehill, for a period of twenty-five years; but the lease was not to comprehend copper, or *any other mineral whatever except those above specified*. In the course of their researches, the Messrs. RUSSEL had previously found an extensive deposit of the Torbanehill coal, which was shown by Dr. PENNY, in 1849, to be invaluable as a coal for the manufacture of gas. As such, it was worked and disposed of by the Messrs. RUSSEL, to whom, at the very small rent at which their right to the minerals was acceded, it promised to be a source of large revenue. In these circumstances, the proprietor of Torbanehill brought an action against the lessees for damages, laid at £10,000, on the ground that the substance was not coal at all, nor any of the minerals comprehended in the lease, and that, therefore, the lessees had no right to remove it. The case was tried at Edinburgh, before the Lord Justice-General and a special Jury, in the months of July and August, 1853, and excited intense interest, both on account of the curious scientific question involved, and the number

of eminent professional authorities cited on both sides as witnesses. The apparently conflicting character of their testimony was also somewhat remarkable. Professor ANSTED, for instance, did not give the substance any name at all; Professor BRANDE said it was a new peculiar mineral; Professor CHAPMAN had no hesitation in pronouncing it a bituminous shale; the late Mr. HUGH MILLER characterized it as the most inflammable shale he had ever seen. Dr. THOMAS ANDERSON said it was not a bituminous shale, whatever it was. Dr. WILSON said he would call it a clay impregnated with bituminous matter, and Mr. MILNE, in like manner, called it a clay bituminated. On the other hand, Dr. FLEMING of Edinburgh, Professor GRAHAM, Dr. JOHN STENHOUSE, Professor JOHNSTON, Dr. PENNY, Dr. HOFMANN, Dr. FRANKLAND, and other equally eminent authorities, pronounced it unquestionably a coal. At the same time, the only material difference, with reference to the facts of the case, appeared in the results of the microscopical examination. The geologists and chemists agreed as to the constitution of the substance—they differed only in the name which they were inclined to give it, according to their special views of what constituted coal; but not so the microscopists, three of whom were examined for the plaintiff, and four for the defendants. Of these gentlemen, the former agreed in asserting that there was no trace of organic structure, no woody fibre or tissue—in short, no trace of vegetal matter in the substance under consideration; on the other hand, the defendants' witnesses affirmed that in every part of it there was the clearest evidence of vegetal structure; and three of these gentlemen were skilful botanists, whilst those examined for the plaintiff did not lay claim to that character. Even the microscopical evidence, therefore, was strongly in favor of the claim of the Torbanehill mineral to be considered a true coal; and this, in concurrence with the general analogies presented, induced the jury to return a verdict for the defendants. In this verdict—which quite harmonized with the opinion pronounced by Dr. PENNY before the Torbanehill coal became a subject of litigation at all—there seems to be no difficulty in acquiescing. Among the recognized true coals, there are infinite diversities in the relative proportion of the ingredients—from anthracite at one end of the scale, to cannel or parrot coal at the other; and the Torbanehill coal appears, from its composition, to be not less justly entitled to the name of a coal than anthracite, though standing at the opposite end of the scale.

In all its leading physical and chemical characters, it is identical with other varieties of cannel coal. It is unquestionably of vegetal origin. It forms a seam varying in thickness from sixteen to twenty-one inches. Its geological position does not differ from that of other Scotch cannel coals, and the associated rocks are similar to those that occur in other coal fields. In the upper part of the seam the color of this coal is brown, and the streak light yellowish-brown; but in the lower part its color is black. Fossil plants, especially stigmaria of various sizes, and with numerous rootlets, are found in every part of the coal. Some are in the shape of large trunks of trees, one or two feet in diameter. The impressions of scalariform

vegetal tissue are also exhibited in almost every fractured surface. The following section of the cannel coal-fields of Scotland, by Mr. JOHN GEDDES of Edinburgh, shows the relative position of the coal, and its depth in fathoms from the surface:—

Caplekrae. Muirkirk. Lesmahago. Inzievar and Tory. Wemyss and Methill. Torbanehill.



a. Surface.
b. Sandstone.
c. Grey bands.
d. Fireclay.
e. Baring.
f. Blue.
g. Ironstone.

h. Fakes.
i. Brown stone.
j. Freestone.
k. Boghead coal.
l. Coal.
m. Coal holing.
n. Hard band.

n. Blue clay.
o. Freestone gravel.
p. Dark grey plies.
q. Sandy plies.
r. Shale.
s. Limestone.
t. Various strata.

The color of this coal varies from dark snuff-brown to dull brownish-black; streak light brown; powder dull olive brown-black. It does not soil the fingers; it adheres to the tongue, and it has, when moistened, the odor of clay. It is exceedingly hard, and very difficult to break in a direction perpendicular to the plane of stratification. It is distinctly laminated, and the large rhomboidal blocks, as brought from the pit's mouth, may be readily split into thin slabs, less than an inch in thickness. Its fracture is slaty, and often beautifully conchoidal. When struck with a hammer, it gives a distinct and deep woody sound. Does not become electrical by friction. Specific gravity varies from 1.155 to 1.260; average about 1.1892.

Its microscopical characters have been ably discussed by Professor REDFERN, in the third volume of the *Quarterly Journal of the Microscopical Society*.

It readily ignites, and burns with a bright, voluminous, and smoky flame. In the open fire it splits, and crackles like other cannel coals. It does not intumesce or melt. When completely burned, it leaves a considerable quantity of fine white ash, amounting on the average to twenty-one per cent. Several cannel coals give a larger quantity of ash—page 85. The ash contains, in 100 parts:—Silica, 56.0; alumina, 43.52; oxide of iron, 0.35; potassa, 0.4; soda, 0.36; with traces of lime, magnesia, phosphoric acid, chlorine, and sulphuric acid. HERAPATH has proposed to use the ash in the manufacture of alum. This coal is not appreciably acted upon by ether, bisulphide of carbon, benzol, oil of turpentine, or naphtha. When distilled in the usual manner, it gives the same products as other cannel coals—namely, gaseous hydrocarbons, tar, paraffin, paraffin-oil, naphtha, naphthalin, benzol, ammonia, *et cetera*.

It contains every ingredient found in other varieties of coal; and there is no substance in it that does not exist in other coals. The results of its elementary analysis by Dr. PENNY, after being dried at 212°, are shown in the following statement:—

	With ash.	Without ash.
Carbon,	63.936	81.159
Hydrogen,	8.858	11.245
Nitrogen,	0.962	1.221
Sulphur,	0.320	0.406
Oxygen,	4.702	5.969
Ash,	21.222	—
	100.000	100.000

It yields about 67.0 per cent. of volatile matter, and 31.7 of coke. Different specimens, however, vary considerably in this respect, as shown in the following table, which exhibits the results of the analysis of four specimens taken from the pit at different dates:—

	Brown.		Black.	
	1849.	1851.	1851.	1853.
Volatile matters, ...	71.0	71.0	62.70	67.11
Fixed carbon, ...	11.3	7.1	9.25	10.52
Ash,	16.8	21.2	26.50	21.0
Sulphur,	0.3	0.2	0.35	0.32
Water,	0.6	0.5	1.20	1.05
	100.0	100.0	100.00	100.00

Coke,

Specific gravity, ... 1.1550.. 1.160.. 1.2185.. 1.1882

In its chemical composition this coal is characterised by containing more hydrogen than any other variety, and by giving less fixed carbon and more ash than most other coals. Its coke, which is valueless as fuel, contains 33·4 per cent. of carbon and hydrogen, and 66·6 per cent. of ash. It surpasses all other cannel coals in its gas-producing powers. It yields from thirteen thousand to fifteen thousand cubic feet per ton, whereas the best qualities of other coals give from eleven thousand to twelve thousand cubic feet. The gas produced from

it is extremely rich in hydrocarbons, which burn with flame possessing a high degree of luminosity; hence this coal is admirably suited to be mixed with inferior varieties of cannel coal in the manufacture of gas. When distilled at comparatively low temperatures, it affords large quantities of paraffin, paraffin-oil, *et cetera*, a discovery made and patented a few years ago by Mr. YOUNG. Several interesting products have recently been obtained from it by GREVILLE WILLIAMS.

The following table will be found useful:—

MEAN COMPOSITION OF VARIOUS SCOTCH CANNEL COALS, ANALYSED BY DR. PENNY OF GLASGOW.

Locality or Name of Coal.	Specific gravity.	Volatile matters.	Fixed carbon.	Ash.	Sulphur.	Water.	Coke.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1. Rochsoles—1851,.....	1·448	53·7	4·9	38·8	1·6	1·0	43·70
2. Hardie's—1852,.....	1·420	34·0	4·0	58·4	*	3·6	62·40
3. Boghead, <i>Brown</i> —1851,.....	1·160	71·06	7·10	21·2	0·24	0·4	28·30
4. Boghead, <i>Black</i> —1851,.....	1·2185	62·7	9·25	26·5	0·35	1·2	35·75
5. Torbanehill—1853,.....	1·1892	67·11	10·52	21·0	0·32	1·05	31·52
6. Boghead—1849,.....	1·1550	71·3	11·3	16·8	(·34)	0·6	28·10
7. Bathville,.....	1·201	64·35	12·6	22·2	0·25	0·60	34·80
8. Stand—Airdrie,.....	1·4647	52·08	14·77	32·0	*	1·15	46·77
9. Methill,.....	1·3002	49·23	17·57	29·7	*	3·50	47·27
10. Capeldrae,.....	1·3603	45·73	19·97	31·5	*	2·80	51·47
11. Wemyss,.....	1·1831	58·52	25·28	14·25	*	1·95	39·53
12. Balbardie—1852,.....	1·420	38·96	29·66	28·0	0·38	3·0	57·66
13. Hillhead—Kilmarnock,.....	{ 1·602 } { 1·320 }	36·65	32·34	27·4	0·61	3·0	59·74
14. Brymbo,.....	*	32·10	36·4	29·4	*	2·1	65·80
15. Lesmahagow—Auchinheath,.....	1·1990	56·23	36·7	4·3	0·55	2·22	41·00
16. Bartonshill,.....	1·280	46·0	39·6	10·0	2·0	2·4	49·60
17. Bartonshill,.....	1·350	38·0	37·9	18·7	2·2	3·2	56·60
18. Stevenson—Ayrshire,.....	1·3850	40·21	40·14	19·35	*	0·3	59·49
19. Lesmahagow—Southfield,.....	1·228	49·34	40·97	6·34	1·35	2·0	47·31
20. Knightswood,.....	1·234	44·77	41·13	11·05	*	3·05	52·18
21. Cairnbroe,.....	1·247	42·83	42·67	8·50	*	6·0	51·17
22. Skaterigg,.....	1·252	49·32	44·83	2·50	*	3·35	47·33
23. Cowdenhill,.....	1·299	46·0	45·0	5·0	0·50	3·50	50·00
24. Breadisholme,.....	1·335	39·0	48·5	8·1	0·4	4·0	56·60
25. Ruchill,.....	1·223	45·73	49·27	2·5	*	2·5	51·77
26. Kelvinside,.....	1·231	40·17	53·42	1·9	0·21	4·3	55·32

* Not estimated.

COKE.—Like wood and peat, coal has been found unadapted for many purposes in its natural state; either the heat which it evolves is insufficient from the presence of water and other ingredients, or the same effect is produced by the tendency of most coals to fuse and form a coherent mass, whereby the air is excluded, and the combustion impeded. Although the latter is the most frequent cause of failure, both contribute to render coals inapplicable to the wants of many of the arts and manufactures. To obviate these difficulties, and to bring the coal to a state in which it will yield the greatest possible amount of heat, recourse has been had to carbonization, the idea being borrowed, doubtless, from the advantage gained by a similar treatment of wood. By this operation, the principles of which have been already explained, the volatile products are expelled, and the liquid bodies decomposed, so that their carbon becomes to a great extent fixed, whilst the hydrogen and oxygen are dispersed. These volatile matters are utilized or not, according to the circumstances and the locality in which the carbonization is carried on. Thus, when the operation is conducted in large towns, the gases become not only a source of profit to the persons engaged in the trade, but of comfort and safety to society by their illuminating power. In

localities which are not populous, or which are far removed from cities and towns, these valuable products are permitted to pass off, not only uselessly, but often injuriously to animal and vegetal life. In either case, the fixed matter left is known as coal-charcoal or coke.

The charring of coals is conducted under these circumstances with very different objects. In towns, the coke is, in fact, only a secondary product, and is little regarded in comparison to the volatile matters, whilst in those places where the coal is burned on the field for the smelters and for locomotive purposes, all the value is attached to the solid body remaining. These latter—the iron trade and steam locomotion—are the principal sources of consumption of this kind of fuel; and since the introduction of both upon an extended scale, the inventive genius of scientific men has been exercised to discover methods of carbonizing the coal, not only more rapid in action, but also more effective, and calculated to produce a substance as much as possible divested of the volatile bodies which diminish its heating power. It could scarcely be expected that a subject so interesting as this, so important to many branches of manufacturing industry, and consequently so well meriting the attention of intelligent

scientific and practical men, could long rest without eliciting many suggestions towards improvement. How far these have been attended with success, will appear in the following pages.

Adopting the same arrangement as in former cases, it may be well to say a few words, in the first place, on the charring or coking properties of *brown coal*, which is sometimes employed for this purpose. In Great Britain, where bituminous and stone coal abound to the extent already stated, and where the presence of lignite is very partial, the latter is carbonized with the view of rendering it more useful—a practice, however, restricted to those places where the more perfect coal is scarce. Where such conditions exist, the charring of lignite—a work which is difficult and troublesome to effect—is repaid with very indifferent results. This arises from its peculiar property of splitting asunder as the heat enters, and hence the mass when charred is little else than a heap of small fragments which are unsuited for those works requiring the use of a compact coke. It is stated by ROSCHERS, that lignite, if thoroughly dried in the air immediately after it is taken from the pit, and then slowly charred, affords a charcoal possessing considerable cohesive properties; and MAYER, in like manner, affirms that the inconvenience may be obviated by subjecting the coal to slow carbonization after it is taken from the mine. The methods usually adopted are similar to those already described for the charring of wood and peat; but the yield from this species of coal is so small, that the labor bestowed upon the operation is hardly repaid. In the German works, where lignites have been charred, the per centage of charcoal by weight averaged from fifteen to eighteen per cent., and by volume from about thirty-two to thirty-five; but this quantity is much below that obtained on a small scale, when the carbonizers used are close crucibles.

The annexed table gives a synopsis of the per centage which various lignites afforded by this treatment:—

	Per cent of charcoal.
Earthly coal from Dax,	49.1
“ “ Bouch-d-R.,	41.1
“ “ Basses-Alpes,	48.5
Lignite from Greece,	39.8
“ Cologne,	36.1
“ Iceland,	57.0
“ Raddergrube,	41.6
“ “ “	40.7
“ Grube Urwelt,	44.3
“ “ “	43.9
“ “ “	51.3
“ Friesdorf,	28.2
“ “ “	48.2
“ “ “	46.8
Earthly coal from Utterweiler,	68.2
“ Raddergrube,	48.3
“ “ “	46.4
Lignite from Pützchen,	46.4
“ “ “	44.7
“ “ “	51.0
“ Stösschen,	29.1
“ “ “	40.6
“ Orsberg,	62.8
“ “ “	68.4
“ Aussig,	40.1
“ “ “	40.0
“ Hegendorf,	41.2
“ Neundorf,	38.4
“ Coulang,	38.1

Bohemia. Right side, near Bonn. }
Left side of the Rhine, near Düren. }

	Per cent. of charcoal.
Lignite from Jahnsdorf,	32.8
“ Paredel, 1.	39.6
“ “ 2.	40.7
“ “ 3.	42.0
“ Antoni-Zeche,	40.0
“ Wellonitzer, Br.	35.9
“ Nempschauer, Br.	34.7
“ Hartenberg, 1.	37.2
“ “ 2.	34.6
“ Kanden,	37.5
Pitch coal from Grünlat,	37.2
Earthly coal from Hartenberg, 1.	42.1
“ “ 2.	48.4
“ “ 3.	36.8
“ “ 4.	39.0
Pitch coal from Hartenberg, 1.	43.9
“ “ 2.	40.3
Earthly coal from Joaz,	46.4
Pitch coal from Reichenau,	38.1
“ “ “	29.3
“ Altsattel,	40.3
“ “ “	35.0
Bavarian Oberb-falz. } Earthly coal from Verau,	35.6
“ “ “ } Lignite,	46.0

Bohemia.

The carbonization of lignite is a subject of but little interest to manufacturers, in consequence of its use being so very limited. The Editor will, therefore, proceed to the consideration of pit charcoal, which is of vast importance to every country aspiring to progress in civilization and manufacturing industry. More particularly is this the case as regards Great Britain; for the extent of her smelting establishments, and her vast application of steam power in locomotion, as well as in various manufactures, call forth every exertion to supply the most perfect source of heat which skill and science can provide. Not only do her own industrial wants demand this, but other countries, which are not so highly favored in the amount of fossil fuel at their command, make urgent calls upon her resources; and coals and coke are exported to a considerable extent to supply the railways and steam navigation of other states.

The extensive variety of coal met with necessarily suggests a corresponding difference in the effects produced by the action of heat upon them, and it is to be expected that the products should indicate similar differences. All coals which are in any degree bituminous, yield three classes of bodies—namely, the residuary matter, containing carbon in excess; the liquid substances, which are in like manner very carbonaceous; and the gaseous bodies, of which there are several. It is almost needless to remark, that the proportion of the second class will be dependent upon the fusibility of the coals; and even the third is chiefly derived from fusible or caking coals. As a general example of the nature and relative proportions of these three varieties of products, the following analysis may be taken:—

	Centesimally.
Coke,	68.925
Liquid products. { Tar,	12.230
“ { Water,	7.569
“ { Light carbide of hydrogen,	7.021
“ { Carbonic oxide,	1.135
“ { Carbonic acid,	1.073
Gaseous products. { Olefiant gas,	0.753
“ { Sulphide of hydrogen,	0.549
“ { Hydrogen,	0.499
“ { Ammonia,	0.211
“ { Nitrogen,	0.035

While the absolute and relative yield of these products depends chiefly on the composition of the coal, the method and management of the operation to which they are submitted exercises a marked influence. Thus it may be seen practically that the products differ to the extent of several units per cent., according as the heat applied in the charring is low and gradual, or elevated and rapid. In the amount of coke, which constitutes by much the largest product, or more correctly, the residue, the observed variation from this cause is sometimes so high as six per cent., but generally it ranges from three to four per cent. It is not only in quantity, however, that the mode in which the heat is applied produces a marked effect, the quality is liable to not less variation from the same cause. By the application of a low prolonged heat, gradually raised till it reaches the strongest red heat towards the completion of the carbonization, the coke is more compact, from the circumstance that the fusion of the coal is more perfect under the gradually increasing temperature, than if the latter were applied suddenly in full force. As a general rule, these matters are little attended to in the British coke districts, the coal employed being so bituminous as to yield, under either of the conditions above stated, a compact mass, which can endure the effects of carriage, *et cetera*, without sustaining much injury.

The several methods in use for the charring of coal, for whatever purpose, may be comprehended under three heads: namely, distillation in close vessels; heating in open heaps; and a method in which the principle of both is to a certain extent brought into requisition.

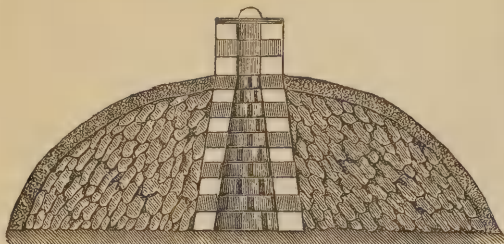
Of the first mode it is sufficient to say, in addition to what has been already stated, that the coke so produced is not only limited in amount, but is of such a nature as to render it inefficient where a very compact dense fuel is required, as in the iron furnaces and the like. Indeed, when close distillation is resorted to, the coke is less an object of consideration than the liquid and volatile products; and, therefore, it will be more in keeping with the Editor's plan to speak of it hereafter under the article GAS. By the second method, the advantage is gained of preparing a large quantity of the fuel in a short time; but at the loss of considerable quantities of material, as will be seen afterwards. The third method in which a furnace of a special form is employed, and which admits of operating upon a large quantity of coals at once, is that which is daily becoming recognised as the most economical, for it operates quicker, with less loss, and requires less attention than the others.

Coking by the second method, or the open heap, requires nearly the same operations as the carbonization of wood, only that the mounds are not so large, and they require less attention. Two systems are followed, the one characterized by the round heap or pile process, and the other by the coals being arranged in rows or ridges. For the purpose of coking in heaps, a level plot of ground is selected, the area of the heap marked out, and the coals piled upon it, placing the larger pieces at the base, and so on to the top. Fire is then applied in a cavity of about a foot in diameter, which is formed in the top for this purpose, and the

carbonization allowed to proceed. In a short time the entire mass is covered with the fire, owing to the combustible gases which are discharged, and which, igniting, conduct the fire over the whole of the coals, at the same time that they prevent its loss by shielding the heated solid carbonaceous matters from contact with oxygen. When the whole mass is at a red heat, or nearly so, and the dense heavy smoke which is emitted as long as the decomposition of the volatile ingredients in the fuel is actively proceeding has ceased, a light coating of coke ashes, or the rubbish which has accumulated, is thrown on, and the air entirely excluded. Sometimes the mound is covered with straw, dried leaves, or brambles, and coke dust or clay, before it is ignited; but this is not generally thought necessary, as the density of the coal and the downward progress of the fire, till it reaches the base of the heap, are sufficient protection against any greater loss than that which it would sustain even when covered. The period of charring a heap of twelve to sixteen feet in diameter, and two and a half to three in height, extends over two or three days before the work is finished. WILKINSON'S modification of the process, by the construction of a chimney in the middle of the meiler, so that it may serve as a draught to any portion of the mass, has been productive of great advantages in coke-making, and has, with slight modifications, been adopted in Staffordshire, on the Clyde, in Scotland, and at several other places. This appendage to the meiler is usually of a conical form, the base being about three feet in diameter, and from one foot and a half to two feet at the top. The bricks are laid so that intermediate channels present themselves all round the pile. At the top it is solid, and closed with a lid. Its height is usually three or four feet. Around the base of this chimney the coals are piled, employing the larger pieces for the base, and putting the smaller ones on towards the top and outer surface. Several channels are fashioned in the mass from the base of the chimney to the outside of the heap, through which a supply of air traverses to the region of combustion. The preliminaries being effected, and the heap coated with powdered coke or rubbish, fire is introduced at the mouth of the chimney, either by means of ignited coals or wood. The calorific which is evolved laterally through the openings in the chimney, very soon ignites the coal adjoining, and the heat extends gradually outwards to the circumference as the charring advances. As soon as the thick heavy smoke from the chimney is replaced by a lambent blue flame, it is significant that the fire has traversed the entire mass. It is now watched till the azure flame abates, at which time the draught of the chimney is cut off, by depressing the cover, and filling any chinks or cracks in the coating with fresh material. After the lapse of a few days, the process is finished, and the coke is ready for drawing. Fig. 57 represents an elevated section of this mode of charring, showing the chimney and the draught holes opening in all its circumference, and thus offering a flue for the volatile products to pass away. Sometimes this kind of meiler is ignited at several parts at the outside, near the channel flues at the base. In a short time the fire will reach almost to the centre. A few air or vent holes may now

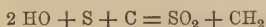
be made in the covering, by thrusting an iron bar into the heap. The smoke and other volatile compounds issue

Fig. 57.



partly by these, but care must be taken to frequently renew the perforations, as, when the coals are very bituminous, the fusion of the mass is apt to choke them up. In about twelve hours or less after ignition, the fire will have spread over the whole heap, which may then be loosely covered with coke refuse, ashes, *et cetera*, leaving the vent or chimney still free. During two or three days the smouldering proceeds, by which the volatile portions suffer distillation, and are emitted by the orifice last mentioned, and the cooling will have advanced so far as to allow of the coke being used. By this mode of permitting the whole heap to get ignited before covering, and subsequently leaving the chimney open, the elevated temperature is retained sufficiently to carbonize the mass, and at the same time a waste of coke is avoided; moreover, another important advantage is gained in the expulsion of much more sulphur than could be effected if the air were more freely admitted during the operation.

It deserves also to be mentioned, that the coke manufacturer, by constructing the meiler upon a moist ground, effects a purification from the sulphur by means of the vapors arising from the soil, and passing through the red-hot mass. In this case the water must suffer decomposition, its oxygen passing over to the sulphur, so as to form sulphurous acid, and the hydrogen constituting, with the carbon, light carbide of hydrogen, thus :—



When the sulphur is united to a metal, and the aqueous vapor transmitted over it, the following changes are more prevalent, assuming M to represent the metal in combination :—



If, however, the heat be too great, or more air than is requisite be permitted to pass through the mass, this decomposition will not take place, and the sulphur in great part remains. The same end might be obtained by suffusing the ground with water before forming the heap.

It should be remembered, however, that in this case, as in the charring of wood, in proportion as watery vapor traverses the incandescent mass, so a loss of the carbonaceous substance is sustained. This will be evident from the above formulæ; but the importance of having the sulphur removed from the coke, especially when destined to be used in the smelting of iron,

is much more thought of than the advantage of obtaining a large product.

For the most part it happens that the circular mound, notwithstanding the assistance which the central chimney affords, is too massive and solid to allow the heat to operate with its fullest effect upon the coals. The want of this distribution of caloric is supposed to be the cause of the coke retaining more or less hydrogen and oxygen, which injure in some degree its value. To remedy this, the method of *coking in rows* is resorted to. A site is marked out, the extent of which depends upon the amount of coke which is to be prepared. A line is stretched along the length of the plane, in the middle of the space which the ridge is to occupy. At the distance of seven or eight feet apart, stakes, six to eight inches in diameter, are fixed in the ground. Large pieces of coal are then laid at each side of the string, and inclined to one another, so as to leave a channel in the midst. To insure greater strength to the walls, if the first rows may be so termed, the plane of cleavage of the coal should form a right angle with the length of the heap. Other layers of coal in proportion to the size are placed beside and upon the first two, using the largest coal first, till the row is sufficiently high and wide, taking care that air channels are left at intervals in the base. The usual height to which these ridges are raised is about three feet. When completed, the whole is covered with coal dust or cinders, and fire applied at several parts adjoining the air channels; the stakes are likewise drawn, and live coals thrown into the vacant space which they leave. In a short time the whole mass will be in a state of active combustion. As soon as the heat has penetrated to the centre, the pile may be covered more closely, leaving the portion left void by the stakes as free as possible, so as to perform the office of a chimney. In case these should get choked by the fusion of the coal, they must from time to time be cleared by thrusting a bar of iron into them, or into any parts where the combustion is dilatory. As soon as the white flame resulting from the combustion of the carbide of hydrogen disappears, and is succeeded by a lambent bluish blaze, all the orifices are closely covered, and the whole is left to cool.

Such is the simple mode of coking in heaps and rows, but it may be remarked that particular modifications are required according to the kind of coal which is to be carbonized. Thus, when there is a large portion of fusible matter in the coal, care must be taken that the draught holes or flues are sufficiently wide to admit of the increased volume which it acquires by the effects of the heat upon it, without being closed thereby; the fire, also, must be allowed to spread over the whole heap, as well interiorly as exteriorly, before it is partially covered with the refuse matter. When, by a closing of the draught or flue holes, air is prevented from entering to the heart of the mass, considerable time may elapse, and much of the exterior may be consumed, before the interior portions are charred; and it not unfrequently happens that while the outside of a ridge is completely coked, the interior is left intact. As an auxiliary to the process, when very bituminous coals are operated upon, the fire should not be kindled in the chimneys or spaces left by

the stakes till the base be well ignited; the facility which these afford for the escape of the products of combustion will expedite the process, and the result will be the general charring of the heap, whereas, if these precautions were not taken, the work would be but partially performed. The same observations will apply when the coal is small, and, therefore, forms a ridge which is less impervious to air. In the latter case, instead of stakes being driven into the centre, brick chimneys are erected, as in the meiler system.

Where there is great demand for coke, and the area admits of the construction of a large heap, one portion may be undergoing carbonization, whilst the other is being constructed, and thus the process of coking may be rendered continuous. The method of charring in ridges is preferred in most establishments where furnaces are not erected, as it affords a better coke, and is more expeditious than the other method. Among the more recognised benefits are the partial purification from sulphur, which arises, as has been stated, from the fact that the steam which evaporates from the base of the heap passes over the coke whilst at a red heat, and operates as already mentioned; hence, to insure this, it is customary, wherever practicable, to cut a dyke around the carbonizing plot, the water from which keeps the ground always damp. Besides the advantages which accrue from the floor of the heap being moist, the water is always required to arrest the too rapid combustion which is apt to take place in some parts of the ridge, and also to extinguish the incandescent charcoal when it cannot be allowed to cool spontaneously.

A modification of this method of coking has been followed for some time at the Janon Works, near Saint Etienne, in France, and is useful for economising the rubbish, slack, or small coal which could not be worked in the manner detailed. It is evident that the

adoption of some similar plan at many of the British collieries, where considerable quantities of coal of average quality are allowed to go to waste, would be highly advantageous.

The heaps or ridges which are constructed at the establishment alluded to, are almost of the same dimensions as those formed with large coal, and, like the last mentioned, may be either of an oblong or conical form, according as the ground affords the necessary facilities. To construct an oblong ridge, a board, *a*—Fig. 58—is placed in an inclined position, suited to that of the heap, and resting on two iron levers sunk in the ground. Against this are fixed other boards, *b b b*, one over another, and secured by

levers or bars of iron sunk in the ground at regular distances apart, and iron hooks. After the sides are ten or twelve feet in length, the prism is provisionally closed by a board, *c*, similar to

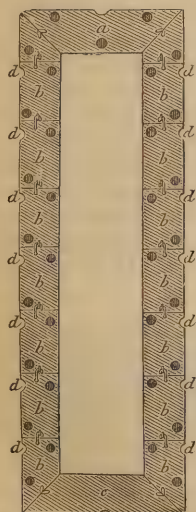
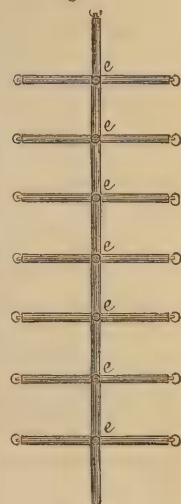


Fig. 58.

the first. All these boards are perforated, in order that conical stakes may be introduced to the interior through them, for the purpose of yielding ingress to the air in the spaces which are left after the latter are removed.

The arrangement of the lower conical stakes, by which these internal air spaces are formed, is seen in the annexed Fig. 59, where the stakes are represented in the position they would occupy when passing through the lowermost series of holes, *d d d*, in the walls of the ridge. A large stake, running longitudinally in the middle of the prism, forms the principal one. Upon this other smaller ones are fixed, as at *eee*, perpendicular to it. These being adjusted, or in readiness, a layer of the small coal, moistened to give it consistency, is thrown in till it rises to the level of the central stake, when the vertical ones are arranged as already stated, and a fresh quantity of coals added. By means of a heavy beater, the mass is rendered as compact as possible. A fresh layer of the slack is added, and beaten down as before, till the mass rises to the level of the second range of holes in the side boards, when horizontal stakes are laid from them, so as to abut against the vertical ones at a slight inclination. After the coal has been arranged

Fig. 59.



the third level, another series of rollers is laid down as before, only that it is not requisite they should be set obliquely. All these posts are generally three or four inches in diameter, and have a ring in the outer end to facilitate the drawing after the heap is formed. At this period the vertical stakes are drawn out, and then the side ones, beginning with those uppermost, and proceeding to the lowest. When this is done, the boards forming the walls are taken down and laid in continuation of the ridge, and the same order and operations are followed. In this way the prism is extended to any required length, but usually it terminates when it reaches from fifty to sixty feet in length, or even less than this, according to circumstances.

Ignition is commenced by lighting some round coal, placed at set distances in the upper holes, as well as in the middle of the heap. Care should be observed that sufficient space is left for the air to traverse these channels. In a short time the fire gains sufficient strength to ignite the whole heap gradually. As this is being attained, attention must be directed to the openings, that they do not become closed through the swelling of the mass, and, likewise, that cracks or fissures forming in the exterior are immediately closed with refuse coal. After the whole mass has become incandescent, and the evolution of whitish flame has ceased, water is poured into the lower longitudinal tunnel. By the conversion of this fluid into steam, and its passage through the mass, a further quantity of hydrogen and oxygen is expelled, as well as some

sulphur. When this operation is performed, the fire is extinguished by suffocation in the usual way. From six to ten days are required to complete the operation, and the coals afford half their weight of coke of fair average quality. It is evident that only caking coals are capable of being charred in this manner, as the non-bituminous varieties would not remain compact enough during the period of the firing.

The only drawback to this method, is the considerable consumption of coals which is necessary to ignite the mass, and which amounts to one-twentieth of the whole. By constructing the heap of a conical form, this may be reduced by one-half. It is done by an arrangement of boards, secured as in the prismatic heap, presenting the form of Fig. 60, and including a space of ten or twelve feet in diameter. A square stake, *a*—Fig. 61—is fixed in the centre of the pile, against which lean six conical stakes, *b b b*, placed at equal distances. The latter are perforated in the sides and upper part, for the purpose of receiving other stakes, *c c c*, which assume a vertical and horizontal position to each of the six principal ones. Coal is thrown in, and well rammed down, till it rises about three inches above them, when another series of stakes is laid down similar to the foregoing, only that the smaller stakes leading from the six larger ones are not directed above the preceding, as may be seen from the position of the holes in the larger ones. Another layer of coals is then laid on, and this course is pursued till the pile has risen to a height of three feet and a half, with a diameter of seven at the top. A number of smaller chimneys is

Fig. 60.

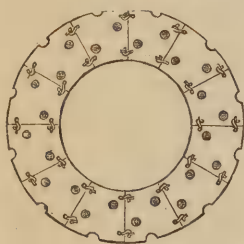
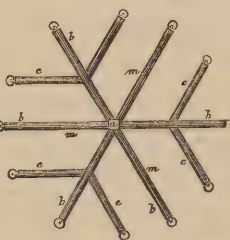


Fig. 61.



constructed by fixing, in the first series of stakes, vertical ones at the points, *m m m*, which rise higher than the top of the pile. In the subsequent details of pulling out the stakes and igniting the heap, no material difference exists between the method already described and that under consideration; the particulars of the carbonization are likewise the same in each. In this way much of the fuel which would otherwise be unsuited to such work as the smelting of metals, or for railways, is made to answer the same purposes as the best coal, and at little expense.

Another system to which the coke manufacturer has recourse, is that of heating in ovens. In this case the heat employed for effecting the carbonization is generated within the oven or furnace, and at the expense of a portion of the fuel. Were this not so, the product would be wanting in the necessary density and compactness for the iron furnaces, and, like the coke from the gas-works, would not be adapted for generating

high degrees of temperature. The method of coking in ovens is practised also for economy, as not only yielding a larger product of coke, but affording the means of recovering some of the products of the distillation. It is not, indeed, without its inconveniences, more especially if the coals be very much charged with sulphur; for, in this case, the coke retains that injurious element in much larger quantities than if the carbonization were effected in the open meiler. The ovens, however, can hardly be excelled for the production of a hard dense coke; and hence they are employed by several iron-smelters, especially those upon the Tyne.

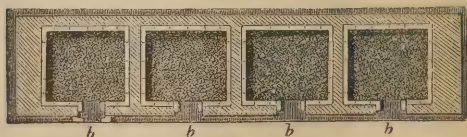
The commoner arrangement for the coking of coals in this manner, is seen in the annexed engravings—Figs. 62 and 63—the first of which shows an elevation, partly

Fig. 62.



in section, of a series of four ovens constructed in a line, for the purpose of economising the heat; and the other a plan. They have a square or oblong form, with an area of twelve feet by ten, or less, according to circumstances. The height of the furnace is also variable, differing from three to ten feet. Sometimes about twelve hundred cubic feet of coal are charred in each at once. The walls of this construction, including the fireproof facing, are about two feet thick. In the arch is an opening, *a*, two feet in diameter, through which the gases and other products of combustion pass off. No grating is supplied in this case, the air being admitted through a perforated door, *b b b*, about three feet square, in the front near the base. This door is sometimes constructed of a stout perforated cast-iron plate; sometimes it consists of a mere frame, *d*, within which bricks are laid at such distances as will leave sufficient space for the admission of air. It is movable in grooves, *c c*, by means of a main, *z*, attached to a counterpoised lever. The coals are introduced through this as well as by the superior orifice; but it is stated, that when the charge is supplied from the top, the coke is not so good as when it is deposited in the furnace through the front door. It appears difficult to assign any

Fig. 63.



cause for this, other than that, when the filling takes place from above, the central part becomes so compact as to obstruct the free passage of air through it. Before charging, if the interior be not sufficiently hot, some wood is ignited inside the front door, and

allowed to burn, and, at the first charges, the combustion is assisted by throwing powdered sulphur upon the mass. During the evolution of dense volumes of smoke, the top door is left open, and also the apertures in the door at the base; as soon as these disappear, however, both are closed, and the contents are allowed to cool. After twelve hours, or longer according to circumstances, the solid mass of coke is broken, drawn out with rakes, and wheeled off in iron barrows to a receptacle where it is cooled by sprinkling it with water. After a furnace is lighted, the first and second batch of coke which it yields is very much inferior to what is produced when it has been in operation regularly for some time; this arises from the circumstance of the base and appendages not being sufficiently heated. After a few charges have been carbonized, and the masonry has become heated, the coke has not the sponginess which characterizes the first charges; the time occupied is also shorter, and there is no occasion for adding any fire, as the heat of the base and side walls is sufficient to ignite the coal in contact with them.

An improved form of this kind of coking oven is used in the neighborhood of Pittsburg in America. This is represented in elevation and section in Fig. 64. For the most part it is constructed of bricks, and on the side of an incline, affording a facility for unloading

Fig. 64.

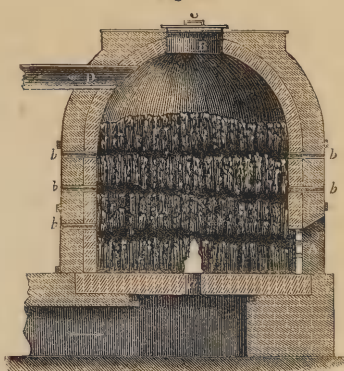


the coal on the top of the oven, and therefore erected in a position accessible by rail or common road. The hearth is oval, this form being preferred in order to avoid the inconvenience arising from the adhering of the coke to the angular parts; its area is about the same as the English ones, but the depth is only about three feet and a half, instead of being ten, as in the preceding case. In all the other details, the two methods are similar.

In many parts of Germany and France, some of the products of the distillation are recovered, more especially the tar. This economy is not so much practised in the *coking* establishments of England, although her maritime wants require considerable quantities of this substance. The kind of furnace or oven constructed for the charring of coal and the collection of coal-tar in Silesia, is represented in section in Fig. 65. The oven is of a cylindrical form, eight to nine feet in height, and four in diameter. Any ordinary building materials are employed in constructing the exterior portion of this oven, but the interior must be composed of very refractory clay or fire-bricks. There are two principal openings, A and B, through which the coal forming the charge is introduced: the aperture, B, is closed by nicely fitting cast-iron lids, c, whilst the former may be secured by bricks and mortar, to which

security is given by a cast-iron plate. In the bed and wall of the oven metallic pipes are laid at intervals,

Fig. 65.



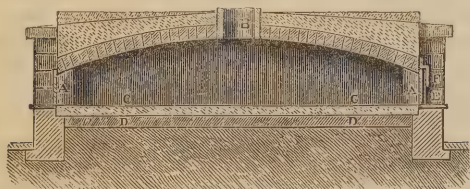
and encased with the masonry and brickwork; these serve to conduct air into the furnace for the purpose of carrying on the combustion to such an extent as will be sufficient to char the mass contained in it. They are seen at *a* in the base, and at *b b b* in the wall. All the volatile matters evolved during the carbonization are carried off through the cast-iron pipe, *D*, to a receiver, wherein the condensable portions are retained. In warm weather, and when work is active, this pipe is immersed in a water tank, intermediate, for the more effectually condensing the tar; but this is not required in the colder seasons. Care must be exercised in filling the oven, to deposit the larger coal upon the hearth, and so on, reserving the smaller for the upper layers. Inside the door, *A*, a space is left for the introduction of lighted coals or wood; but as soon as the coals have taken fire, the top door as well as the lower one are closed tightly, currents of air being circulated in the interior, through the openings in the wall and base of the oven. The upper rows of holes are closed also, the draught being instituted through the lower series, till such time as the contents of the oven have, at this level, reached a red heat. When this occurs, the orifices in the first row are closed, and those of the next opened, and left so till the fuel seen through them has assumed a red heat, after which they are closed like the foregoing, and the next opened. This process of opening the draught-holes is repeated till the whole of the charge becomes ignited. The time for changing the draught becomes pretty definite when the oven is regularly worked; thus, the coals will appear to glow, when viewed through the lower holes, in ten hours after lighting the fire, and this indicates the fit time for closing them; in about the same period, the second row may be secured in like manner; the third series remains open during sixteen hours, and the fourth only three hours. A period of twelve hours is then allowed for the furnace to cool, at the end of which time the coke is drawn. In this furnace the coals operated upon are slightly bituminous; they afford on an average about seventy-four parts by volume, and fifty-three per cent. by weight, of coke, together with rather more than five gallons of tar. The coke which is thus manufactured is very superior, in every particular, to that which

is prepared in the meiler, but the course of operations is, on the other hand, expensive and slow.

In the same locality, a mode is followed for economizing the slack and other small coal, by converting it into coke; and this course of procedure is not very unlike that described for the coking of small coal by the meiler system. The furnace is an oblong rectangle, with doors at each end, through which the small coals are wheeled in, and there, after moistening them with water to make them cohere, they are well beaten down. In the walls a number of air-channels are constructed, leading into the carbonizing space, and pieces of wood are laid between them, extending the whole breadth of the furnace. More coal is piled upon these, and pressed as solidly as possible till it rises as high as the wall, when it is covered with a thick layer of ashes and refuse matter. Some of these ovens are capable of charring from two to three hundred tons of coal, being about eight feet wide, five in height, and from forty to sixty feet in length. Fire is applied to the logs of wood, which have a diameter of four to six inches, and as these are consumed, they develop as much heat as serves to ignite the coal, and the space which they leave acts as a flue by which air is admitted, and the combustion extended to the whole mass. It is said that the loss sustained by the coal subjected to this mode of operation does not exceed twenty per cent.

In the vicinity of St. Etienne, and other localities in France, a coke oven is in use similar to what is represented by Fig. 66 annexed. In appearance it

Fig. 66.



resembles an ordinary baker's oven, with a low arched roof, and a flat hearth without a grate. The bed, *c c*, of the oven, which is nearly twelve feet wide, and twenty-three feet in length, is composed of a layer of refractory clay, well beaten down, and resting upon a base of cinders or other rubbish, *d d*, rendered as compact as possible. At each end of this oven there is a working door, *A A*, two feet nine inches in width and two feet in height, surrounded by a framework of cast-iron fixed in the wall, and in which a small sliding-door, *E*, moves; there are likewise apertures, *F*, for affording a view into the interior of the oven; and in the centre of the arch, a space, *B*, about eighteen inches in diameter, is left to serve for a chimney. The height of the oven, from the hearth to the most elevated portion of the arch, is four feet. Above the arch, which, like the hearth, should be composed of refractory material, common stone, mixed with sand and mortar, serves to give the whole solidity, and to retain the heat. The charge is lighted by first heating the interior with wood, but after a few charges have been drawn, the walls and hearth are sufficiently hot to cause the combustion of the coal. The depth of coal spread upon

the hearth should not exceed eight inches if it be of a caking nature; but when it has little of this property, the layer may be ten inches. A little water is sprinkled on the mass to promote its caking, and the whole is rendered as compact as possible. As soon as the layer is uniformly spread, the doors are drawn down nearly to the bottom, leaving a few inches free, however, for the admission of air. At first, aqueous vapor is given off, followed by sulphurous acid and the other products of combustion; but it is found advisable to suppress the rapid evolution of the latter, and to allow the slow expulsion of all moisture, at such a temperature as will be conducive, in the presence of steam, to dehydrate the coke from sulphur. All these products pass off by the chimney in the roof. When the whole of the moisture has been expelled, the disengagement of the combustible gases becomes more voluminous, and the gases themselves more inflammable; they ignite, and a smoke of a black color succeeds the dense yellow cloud which was given off during the emission of the watery vapors in conjunction with other bodies. When the black smoke appears, the draught is increased by raising the door to the height of three inches, in order to expel the whole of the volatile products. By this means the mass is in a short time raised to a cherry-red heat. After the lapse of from half an hour to an hour, the fuliginous cloud vanishes, and the gases emitted appear whitish. At this stage the heat will have spread over the whole mass, and a contraction in the bulk will have taken place, as may be judged from the appearance of numerous cracks and fissures in the red-hot mass. In about three quarters of an hour, these crevices will have penetrated to the hearth, and the entire contents will be at a full red heat. The doors are now tightly closed, as well as all the other apertures through which air might enter, and the contents of the furnace left to complete the carbonization. It is necessary to watch the operation, lest by the admission of the air through the chimney, which is the only opening left, a loss of coke might occur. After the doors are closed, the flame and smoke still pass off, but the latter by degrees becomes more attenuated and whiter, till it nearly ceases altogether; and as the pressure in the chimney is, at this period, considerably reduced, there is evident danger of a double current being established in it; namely, an outward current of the products of combustion, and an inward one of air. To guard against this, the mouth of the chimney is gradually contracted as the pressure of gases from within becomes less, till at their disappearance it is entirely closed. Attention must now be given to withdraw the coke in such a manner as to retain as much heat in the furnace as possible. To effect this, the doors are thrown open, and the mass of coke quickly broken up with long staves, then raked out, and conveyed away in barrows to a receptacle where it is sprinkled with water whilst red hot, both for the purpose of extinguishing the combustion and removing any excess of sulphur. Another charge is introduced as rapidly as possible, and after the preliminary operations already pointed out have been gone through, the doors are closed, and the charring is again managed in the same manner. Each charge is worked off in about twenty-four hours.

Figs. 67 and 68 represent a coking furnace in use in Belgium for carbonizing coal. In these figures, the

Fig. 67.

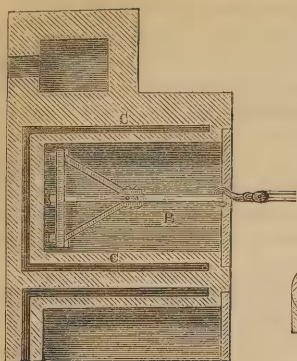
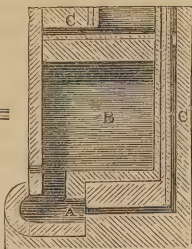


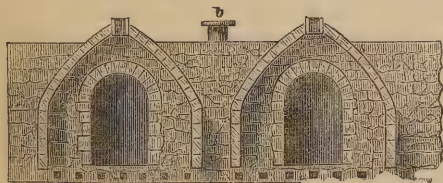
Fig. 68.



oven is represented at B B, the chimney in connection with this by A, and a flue leading to the latter by C C. The order of procedure is about the same in this as with the other kinds of ovens described, only that it contains a framework by which the whole of the charge may be drawn out at once when necessary.

In those ovens which work off only a thin stratum of coal, the coke which is formed is never so good as in those in which a thick bed is charred. It is more difficult, however, to carbonize the coal under the latter circumstances, and the product is less in amount. This arises from the fact, that when the mass is thick, and the coals are of a fusible nature, the air is prevented from passing up through the heap, and the result is a superior layer of coke, a middle band of charred material, and the lower layer of undecomposed coal. Even when the coal is not fusible, but contains considerable quantities of ashes, the effects are the same; for, under the influence of heat, the mass cracks into blocks of some dimensions, and the ashes which result from the entire combustion of a portion of the fuel fill the fissures, so that the draught is as effectually cut off as in the preceding instance. The portion of coke which is formed, however, is, in consequence of the prolonged heat necessary for effecting the carbonization, so compact that it claims preference in the iron furnaces to all other kinds, provided no deleterious substances be contained in it. Experience has shown that such a coke resists the pressure of the materials in the furnace, and affords a more intense heat when it comes within the region of the blast, than the looser kinds.

Fig. 69.



To insure the production of such a coke, a modification of the oven has been devised to enable the coke manufacturer to char from seven to ten tons at a

time. Fig. 69 represents this form of oven. It is constructed of ordinary refractory materials, and has an area of ten feet square, with a height of about four feet to the springing of the arch or dome of the furnace. To economise the heat, the arch should be so constructed that it will reflect the heat of the fire upon the coal as much as possible, and thereby hasten the carbonization. After the mass of coal has attained a red heat, and the volatile matters are expelled at the chimney, the draught-holes are tightly closed, and the mass is left to itself in this state. Under the action of the confined heat the coke contracts in bulk, and acquires a considerable degree of hardness. When the charge of coke is drawn, the floor of the kiln is cooled down to such a degree as that it will not affect the fresh charge, nor cause a partial distillation of those portions in contact with it, for the coal thus acted upon would yield a lighter and porous coke. This effect is produced by means of a winding or sinuous flue beneath the floor, as seen in *aa*, Fig. 70, which terminates in the chimney, *b*, Fig. 69.

Many other beneficial modifications and improvements are introduced where large quantities of coke

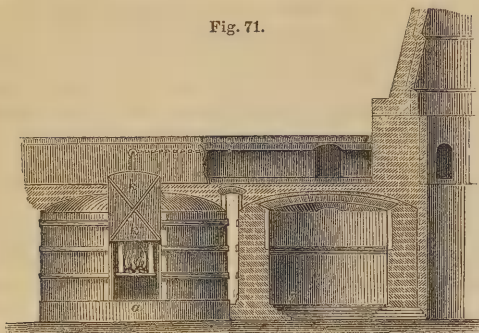
Fig. 70.



are prepared; such as collating several furnaces in a range, by which much loss in the combustion of coal is prevented, owing to the greater amount of heat retained by the materials of the furnace; expedition in charging and discharging the ovens before or after the distillation; and, not the least, the prevention of nuisances by the erection of tall chimneys, which carry the dense volumes of smoke evolved during the action of the fire high into the atmosphere, and, to a great extent, out of the range of vegetal and animal life. Several such improvements may be observed in the coke ovens established at Camden-Town for supplying the railways, especially those of London and Birmingham. Fig. 71 exhibits the disposition of these furnaces, of which there are eighteen or more in a continuous row, and all the volatile products are conducted by a horizontal flue to a tall chimney, which is placed at one end of the line. Like some of those already described, the bed of these furnaces is elliptical in form, the greater diameter being about twelve, and the lesser, eleven feet; the walls are about three feet thick, being

lined with refractory firebrick or clay. The soles of these furnaces are constructed of solid materials, well compacted, the upper layer consisting of firebricks. In

Fig. 71.



the front are the openings, *a*, forming the charging doors, which are three and a half feet wide exteriorly, and about two feet three quarters interiorly; they are closed by cast-iron plates, *k k*, five feet and a quarter in height, by four in breadth, to which counterpoise chains passing over pulleys are appended at the upper extremity, and which facilitate the opening and closing of the door.

The draught of air passing through the furnaces, is regulated by a damper fixed in the horizontal flue; and to prevent smoke from issuing from the mouth of the chimney, a quantity of air adequate to the carbonaceous gases is introduced into the flue, so that the combustion of those products is effected. Each furnace is charged with three and a half to four tons of coal spread over the base. Fire is applied as well at the base as at the front door in the first charge; but after this is charred, and the walls of the furnaces become heated, ignition is produced by lighting some straw or brushwood under the arch of the furnace. Combustion proceeds regularly till the whole contents are at a red heat, and the entire volatile ingredients expelled. This takes place in about forty hours, at which time the dampers are closed, and the mass of coke is left to cool spontaneously, to render it more compact. After cooling, the coked mass is broken, and then drawn out by an iron rake, the handle of which moves on an iron ring suspended before the opening.

Such are the forms of furnaces adopted, and the processes usually followed in the manufacture of coke, but there are many modifications according to the nature of the coal. Some of these are calculated to afford a larger product, whilst others are intended to manufacture a purer coke than can be done by the ordinary method. The principle involved in those improvements which have in view the increase of the product, is such an equalizing of the temperature as to prevent the heat exercising an undue effect on one portion of coals, whilst another may not be fully charred. The advantage gained, however, even by the most careful management, does not, according to the researches of KARSTEN, amount, in the case of the charring of coals, to more than five or six per cent. Generally, the quantity of coke which a coal produces depends more upon its atomic constitution, and the amount of ash which it contains, than upon any other

condition; and without these data, it is nearly impossible to judge what quantity of coke a coal will yield. The analytical tables, given at pages 80, 81, and 82, will throw some light upon the amount of product from many varieties. British coals usually average from fifty-four and a quarter to about seventy-three per cent. American coals examined by JOHNSTON yield about the same quantities. In either case the inorganic constituents, which take from the heating effect of the coke, are included in the calculated amount. By deducting these matters constituting the ash from the coke, and comparing the principal combustible with the content of the original coal, the numbers will stand in nearly the following centesimal proportion for the varieties mentioned:—

	Entire content of carbon in coal.	Pure coke produced therefrom.
Sand coal,	75 to 80	55 to 65
Sinter coal,	80 „ 85	60 „ 70
Caking coal,	85 „ 90	60 „ 80
Anthracite sinter coal, } sand coal,	90 „ 95	85 „ 94

As already intimated, the quantity of carbon in the coal previous to charring is no certain guide to the estimation of the coke which it will produce; for some varieties, very rich in this element, but associated with hydrogen and oxygen to a considerable extent, yield but a low per centage of fixed matter after the fire has exerted its influence upon the mass. To arrive at the knowledge of how much coke any particular kind of coal will afford, recourse must either be had to an accurate analysis of the substance, or a careful observation of the actual mean produce of a number of charges.

The cost of manufacturing coke by the furnace system, averages in England about one shilling and two-pence per ton. In Belgium, the expense amounts to about two shillings and a penny, even when working the large furnaces.

Washing.—Of the improvements for the purpose of producing a better quality of coke, the method of washing lately introduced in France deserves notice. In that country, as well as in Belgium, the veins of coal are intimately blended with shaly matters near the walls, or intersected with such substances, which are in some instances harder, though in others more friable than the coal. In this state, it could not be advantageously employed for coking; and, with a view to economy, it is customary to assort the coal into three classes or qualities. This is done by means of an apparatus called a *gailleterie*, consisting of strong sieves, upon which a stream of water falls. The largest pieces, called *gaillettes*, about two cubic inches in size, are retained in the first sieve; the *gailletins*, or second size, are composed of pieces about one-third of a cubic inch; and the third, or *tails*, consist of fragments smaller than these. From the first, the pieces of schist may be easily removed by picking; but the second, in which considerable quantities of stones and other matters are retained, cannot be so purified; whilst, in the third, or tails, all the earthy, pyritous, and other friable impurities accumulate. M. MARSILLY's experiments showed that the coals from the basins of the Mons and of Valenciennes, when so treated,

and the products converted into coke, gave a result manifesting considerable difference as to quality. The first selection, or *gailletterie*, afforded a good coke, its ashes averaging from six to seven per cent.; the coke from the next selection was not so good, and retained from seven to eleven per cent. of mineral matters. The original coal, when carbonized without any preparation, yielded a product intermediate between these. It was inferred from such results that the substances which affect the purity of the coal are those which are more friable, and that, by a proper course of treatment, they might be concentrated in the *brees* or final refuse of the coal. To effect this, the coals are subjected in some places to a process of washing, similar to that followed in the purification of minerals. In the pyritous coal localities of the Vosges, this process has been practised for a considerable period; but it was not adopted in other collieries till about 1840, when it was introduced into the coal districts of St. Etienne Rive de Gier, and at the Mons

Fig. 72.

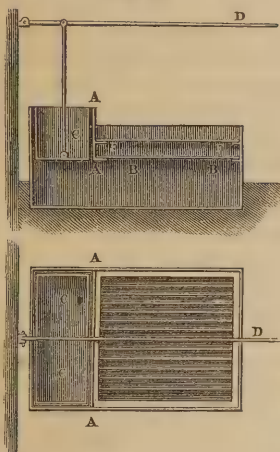


Fig. 73.

and Valenciennes. Fig. 72, annexed, shows a side elevation of a simple machine used for this purpose; and Fig. 73 a plan of the same. It is a rectangular wooden trough, divided into two unequal compartments by a partition, A A, which does not extend to the bottom. In the larger compartment, a grate, B B, of osiers, iron wire, or perforated zinc, is fixed, and upon this the coals are cast. The trough is filled with water till it rises to the coals on the perforated shelf, when the washing is proceeded with. This is effected by moving the piston-rod attached to a box, C, filling the smaller compartment, up and down in the water by means of an arrangement of levers, D, as seen in the drawings—a movement which has the effect of forcing the water higher in the larger division of the trough, and of floating the lighter portions of the materials, so as to cause the schistose matter to gravitate to the bottom by the motion produced by the alternate rise and fall of the water. When the action has been continued for a sufficient length of time, the superior layer of purified coal is removed from the under layer of impurities. To render this part of the work less troublesome, another perforated bottom, F F, is fixed over the grate, B B. During the washing, the pyritous and other matters fall through the first, F F, and accumulate upon the second one, whilst the purified coal still rests upon the former. Under favorable circumstances, three men can work off from twenty to twenty-five cubic yards of coal in the space of twelve hours by this machine. The water is drawn off from time to time, and supplied by a proper adjustment of stop-cocks, *et cetera*.

The apparatus employed at Commentry for washing the coal, is, on the whole, simpler than the preceding. Figs. 74 and 75 show a plan and elevated section of the apparatus. The pipe, R S, conducts the water by the connecting pipes, T T T, to the stages where the fuel is washed, and which are represented at A B C D, A' B' C' D', *et cetera*. The coals are deposited in the upper compartment of those beds, as at A B, A' B', and when

Fig. 74.

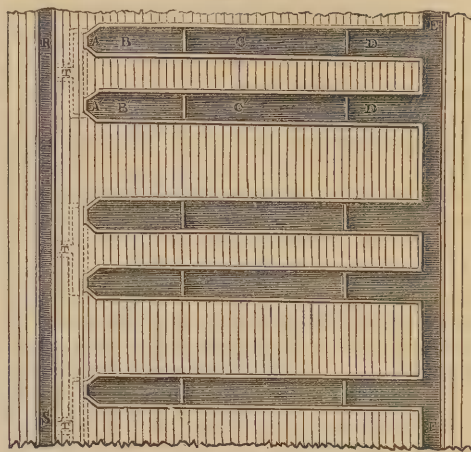
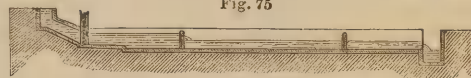


Fig. 75



the water passes through, the larger pieces are retained by the gratings which divide these from C, C'; while those pieces which pass through the openings of the first grating are retained in the second, and so on, the water finally passing off by the exit pipe, E F. Several other machines have been tried; but the most economical seems to be that of M. BERARD, introduced about six or eight years ago, and another of a later date, invented by M. TROEHLICH.

BERARD'S machine consists of an *elevator*, a *separator*, and what he terms *bancs à lavage*. The elevator is formed of an endless chain of buckets, which lift a certain quantity of the coals from the pit or trough where they are deposited. These buckets empty themselves upon the second part, or the separator. This is a long box divided into compartments by perforated plates, the perforations of which decrease as they extend from the upper to the lower part of the box. By a jiggling or shaking motion given to the whole apparatus, the lumps of coal are divided into four sizes, whilst the shaly and pyritous matters settle to the bottom. While effecting this assortment of the coal and separation of the sulphur compounds, the same movement forces out the several kinds of coal by a side opening into the third part of the machine, or the *bancs à lavage*. There are likewise long rectangular frames, nine feet two inches in length by four wide, provided with perforated bottoms, the holes in which are so small as to retain the pieces of coal thrown upon them. Like the separator, these boxes are divided into compartments, and are kept quite filled with water. In one part works

a piston, by which motion is communicated to the water, so as to cause the material to arrange itself in the order of its density. A current of water made to pass through the box, carries the purified coal beyond the box till it falls into a waggon, in which it is conveyed to its destination; the shaly matter which is left is likewise forced by the current to a trap-door, to which the bottom of the box slightly inclines, and is thus removed. It is said that by one of these machines, the cost of which amounts to about four hundred pounds, and with a daily supply of two thousand gallons of water, not less than one hundred and twenty to one hundred and forty tons are washed per day, at an expense not exceeding one penny per ton.

TROEHLICH's machine consists of a large circular cistern coopered in the ordinary way, and in this a wooden framework, or agitator, is made to revolve by means of an upright shaft driven by suitable gearing and steam-power. The bottom of the cistern is dished, and in the centre is a hole to which a sort of cast-iron conical pocket is fitted; the lower end of the latter is shut by a valve, opening downwards into a canal with a bottom of wire-gauze. Immediately above the bottom three pipes enter at equal distances from one another, for the purpose of supplying water; and, a little above the level of these, at one side, is a rectangular aperture provided with a valve, which opens upon another canal with a wire-gauze bottom. When in operation, the cistern is kept three-quarters full of water, and into this the coals lifted by chain buckets or otherwise fall through a hopper. The motion of the agitator causes the fragments to describe curves of more or less length, and this allows time for them to arrange themselves in the order of their gravity. Owing to the greater density of the schist and pyritic coals, they fall at once on the inclined bottom, and thence through the grating into the pocket above-mentioned, which is emptied from time to time by means of the valve. The fragments of pure coal pass out by the rectangular opening and fall upon the grating, which has an oscillating motion given to it that serves to impel the fuel to a waggon at the end, while the water filters through the grating. The power of this machine is said to be such, that, with a cistern nine feet ten inches in diameter and depth, and a working force of ten horses, two hundred tons of coal could be washed in a day. The cost of such a machine would be about four hundred pounds.

Four to five per cent. of mineral ingredients are thus removed from the coal; but still the latter retains about two per cent. of foreign matters, which, by a more careful mechanical contrivance, may be removed. The coke from this coal, thoroughly purified, commands in France a higher price, of about two shillings per ton. Even for general consumption, the purified coal is eagerly sought, as well for its superior quality as for its cheapness; because, where the coal is at a distance, the transport of six to ten per cent. of its weight of useless material increases its cost price without adding to its value. For many uses in the arts, it is of great importance to have the coal, when much mineral ingredients are contained in it, subjected

to a purifying process. This is the more needed for all such operations as require the use of coke, but in an unequal degree. For railway purposes, the nature of the ash considerably affects the quality of the coke—that is, when it is apt to fuse and run into a slag, as then it impedes the draught, besides injuring the furnace bars. In iron smelting, this property of the ash is not of so much consequence; but the presence of sulphur compounds is deleterious, producing a sulphide of iron which runs into the metal, and impairs its tenacity. Of late years, much pains have been taken with the view of expelling the sulphur from the coke, not by washing, as already pointed out, but by the addition of such ingredients as would, by inducing a double decomposition, liberate this element, or produce compounds with it which are decomposed by the heat. This is the principle upon which the patent of Professor CALVERT of Manchester is founded. He directs to add a quantity of salt to the coal in the coking furnace, proportionate to the quantity of sulphur which the latter contains, so as to expel the injurious element, and thereby obtain a coke of a superior quality. The decompositions which concur to produce this effect are:—the reduction of the iron pyrites—bisulphide of iron—into sulphur and a protosulphide of the metal by the action of the carbonizing temperature; the former of these is expelled, but the latter would remain in the coal were it not that the vapor of the volatilized salt, coming in contact with it, induces a mutual decomposition; the chlorine displaces the sulphur, the former being assimilated by the alkali metal. The chloride of iron formed is further resolved into chlorine and a subsalt, the former of which reacts upon the sulphide of sodium, producing an alkaline chloride, as well as chloride of sulphur, which is volatilized. It is thus that the coal is said to be purified from sulphur, or, at least, the quantity of this element reduced to a very small amount—even the portion which is left, being in the state of sulphide of sodium, a compound which is less liable to decomposition than the sulphide of iron, and which would be found intact in the slag of the smelting furnace, or in the ash from that of the locomotive. The coke manufactured thus, it is said, evolves no sulphurous acid when taken from the oven; neither is sulphide of hydrogen given off when it is extinguished with water in the usual way; nor is sulphurous acid generated by its combustion in the cupola or furnace. Even ordinary coke may be improved for the wants of the smelter, by adding a certain quantity of chloride of sodium in the cupola. The reaction which takes place in this case is the same as that previously explained.

As already stated, it is evident that coke, like the coal itself, will exhibit considerable difference, both in the nature and per centage of its constituents. A glance at the analytical tables, submitted at page 80, will show the causes of this difference. It will, therefore, be unnecessary to transcribe here analytical results of the composition of coke, further than may be sufficient to indicate the usual qualities supplied to the manufacturer. Of these, nineteen analyses are subjoined:—

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.
Carbon,	95.51	85.85	90.53	94.21	93.41	93.05	89.87	84.82	96.42	97.60
Ashes,	2.85	12.07	8.46	5.10	5.80	5.37	8.35	14.40	2.75	1.55
Sulphur,	1.64	2.08	1.01	0.69	0.79	1.58	1.78	0.78	0.83	0.85
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

	XI.	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.	XIX.	
Carbon,	94.08	92.44	89.69	91.16	93.54	91.49	94.31	94.67	92.70	
Ashes,	5.04	6.00	8.35	7.65	5.70	7.05	4.97	4.26	5.70	
Sulphur,	0.88	1.56	1.96	1.19	0.76	1.46	0.72	1.07	1.60	
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	

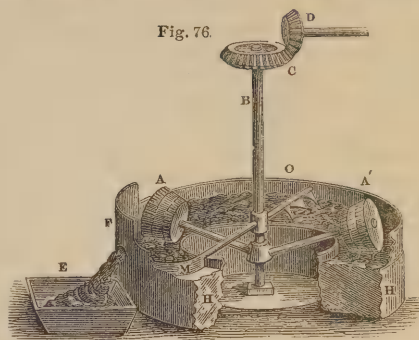
The heating qualities of coke, although easily inferred from the per centage of carbon, will be further considered when the relative value of different kinds of fuel comes to be examined.

PATENT FUEL.—In most of the operations of coal-mining, as also in coking establishments, much refuse accumulates which is frequently very rich in combustible matter; but owing to its being in small dust or powder, it cannot be used in the furnace by itself. A similar waste attends the manufacture of wood and peat charcoal, and without the aid of some cohesive matter, this considerable portion of the original fuel becomes useless.

Attention has for a long time been directed to the means of economizing such products in countries where fossil fuel is scarce, and this has not been confined to the *brees* or small refuse matter of the charcoal manufactory, but has been extended to such bodies as sawdust, wood shavings, and other combustibles. In the district adjoining the Caspian Sea, where petroleum springs are abundant, the inhabitants manufacture a fuel, by impregnating clay with the combustible fluid; the clods are afterwards burned in an ordinary hearth. By the gradual evaporation and combustion of the carbides of hydrogen, a fire of considerable intensity results. Indeed, the various contrivances which now come under the notice of the chemist, with a view to the production of artificial fuel, are little more than a copy or counterpart of the method adopted by the Orientals for solidifying the naphtha. The Norwegians have long economized the large quantities of sawdust which they produce, and convert it into a household fuel, by incorporating it with ordinary clay and a little tar, and moulding the whole into bricks. Of late years attempts have been made in this country to introduce a similar practice, by parties who proposed to employ sawdust, brushwood, shavings, spent tanner's bark, and the like substances, in the manufacture of fuel and combustible gases; but hitherto the speculation has not succeeded. The principal ingredients which are taken for the production of artificial fuel are small coal or slack, friable anthracite, the refuse or *brees* from charcoal and coke ovens, and peat—all of which are mixed with more or less pitch tar, or refuse fatty bodies. The product of some of these ingredients is found in many respects superior to natural fossil fuel, and may be used where the highest temperatures are required. For generating steam, a fuel carefully manufactured with small or refuse coal and pitch, or sub-

stances of a similar nature, is often preferred to ordinary steam coal, as it offers conveniences for stowage which coal does not, whilst its heating power is equal to, if not greater than, that of the mineral fossil.

In France, a very fair quality of charcoal is prepared with the refuse from the charcoal furnaces, by mixing it with other substances, such as charred peat, spent tan, and the like, adding tar or pitch. The course of procedure is to grind the solid with the fluid ingredients into a homogeneous pasty mass, which, after being moulded and dried in the air, is subjected to heat in close vessels, and all volatile gases

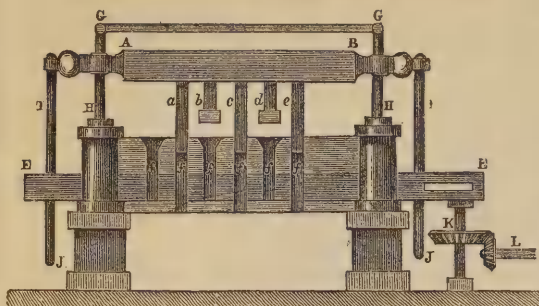


expelled. Fig. 76 represents the mill employed for mixing the charcoal, after being reduced to coarse powder by a preliminary grinding, with the tar or other liquid. It consists of two fluted cast-iron rollers, A A', connected with an upright central shaft, B, bearing a mitre-wheel, c, which is turned by a pinion, D, gearing into it. The rollers move upon the bed-plate, H H, on which the materials are laid and submitted to the action of the revolving masses till thoroughly mixed. A scraper, O, follows the rollers in the usual way, in order to bring the substances within their range, and by means of another, M, the material is discharged at the slide, F, into the box, E. About six or seven thousand gallons of the mixture are prepared by this machine in twenty-four hours, and the force required to work it is calculated as one horse. From seven to nine gallons of the tar is doled to about two hundred-weight of charcoal powder.

After the mixture is prepared, the pasty mass is moulded into appropriate forms by a machine such as that sketched in the annexed Fig. 77. By this machine the fuel is formed into quadrangular or circular masses by moulds into which it is introduced, and

therein submitted to pressure by means of a heavy log or beam of wood, which carries pistons that work

Fig. 77.

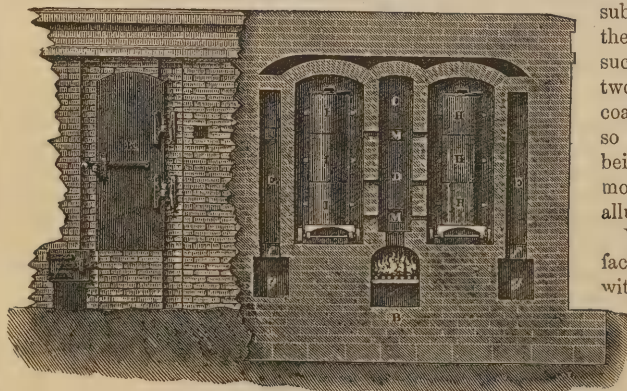


into those frames. In the above figure, the beam is represented by *AB* moving on the uprights, *GH*, *GH*, which keep it in its place by the eccentric motion communicated to the rods, *IJ*, *IJ*; *a*, *b*, *c*, *d*, *e*, indicate the pistons which press the material in, and discharge it from the moulds, *f*, *f*, *f*, *f*, *f*. Two women are constantly employed in filling the moulds; and whilst the one set are being pressed and discharged by the pistons, *a*, *c*, *e*, the others are replenished. When the beam, *AB*, is raised, the filled moulds are brought under the pistons by a horizontal motion communicated to the casting, *EE*, by the pinion and wheel, *L*, *K*; on the descent of the beam, these are in turn discharged, the others being filled in the meantime, and the motion of *EE* reversed. In this way the operation of moulding goes on without interruption. An equivalent of six horse-power is required to work this machine, but with it one man and four women can produce about four hundred and fifty bushels of the fuel in a day.

After the moulding, the next operation to which the material is subjected is the drying, which is merely an exposure of from two to three days to a current of air.

The carbonization of the bricks is effected in a kind of muffle furnace, shown partly in section, and partly

Fig. 78.



in elevation, in Fig. 78. The muffle in this furnace is about four and a half inches thick of refractory material. It is heated by a fire at *B*, the flame from

which circumscribes the whole of the muffle. The products of combustion pass behind the muffles by the channel, *CD*, but return to the front by the flue, *E*, and ultimately depart by the openings, *f*, *f*, into the subterranean channels, *g*, *g*, leading to the chimney at the back. The bricks or moulds, which are generally four and a half inches in length, by one and a half in diameter, are packed in the carbonizers, which may be sheet-iron boxes, *HHH*, or cast-iron cylinders, *III*; these are fixed on trucks, to facilitate their introduction and withdrawal from the muffle by a door in front of the case, lined with firebrick and refractory clay, which may be opened and shut at will. This door is shown at *K*, and when the carbonization is proceeding, all crevices in it are carefully stopped by clay luting.

The first effect of the heat is to eliminate moisture from the charring mass; this is followed by some carbides of hydrogen, all of which escape from the cylinders or boxes by small apertures, about the time that the cylinders are beginning to become red-hot. Air is then admitted cautiously at *M*, *M*, whereby the evolved gases are burned, giving out as much heat as is sufficient to complete the operation. By having a series of eight muffles and cylinders, two may be charged every six hours, the material being charred in a day. When no more flame is observed in the space, *C*, examined through *M*, the workman knows that the charring is completed, and the cylinders are then withdrawn.

Waste cuttings, brushwood, and such materials as could not be employed in the manufacture of ordinary charcoal, may be carbonized, and then turned to profitable account in the manner just described.

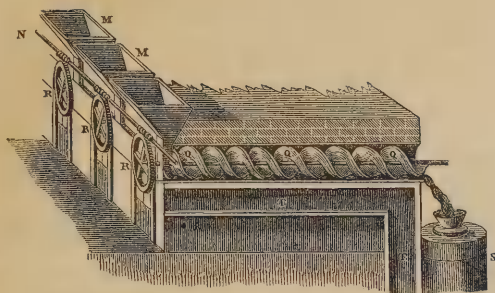
The same principle is developed in the manufacture of patent fuel from refuse coal or slack, and also from the waste matter of the coke ovens. In either case, it is necessary to mix them with substances which will give a sufficient consistency to the mass, to cause the particles to adhere whilst coking or burning in the open or furnace grate. In selecting the cementing material, there are some who do not confine themselves to oleaginous, fatty, or tarry matters, but employ also loam, hydrate and sulphate of lime, and various other mineral substances, whilst others—and doubtless this is the best course to adopt—discard the use of all such bodies; and, by a judicious admixture of two varieties of coal, or by operating upon the coal in a particular way, cause it to adhere, and so bring it into such a form as will admit of its being burned as ordinary fuel, or coke. The most important of the patent fuels will here be alluded to.

WYLAM directs, in his patent for the manufacture of artificial fuel, that small coal be mixed with pitch, and the compound afterwards moulded.

The proportions in which these ingredients are taken, are four parts of slack to one of pitch. By means of edge stones, or other machinery, the pitch and coal are ground together, or otherwise mixed, and the mass is put into a large hopper, from which it passes into a retort. This arrangement is seen in Fig. 79, where *MM*

are the receivers or hoppers, from which the mixture is carried into the retort by the plain rollers, R R R, moved by the shaft, N. By the same agency, motion

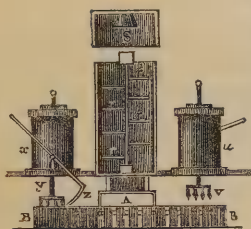
Fig. 79.



is communicated to an Archimedean screw, Q, which works within the retort, and the matter is discharged at each revolution of the screw as fast as it enters the retort from the hopper. As the retort is maintained at a red heat by the hot air in the flue, T, the material becomes more or less liquefied during the passage from one end to the other.

This pasty mass having fallen into the receiver, S, is agitated by the arms, r r—Fig. 80—to prevent it

Fig. 80.



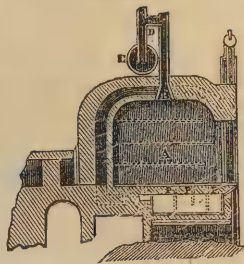
hardening into lumps before it is moulded. The moulds, B B, are ranged upon a movable oval table, A, to receive the pasty mass. Into these moulds, rams, connected by pistons, v y, are forced, by means of the pressure exerted upon them in the cylinders, u x, and which are worked by water. The table is made

to revolve by means of a lever, z, by the motion which the piston, y, communicates to it; and while in its revolution the filled boxes are conducted under the rams of the piston, v, those of y discharge the formed masses into a receiver, where they are further impressed with the maker's name.

If the pitch be not well distilled, and a portion of the oleaginous constituents are retained, the fuel, when stowed where the temperature is somewhat elevated, is apt to ignite spontaneously, in consequence of the evolution and oxidation of those matters. The tendency to this is always greater when fatty matters or oils have been used with the small coal. Numerous instances of the spontaneous combustion of artificial fuels, and even of coals, have been traced to this cause. Such a disaster occurring in the hold of a vessel at sea, is almost certain destruction to the ship.

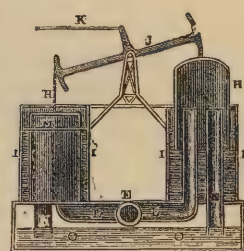
the ignition in the grate. A longitudinal section of the furnace and retort for heating and exhausting the fuel of its more inflammable constituents, is shown in Fig. 81, where A represents the retort, or the chamber wherein the fuel is heated, furnished with sliding-doors and rails, upon which the carriages loaded with the fuel run. Caloric is communicated to the matter in this chamber by means of superheated air forced in by the openings, P P, from the furnace beneath. The gaseous products are conveyed by a pipe, B, and dip-pipe, D, into a main, E,

Fig. 81.



arranged nearly in the same manner as in the manufacture of coal gas. By means of the exhausting apparatus—Fig. 82—the volatile products are drawn off. This consists of two cylinders, H H, open at the bottom, and working in vessels, I I, containing water. The cylinders are connected by a chain with the beam, J, and this again with the connecting-rod, K, by the motion of which the ends of the former are alternately raised and lowered, and consequently the cylinders, H H, also. At each elevation, the gases disengaged flow from the main, E, by the branch pipes, L L, into one or other of these cylinders; and as this cylinder is made to descend, the gases are forced out by the pipes, N N, which dip into the tank, O; they are secured from being driven back into the main by a valve, M M, in connection with the pipes, L L, which opens into the cylinders when the pressure is removed, and shuts when this is exerted.

Fig. 82.

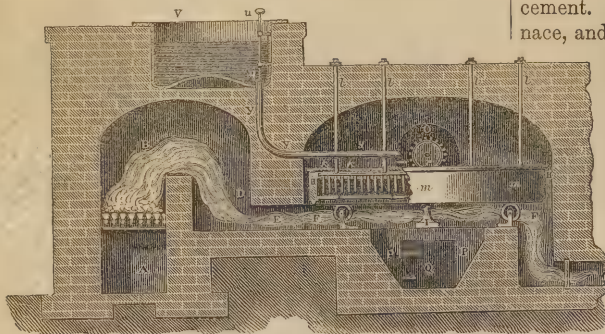


At the expiration of six to eight hours the operation is finished, and a fresh charge is introduced.

At Blanz, the waste coal is worked into a patent fuel in the following manner:—The coal is screened or purified from fragments of pyritous and shaly substances, by placing the matter upon a metal sieve, fixed in a large vat, communicating with a pump by means of a large pipe. When the pump is worked, the water is agitated in the vat, and this agitation causes the matter on the sieve to arrange itself in the order of its density, the heavier particles falling through to the bottom of the vat. The principle of this washing process is precisely the same as that represented in Figs. 72 and 73. After the matter remaining on the sieve is drained, it is removed and crushed between rollers, so as to render it more homogeneous. The coal thus crushed is mixed with seven or eight per cent. of tar, and moulded into bricks. The apparatus by which this is performed is shown in Fig. 83, where B represents the furnace by which the materials are heated, and A the ashpit. D is an arch which serves to depress the flame, so that it shall pass the bridge, E,

and spread itself over an extended surface at *f f*, for the purpose of heating a metal cistern, *m m*, which turns on a pivot, *i*, and is moved by a pinion, *r*, working into the toothed edges, *h h*, of the cistern. A flue carries off the smoke to the chimney. The coal, when thrown into the furnace, is spread evenly by a rake,

Fig. 83.



k k, attached to rods, *l l*, that pass through the masonry of the furnace, and are secured exteriorly by nuts. A boiler, *v*, placed over the arch of the furnace holds the tar or pitch in a fluid state, and the necessary proportion may be let into the charge of coal in the furnace by a valve, *w*, at the bottom, which may be closed at pleasure by means of the rod, *u*. From this valve it flows along the pipe, *y y*, which runs the whole length of the rakes, *k k*. In this way, a comminution of the tar and coal is effected; and when the operation is judged to be complete, two scrapers are lowered, which collect the material, and as soon as the cistern has made about two-thirds of its revolution, two trap-doors are opened, and it falls into a receptacle, *p p*, below, whence it is afterwards removed while plastic by the door, *q*, and pressed into bricks by the hydraulic machine.

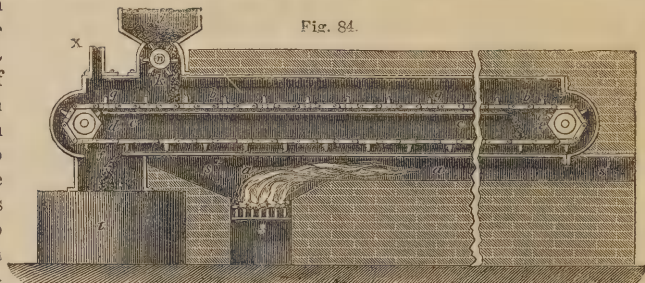
Several other patent processes for solidifying small coal and tar into a substance fit to be used as fuel, differ but slightly from the foregoing. The process of Mr. BESSEMER is considerably superior to any of these, as it enables proprietors to convert *the whole of the combustible material* into first-class coal, without suffering the loss which is invariably attendant upon colliery operations. It consists in heating small bituminous coal to a temperature at which it fuses, and while in this state moulding it into convenient shapes. By this means the use of mineral, tarry, or oleaginous contents are dispensed with, and a fuel is produced nearly equal in heating qualities to the round coal of the working, and much more convenient for stowage, from its being in regular shapes. In this operation, a series of very ingenious contrivances are brought into requisition, and made to perform the work with admirable regularity. The apparatus by which these improvements are effected is shown in the annexed engravings—Figs. 84, 85, and 86. Fig. 84 is a longitudinal section of the furnace and retort; Fig. 85 a longitudinal elevation of the pressing machinery,

showing also the end of the furnace; and Fig. 86 a plan of the pressing machinery, with part of the furnace and retort.

In Fig. 84, the furnace, *a a*, contains a retort, *b b*, which is represented broken, to indicate that it may be of larger dimensions than here shown. For convenience of erection, it should be made of three lengths united by flanges, and the joints made tight by iron cement. One end of this retort projects from the furnace, and overhangs a part of the pressing apparatus, as shown in Fig. 85. It has a shelf or partition, *c c*, extending nearly to its whole length, and in a tangent line with the upper surface of the polygonal drums, *e* and *d*. Over the latter, two chains are made to pass, which are connected by broad plates of iron, *g*, with flanged ends, which are riveted to the single links of the chain; the edges of the plates, *g*, which project, are beveled so as to form a scraper. Motion is given to this chain by the drums, *e d*, which have projections,

z, that fall into the spaces between the binding plates, and thus carry them round the drums. On the upper side of the retort there is fixed a hopper, *j*, in the lower part of which, where the slack or coal-dust is placed, is fixed a feeding drum, *k*, with ribs or leaves

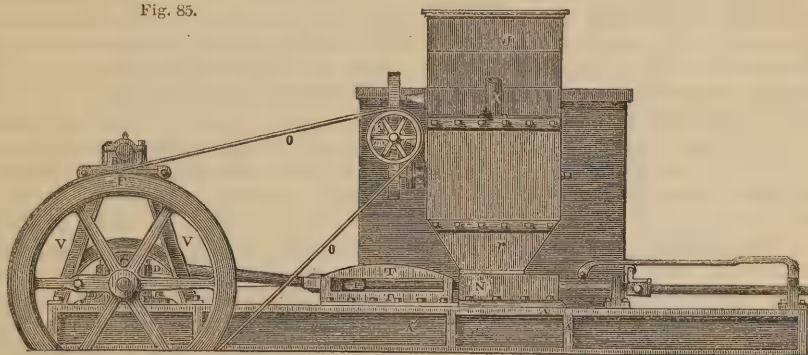
Fig. 84.



closely fitting the tube of the hopper. Appended to the side of the hopper are bosses, in which the shaft, *n*, of the feeding drum revolves. The action of this part of the apparatus is as follows:—A fire having been lighted in the fireplace, *s*, the products of combustion pass under the retort, and escape at the open end of the flue, *s'*, whence they may be conducted spirally about a boiler, for the purpose of generating the steam required to work the apparatus. When the economy of the waste heat comes to be considered, it will be preferable to set the retort so that the heat may ascend a narrow space between its sides and the walls of the furnace. An enlargement of the fire-chamber is shown at *s'*, for the purpose of transmitting radiant heat to the under side of the projecting part of the retort. The temperature of the furnace having brought the retort up to a heat approaching redness, the feeding drum is put in motion, when the small coal or coal-dust will be deposited upon the shelf, *c c*; but the motion of the chains and scrapers will move it along the shelf; and, as each scraper comes in turn under the feeding drum, the coal which has fallen between each of them will be carried forward to the right end of the shelf, off which it falls on to the lower and hotter part of the retort, occupying here

as before the space between the scrapers. It will be observed that the entire weight of the chains and scrapers rests on the bottom of the retort, and hence, by the constant passage of the former, the coal is prevented from sticking to it, and rendering its interior surface uneven. This movement not only prevents the caking of the coal to the wall of the retort, but it turns it over repeatedly, thus presenting to the heated surface fresh portions; the effect of the heat is thus equalized, and the fuel is conducted in a softened state over the opening, *f*, in the lower side of the retort, and falls into the receptacle, *t*, where it is submitted, in regular course, to compression in the apparatus, represented in plan in Fig. 86, and in elevation in Fig. 85. In these figures, *A* is the

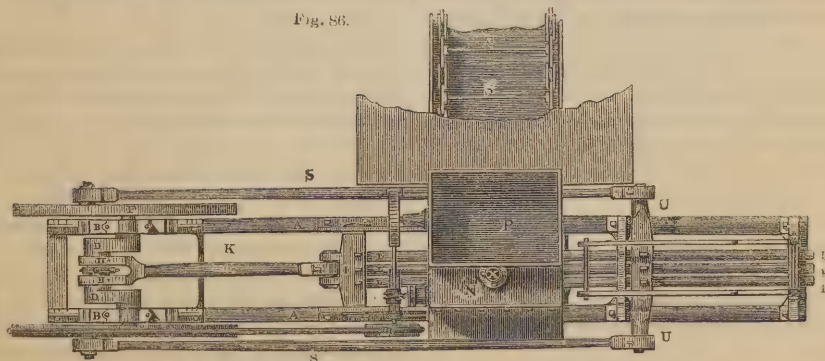
Fig. 85.



there supported by trunnions, working as usual in plummer-blocks bolted to the two frames, *v v*. In order to regulate the motion of the apparatus, fly-wheels, *F*, are keyed on to each end of the crank. A stout connecting-rod, *K*, is made with a double gib-head, *h h*, to receive motion from the same crank-throw. The other end of the connecting-rod, *K*, is jointed by a gib-head and pin to two lugs, which project from the stout cross-head, *I*; the ends of the cross-head slide in guides, *T T*, which are secured by bolts to the flange of the bed-plate. There are three plungers, *L L L*, keyed into the cross-head, and working in cylinder holes bored truly through the massive block of iron,

N, which is secured by bolts to the bed-plate by a flange, and keyed up between steps cast on the same. The upper part of the cylindrical block, *N*, has a large opening made in it, through the bottom of which the plungers, *M*, move. Immediately over this opening is the receptacle, into which the softened coal falls from the retort. Another set of plungers, *R R R*, work in the cylindrical holes of the block, *N*, at the opposite end to that occupied by *MMM*. Two guide-bars are bolted to the flange of the bed-plate, and have holes bored in them of sufficient size for the plungers, *R R R*, to work in. The latter are made large enough to work through both these guides, so that when they

Fig. 86.



are entirely withdrawn from their respective cylinders in the block, *N*, they will be so guided as to re-enter them without difficulty. The plungers, *R R R*, are keyed to a cross-head, *U U*, on the ends of which are fitted, with gib-heads, two long connecting-rods, *s s*, seen in Fig. 86, the opposite ends of which are likewise

furnished with gib-heads, and work on crank-pins, which project from one of the arms of each fly-wheel. These crank-pins are so placed with reference to the central crank-throw, that the latter forms an angle of 45° with them; that is, the one is the one-eighth part of a circle in advance of the other, and thus the action of

their respective plungers will be such, that they will alternately approach and recede from one another at the end of their respective strokes.

The motion of the chain and feeding drum is regulated by passing a strap over one of the fly-wheels; this strap works on the drum, *F*, on a shaft, *m*, which carries a worm that works upon the upper side of a wheel, keyed on to the shaft of the polygonal drum, *d*, Fig. 84; another worm works into the lower side of a wheel, keyed on to the axis of the feeding drum. From this description, the reader will understand how the steam piston, acting upon its crank, will put in motion the whole apparatus, and that this motion will be regulated by the fly-wheels; also the manner in which the cross-heads will be acted upon by their respective connecting rods, and likewise how the sets of plungers, *L L L* and *R R R*, are made to reciprocate in their respective ends of the block, *N*. Supposing the operation commences when the crank, *D*, and its connecting-rod are in a horizontal position, and the plungers, *L L L*, withdrawn as far as possible from the block, *N*; if one-eighth of the revolution be now made, the plungers, *L*, will be moved forward a little, and the crank-pins will have risen to the horizontal level, and brought the plungers, *R*, nearer towards the centre of the block, *N*. Upon turning the crank an eighth further, *L* will advance a considerable distance, being at half stroke, and at the same time the plungers, *R*, will have receded to their starting position. Here it must be observed, that the soft coal which was carried forward by the plungers, *L*, is compressed between the opposing ends of the two sets of plungers. In this position of *L* and *R*, there is a small space between them where any surplus quantity of coal may squeeze out, before it is made to enter the close part of the cylinder; after which they will approach a very little nearer to each other, and thus give the final pressure. If another eighth of a revolution is now made, the relative position of the crank and crank-pins will give a quicker motion to the plungers, *R*, which will commence receding from the plungers, *L*, and thus leave no pressure on the solidified lump of coal. If the pressure were not thus relieved, the lump of coal, as it merges from its cylindrical hole in the block, *N*, would be broken, there being no longer any circumferential support for it. Another eighth of a turn will complete a single stroke of the plungers, *L*, and have entirely expelled the block of coal, which then falls down into the receptacle, *t*, the plungers, *R*, having receded still further, and allowed ample space for the block of fuel to fall.

Another eighth of a revolution will commence the return stroke of the plungers, and by following on in the same way until one complete revolution is performed, the respective plungers will again have resumed their original position, and be ready to renew the operation.

If three plungers are made use of, as here represented, three blocks or cylinders of fuel, of equal length and diameter, will be formed at each complete stroke of the engine. As there is a tendency in the block of fuel to stick to the plungers, *L*, a detaching frame is placed at the end of the machine where the blocks are expelled.

This consists of thin bars of iron, fixed on an axis, the ends of which work in lugs on the guide bar, *U U*; the other ends of the bars are connected by a rod, and upon the cross-head there are bolted two small frames, which carry rollers, upon which the bars rest. When the cross-head, *s*, moves backward, and allows the blocks of coal to be projected outwards by the plungers, *L*, then the rollers will pass under the inclined part of the bars, and descend by their own weight, and the rod will come in contact with the blocks of coal, and detach them from the end of the plungers; if they should adhere, the reverse motion of the cross-head will again raise up the bars in readiness for a repetition of the process.

From what has been before stated in reference to the softening process by heat, it will have been understood that the coal-dust may be made to traverse the shelf, *cc*, where it will receive a preparatory heating, and afterwards traverse the bottom of the retort so quickly, as to produce such a slight effect upon the bituminous portion of the coal, as only to soften it a little, and render it fit for the operation of compressing into solid lumps possessing the general properties of the coal from which it is produced. One of the objects for which these operations are performed, is to alter and modify the composition of the resulting fuel, by driving off certain of the volatile constituents of the coal, and thereby rendering such fuel more fitted for certain processes in the arts than ordinary coal. To effect this object, the speed of the feeding and polygonal drums may be adapted so as to subject the coal to any assigned period of operation, and the intensity of the fire being also regulated, the extent to which the distillatory process is carried will be under perfect control. The gaseous matter eliminated from the coal, as it traverses the hottest part of the retort, over the fire-plate, *s*, will have to pass over the surface of the coal which is advancing in that direction, and help to heat it, while it also assists in transmitting caloric to the under side of the shelf, *cc*. Having contributed in this way to heat the materials, it ascends through an opening at the end of the furnace, and passes along over the coal-dust spread upon the shelf, and farther assists in heating it, and finally makes its escape through the pipe, *x*.

This pipe should have an elbow descending in the manner usually adopted in gas-works, and known as the hydraulic main. In this vessel the liquefiable portion of the volatile matters will be condensed, and the gas may be passed to a gasometer, where it may be stored for use. The fuel resulting from this partial distillatory process will be found to be less fusible in the furnace than ordinary raw coal, and consequently the caking in the furnace will be prevented. To divest the coal of as much of the volatile gases at as low a temperature as possible, an air-pump, constructed in the manner generally employed for exhausting sugar vacuum pans, is used. The pump is connected with the pipe, *x*, and by the application of steam or other motive power, the retort is kept in a state of exhaustion, which should, if possible, be equal to twenty-four or twenty-five inches of mercury in the barometer.

By this exhaustion, the liberation of the volatile gases from the cells and interstices of the fuel is facilitated.

and the residuary matter is rendered much more dense and compact when subsequently pressed. When the air-pump is used, the eduction valve must be made to communicate with the hydraulic main, so that the gaseous matters pumped out may pass off into the gasometer. Instead of applying fire directly to the under side of the retort, as shown in Fig. 84, superheated steam may be used for softening the fuel. When this plan is adopted, a set of cast-iron pipes are arranged in a furnace in the same way as is now commonly used for heating air and steam for blast and other purposes. Into one end of this series of heating pipes, the waste steam of the engine is allowed to pass, and the pipes being kept at a red heat, the steam will acquire a very high temperature, and in this state is to be supplied to the interior of the retort, to soften the coal. The retort, which may be constructed as already described, will not, in the event of steam being used, require any flue beneath it or fireplace, but it ought to be enveloped in brickwork, or some other non-conducting material, in order to retain the heat as much as possible. The steam-pipe should open into the retort at the hopper, *t*, the outlet for the waste vapor and gases being the pipe, *x*, leading to the hydraulic main and gasometer.

Besides these, several other patents have been obtained for the manufacture of patent fuel from waste combustible materials, many of which are but of little interest.

ANALYSIS OF FUELS.—Having explained, in the preceding pages, the nature of the more commonly occurring fuels, as well as the processes by which certain varieties of them are prepared, to render them better suited for particular uses, it remains only to describe briefly the methods of analysis which are usually followed when determining their constituents, and indicate the way by which their value, in point of heating effect and practical working in the furnace, may be arrived at.

There are various processes whereby the composition of wood, charcoal, *et cetera*, may be found. Many of these are so simple, that any person having only a partial knowledge of chemical manipulation, can conduct them with sufficient accuracy; several, on the contrary, require the experience of the advanced analyst to insure success. The examination, with reference to the quantities of carbonaceous and mineral matters, may be made by simply burning a weighed portion of the fuel in a tared crucible of platinum or porcelain till all blackness disappears, and only the white or brownish ash remains. The difference between the weight of the latter and that of the original substance, will give the proportion of combustible ingredients. But before an estimate of the value of a fuel can be formed, something more than the preceding is necessary; and this will be evident from the consideration of its different applications in the arts and manufactures. For instance, the charcoal or coke manufacturer is chiefly interested in the quantity of carbon which he can retain after modifying the wood, peat, or coal, by the action of heat; he has little regard to the quantity of volatile or liquid products which can be generated from them. The gas-maker, on the contrary, is mainly desirous to secure such materials as

will yield the largest volume of gas, whereas the liquid products of the distillation, and the coke, engage only a secondary part of his attention.

To find in the simplest and readiest way whether a fuel, such as coal, is best adapted for one or other of these applications, it is necessary, in the first place, to dry the weighed sample thoroughly, and to find, by again weighing it after desiccation, how much moisture it contained. The heat of a water-bath will serve for this purpose, but an air or oil-bath kept at a temperature of about 300° will answer better. Having determined the quantity of water, the weighed sample must next be subjected to a full red heat in a crucible carefully covered to exclude the air; and, for greater security, the latter is placed in a Hessian crucible, also covered, and containing calcined magnesia. The whole is then introduced into the furnace. The magnesia serves as a support for the crucible containing the substance to be examined, as well as to prevent contact with the outer vessel. The fire is raised to bright redness, and after being maintained at this temperature for an hour, the vessels are withdrawn from the fire, and the enclosed crucible taken out, wiped clean, and weighed. The loss which appears on weighing will represent the liquid and gaseous matters present, and the residue the coke or charcoal which the sample yields. If the per centage of mineral matters be already found, the quantity of carbon in the coke is estimated by deducting this per centage from that of the total amount of coke; but if the proportion of ash has not been ascertained, the crucible containing the coke is heated over a gas-lamp or in the muffle of a furnace, so arranged that a current of air shall circulate through it, till all the charcoal is consumed.

In this way, the quantity of moisture, of volatile matter—consisting of permanent gases and liquids—of coke, and of ash, which a fuel yields, is ascertained; and from them an average inference as to the value of the substance for the production of coke may be deduced, though not for gas-making, because it leaves doubtful how much of the volatile matter consists of inflammable gases, and how much of fluid products. When a very exact knowledge of a fuel is required, nothing short of an elementary analysis can be satisfactory; and this must be coupled with another, showing the quantities of the different products derived from the fuel, when acted upon by heat, out of contact with air. Even both these fail in some cases to give the information required in relation to many applications of the combustible.

By an elementary analysis, is understood the determination of the simple elements of matter entering into the composition of a substance. To enter fully into the particulars of such an analysis would rather confuse than enlighten the reader who may not be conversant with analytical chemistry, and those who are practised in organic analysis do not require a detailed description. A mere outline of the process will, therefore, be given. The first thing to be done is to rasp or abrade a portion of the substance into as fine a powder as possible. A certain weight of this powder is then to be desiccated either in the water-bath or over sulphuric acid in an exhausted receiver, or by

passing over it dry air partially heated. The loss in either case will indicate the moisture it had contained. About ten grains of the dried matter are then taken, and intimately mixed with eight or ten times the quantity of chromate of lead or oxide of copper in a heated mortar, and immediately introduced into a dry combustion tube of hard German glass. Care must be taken that the oxidizing agent, whether it be chromate of lead or oxide of copper, be subjected to a red heat immediately before its admixture with the combustible, to insure the absence of water; also, that twenty or thirty grains of dry chlorate of potassa are put into the inner part of the combustion tube, and an inch or two of the oxidizing agent, before the substance to be examined. Having rinsed the mortar with a fresh portion of the chromate or oxide, and added this to that in the tube, the latter is tapped in a horizontal position on the table, in order to form a channel in the upper part for the gases and vapors to flow over. A few fragments of copper turnings are placed in the front part of the tube, and then a little asbestos. Having introduced these, the mouth of the tube is secured by a cork fitted with a small piece of tubing for connecting it with a poised chloride of calcium tube, in which to intercept the water generated during the combustion. To the latter, another tube filled with a solution of caustic potassa, specific gravity 1.26, and commonly known as a LIEBIG'S apparatus, also previously balanced, is joined by means of a caoutchouc connector. The success of the experiment will very much depend on the connections of the various parts being quite secure. During the fitting of these parts, the tube may be placed in the combustion furnace. As soon as the several parts are carefully adjusted, a few fragments of ignited charcoal may be laid on the sealed end of the tube containing the chlorate of potassa, and after the air of the apparatus is replaced by oxygen, the combustion is commenced by applying red-hot charcoal to the front of the tube. Care must be taken that the development of gas be not too rapid, as in this case portions may escape absorption; neither, on the other hand, must it be too slow, lest a vacuum be formed in the combustion tube, causing a reflux of the solution of potassa, which would be fatal to the experiment. A steady even stream is kept up by extending the ignited charcoal to fresh parts of the tube as the evolution begins to slacken. After that part of it containing the combustible has been brought to a red heat, and no more gas is evolved, the fire is applied gently to the part containing the chlorate of potassa, so as to produce a gradual stream of oxygen gas, the combustion tube being still kept at a red heat. This has the effect of forcing over into the absorbing apparatus any carbonic acid and aqueous vapor which may remain, and at the same time insure the entire combustion of any particles of charcoal that may not have been exposed to the full heat. Finally, the closed point of the tube is broken, and a U-shaped tube containing fragments of pumice-stone, saturated with sulphuric acid in one limb, and pieces of hydrate of potassa in the other, is connected with it; suction is then applied at the open limb of the potassa apparatus, to draw over all carbonic acid and moisture; after which the chloride of calcium tube and bulbs are

detached and reweighed, and the increase in each case noted carefully, as from this the carbon and hydrogen of the substance is calculated.

The calculation is founded upon the data afforded by the composition of water and carbonic acid—namely, that nine parts of the former contain exactly one of hydrogen, and twenty-two parts of the latter six parts of carbon. All the water resulting from the combustion of the hydrogen with the chromate of lead, *et cetera*, is retained in the chloride of calcium tube, and the whole of the carbonic acid, generated under similar circumstances, is absorbed in the bulbs; hence, when due care has been exercised, the results are very accurate. Sometimes a second chloride of calcium tube is attached to the apparatus for absorbing the carbonic acid, when the amount of nitrogen in the sample is appreciable, with the view of arresting the aqueous vapor which this non-condensable gas carries with it from the potassa liquor. It will be evident, indeed, that, in almost all cases, this precaution ought to be adopted; for even when no nitrogen is contained in a substance submitted to organic analysis, the air drawn over at the termination of the combustion becomes loaded with moisture in passing through the bulbs, and so far the weight of the latter is reduced, on which account the amount of carbon found is less than the true quantity; but by attaching a second chloride of calcium tube, filled with fragments of this salt after being fused, and which should be weighed before and after the operation, and adding the gain to that of the bulbs, this error may be prevented.

Instead of compounding the substance with a solid oxidizing agent as in the manner described, it may be introduced at once, provided it has been previously dried, into the combustion tube in a tolerably coarse state, and a stream of pure dry oxygen gas passed over it. The tube should be open at both ends, one of which is to be put in connection with the reservoir of oxygen, and the other attached to the usual absorbing media. It is necessary that the oxygen be entirely free from carbonic acid and moisture, and for the greater safety it should be transmitted through a U-tube, holding in one limb fragments of fused chloride of calcium, and in the other pieces of solid potassa, before entering the combustion tube. In this process it is absolutely essential that the potassa apparatus should have a chloride of calcium tube connected with its escaping limb, otherwise the excess of oxygen would carry with it considerable quantities of aqueous vapor, and so reduce the indication from which the carbon is to be calculated. Connection of the several parts being made, a gentle stream from the reservoir is allowed to flow through till all the air is displaced. As soon as this happens, heat is applied to the tube by placing incandescent charcoal around it in the usual progressive way, the current of oxygen being still maintained, till it assumes a red heat, or nearly so, and it is kept in this state till all the carbonaceous matter of the substance operated upon is consumed. Gas may be very advantageously substituted for charcoal in conducting an operation of this kind. When all combustible matter is eradicated from the tube, the fire is slackened, and the current of oxygen maintained for a short time. The parts for

absorbing the water and carbonic acid eliminated during the foregoing process are detached, wiped, and balanced, as already detailed, and the hydrogen and oxygen are calculated from their augmentation in weight.

To estimate the nitrogen, a second combustion is in some cases requisite. When the quantity is ascertained volumetrically, the work may be accomplished at one combustion, by establishing a connection between those parts in which the hydrogen and carbon are retained as water and carbonic acid, and an apparatus for measuring the gas. A long combustion tube is required in this instance, so as to admit of a few inches of it being filled with copper turnings, to decompose any bin oxide of nitrogen which may be produced during the action of the heat. The nitrogen traverses the chloride of calcium tubes as well as the potassa bulbs, and finally enters the graduated tube, and displaces the mercury with which it is filled. When the operation is finished, some oxygen is generated from the chromate of potassa, in order to force over all the nitrogen and other gases remaining in the apparatus. A portion of this oxygen enters the graduated jar or tube, and must be removed before reading off the volume of nitrogen. For this purpose, after reading off the volume of mixed gases, a quantity of hydrogen equal in bulk to this mixture should be added, and as soon as diffused a measured portion should be transferred into an eudiometer, and exploded by the electric spark. By noting the reduction in the portion taken, the quantity or volume of oxygen in the whole may be ascertained, from the knowledge that one-third of the decrease is oxygen. Deducting the volume of oxygen thus found from that of the mixed bulk of oxygen and nitrogen, the remainder will be the volume of the latter in the portion of the substance submitted to combustion, and from which the weight is deduced, since, at a barometric pressure of thirty inches and a temperature of 60°, the weight of one hundred cubic inches of nitrogen is 29.2914 grains.

WILL and VARRENTRAP's method is a considerable improvement upon the system of analysis pursued in the determination of nitrogen, inasmuch as it dispenses with the use of mercurial troughs, graduated measures, barometers, thermometers, *et cetera*; it is besides much simpler and less laborious, for whilst numerous corrections have to be made for temperature, pressure, and the like in the old process, by this the work is most accurately performed by simply weighing. It is based upon the property which the fixed alkalies have, of converting nitrogen, in whatever state it is contained in a substance, into ammonia, when aided by heat. The ammonia is fixed by an acid—generally hydrochloric—and subsequently in the form of ammoniochloride of platinum, which is collected, dried, and weighed, and the nitrogen calculated therefrom; 222.5 parts of the salt representing fourteen parts of the gas.

The agent used for the conversion of the nitrogen into ammonia is soda-lime, which is prepared by slaking caustic lime with a concentrated solution of hydrate of soda. The compound should be thoroughly dried, and kept in well-stoppered bottles. In the cold it does not

act upon the nitrogenous element of the substance to be analysed, and, therefore, both bodies may be mixed in a mortar, provided they are thoroughly dry, without any fear of ammonia being disengaged or loss occasioned. The ordinary combustion tube answers the purpose, and the course to be pursued is the same as that already mentioned for mixing the ingredients and heating, *et cetera*. The details of the estimation of the ammonia, quantitatively, have been already stated at page 198, Vol. I., to which the reader is referred.

The modification of this process, introduced by ULLGREN, may be advantageously noticed here. The combustion with the soda-lime is essentially the same in this as in the preceding operation; the only difference lies in the manner of condensing the ammonia adopted by this chemist. Fig. 87 represents the form of apparatus employed. In this cut, A and B are two U-shaped tubes, in the first of which the connector from the combustion tube opens; the upper portion of the first limb of the part A is charged with a plug of asbestos, *a*, and in the remainder, *b*, small pieces of hydrate of potassa are placed; fragments of glass occupy the bend, *c*, and the second limb, *d*, is filled with little lumps of caoutchouc. A tube, *e*, bent at right angles, and passing through perforated airtight corks, connects A

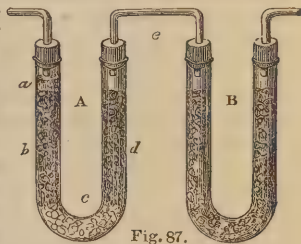


Fig. 87.

with B, which is filled with dry sulphate of zinc, and which should be accurately weighed before the experiment. The asbestos in the portion *a* prevents solid particles from passing by the force of the vapor upon the potassa; the latter absorbs the carbonic acid and water, leaving the ammoniacal vapor and hydrocarbon gases to traverse further; the pieces of caoutchouc take up the combustible products, so that only the ammonia enters the tube B, where it is completely absorbed by the zinc salt. To insure accuracy in this operation, it is directed that the part A be immersed in water marking 170° before and after the experiment, so that any ammoniacal vapors contained in it may be driven over to B.

By weighing the tube B after the whole of the volatile alkali has been taken up, the increase of weight will show the quantity of ammonia produced, and from this the nitrogen is found, for seventeen parts by weight of the dry ammoniacal gas represent fourteen of nitrogen.

Having, by one or other of these processes, arrived at the knowledge of the quantity of carbon, hydrogen, and nitrogen contained in the fuel, the oxygen, if any, will be the difference between the combined weight of the three, and that of the entire organic or combustible matter. Sometimes, however, it is necessary to consider the sulphur in the analysis of coals, when this element is present in appreciable quantity; because, during the combustion of the substance in the air, it becomes oxidized, and passes off with the carbonic acid and water as sulphurous acid. Its quantity may

be determined by deflagrating a known weight of the coal with about two parts of nitre, and eight or ten of chloride of sodium, care being taken that both compounds be free from sulphuric acid; the sulphur is by this means oxidized into sulphuric acid, which becomes fixed by combining with the base of the nitre. By washing the mass with water, precipitating the acidified solution by chloride of barium, collecting the sulphate of baryta, and drying, burning, and weighing the latter, the quantity of sulphur may be calculated. About five-eighths of the portion of sulphur should be deducted from the oxygen or loss expressed in the foregoing, and the difference taken as the true value of the oxygen contained in the compound.

Although the ultimate analysis gives a comprehensive insight into the nature of a fuel, and likewise a means of finding its heating power theoretically; still it leaves much to be desired in practice to enable one to form a correct estimate of its actual heating effect in manufacturing operations. Many circumstances concur to render the amount of work which a given quantity of fuel will perform, less than theory indicates—the principal cause of the discrepancy being the want of such an arrangement of furnaces, as that the whole of the caloric should be directed to, and actually enter into, the performance of the work to be done. This is a desideratum which can scarcely be expected to be attained in so complete a manner as to yield practical results, agreeing exactly with calculations founded on the nature of the fuel; the closer, however, that one can approach to this standard the greater will be the economy realized, and the nearer will the practical results coincide with the deductions of theory.

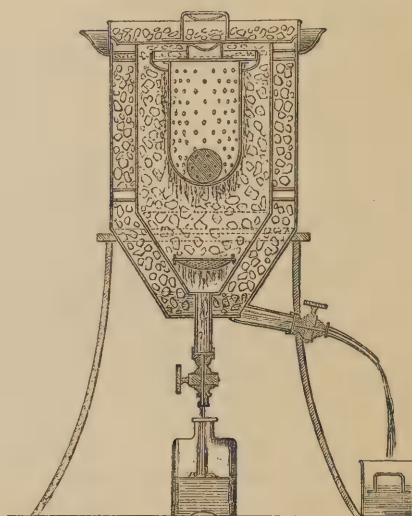
To arrive at an exact knowledge of the actual quantity of heat which a fuel ought to produce by combustion is impossible, no means being at hand for insuring definiteness to the result; but when, as in the determination of the atomic equivalent of a body, an arbitrary standard is taken, and the quantity of heat which other bodies produce is estimated with relation to such a standard, a comparative measurement is arrived at, which, though not expressing the absolute amount of heat produced, serves all the requirements of the arts. The arbitrary standard assumed, is the quantity of the fuel required to raise the temperature of a given weight of water a certain number of degrees, or the quantity of water which a given weight of the fuel or combustible will raise one degree. This amount, whatever it may be, is taken as the unit of heating power, and the number of such units, or the fractions thereof, which an equal weight of any particular fuel indicates by experiment, is taken as the heating or calorific power of that combustible.

ESTIMATION OF HEATING POWER.—Several investigators have bestowed considerable attention upon the subject of the quantity of caloric developed by the combustion of different substances. LAVOISIER, LAPLACE, and RUMFORD, were the first to enter this field, and the research has been prosecuted with increasing success by several others, down to the recent investigations of DESPRETZ, DULONG, and ANDREWS. The

principle upon which one and all founded their experiments, was that of determining the effect produced upon a third body by the heat given out during the union of the combustible under examination with oxygen.

In the experiments of LAVOISIER and LAPLACE, the body employed for this purpose was pounded ice, which was so applied around a balloon as to intercept all the heat. Fig. 88 shows a section of their apparatus, which they termed a *calorimeter*. The heating power

Fig. 88.



was estimated in this case from the quantity of water produced by the melting of the ice, and which flowed into the receivers, as seen in the engraving. These philosophers determined the amount of heat requisite to melt one pound of ice, as being sufficient to raise the same weight of water at 32° to 135°, or 103 pounds of water one degree. The more accurate experiments of PREVOSTAYE, DESAINS, REGNAULT, and others, as stated in a preceding part of this article—Vol. II., page 20—have shown that the heat which melts one pound of ice is sufficient to raise an equal weight of water to 142°, or seven degrees higher than was estimated by LAPLACE and LAVOISIER.

A moment's consideration of this method will convince the reader that it was liable to lead to wrong results, because it was impossible to recover the whole of the water produced by the liquefaction of the ice. This is the principal reason why the numbers given by these original investigators are too low. RUMFORD substituted water for the ice, the increase of the temperature of which, after the absorption of the caloric, as indicated by a delicate thermometer, was taken as the measure of the heating power of the substance tested. Many improvements have been made on RUMFORD'S method, which is now generally followed in the prosecution of these inquiries. The heating value of any substance is estimated from the number of pounds or parts of a pound of water, which one pound weight of the substance to be tried will

raise one degree of Fahrenheit. The following table shows the results arrived at by different experimenters:—

Name of Combustible.	Symbol.	Symbol of product of combustion.	Pounds of water raised 1° by one pound of substance or units of heat.	Pounds of water raised 1° when one pound of oxygen combines with the combustible.	Authorities.
Hydrogen,.....	H	HO	20,624	2,578	Despretz.
			23,640	2,955	Despretz.
			21,375	2,672	Lavoisier.
			24,000	3,000	Dalton.
			34,743	4,343	Dulong.
			34,792	4,349	Hess.
			36,000	4,500	Crawford.
			34,666	4,333	Grassi.
			34,662	4,333	Favre and Selbermann.
			33,808	4,226	Andrews.
			3,000	1,125	Dalton.
			5,175	1,941	Crawford.
			5,325	1,997	Rumford.
			7,167	2,688	Dulong.
Carbon,	C	CO ₂	7,237	2,714	Lavoisier.
			7,815	2,931	Despretz.
			7,912	2,967	Despretz.
			7,714	2,893	Grassi.
			7,900	2,962	Andrews.
			1,875	3,031	Dalton.
Carbonic oxide,	CO	CO ₂	2,634	4,609	Dulong.
			1,854	3,214	Grassi.
			2,431	4,254	Andrews.
			4,500	3,532	Dalton.
Phosphorus,	P	PO ₅	7,500	5,696	Lavoisier.
			5,747	4,509	Andrews.
			1,500	1,500	Dalton.
Sulphur,	S	SO ₂	2,571	2,571	Hess.
			2,601	2,601	Dulong.
			2,307	2,307	Andrews.
Antimony,	Sb	Sb O ₃	961	5,875	Dulong.
Zinc,	Zn	Zn O	1,314	5,290	Dulong.
			1,301	5,366	Andrews.
Tin,	Sn	Sn O ₂	1,233	4,545	Dulong.
			1,144	4,230	Andrews.
Protoxide of tin,	Sn O	Sn O ₂	534	4,473	Dulong.
			521	4,349	Andrews.
			1,702	4,340	Dulong.
Iron,	Fe	Fe ₃ O ₄	2,088	5,325	Despretz.
			1,576	4,134	Andrews.
Cobalt,	Co	Co O	1,080	3,995	Dulong.
Nickel,	Ni	Ni O	1,006	3,723	Dulong.
Copper,	Cu	Cu O	632	2,512	Dulong.
			602	2,394	Andrews.
Suboxide of copper,	Cu ₂ O	2 Cu O	244	2,185	Dulong.
			256	2,288	Andrews.
Cyanogen,	C ₂ N	2 CO ₂ , N	5,195	4,241	Dulong.
			6,375	1,594	Dalton.
			13,185	3,296	Dulong.
Marsh gas,	C H ₂	CO ₂ , 2 HO	11,098	2,774	Grassi.
			13,158	3,289	Favre and Selbermann.
			13,108	3,277	Andrews.
			6,600	1,925	Dalton.
			12,030	3,296	Dulong.
Olefiant gas,	CH	CO ₂ , HO	8,436	2,461	Grassi.
			11,900	3,471	Favre and Selbermann.
			11,942	3,483	Andrews.
			4,350	2,084	Dalton.
			6,750	3,234	Rumford.
Alcohol,	C ₄ H ₆ O ₂	4 CO ₂ , 6 HO	6,909	3,311	Dulong.
			6,566	3,146	Grassi.
			7,183	3,442	Favre and Selbermann.
			6,850	3,282	Andrews.
			4,650	1,792	Dalton.
Ether,	C ₄ H ₅ O	4 CO ₂ , 5 HO	8,025	2,093	Rumford.
			9,431	3,634	Dulong.
			9,027	3,480	Favre and Selbermann.
			5,839	3,893	Grassi.
Wood spirit,	C ₂ H ₄ O ₂	2 CO ₂ , 4 HO	5,304	3,536	Favre and Selbermann.
Fousel oil,	C ₁₀ H ₁₂ O ₂	10 CO ₂ , 12 HO	8,959	3,285	Favre and Selbermann.
Amylic ether,	C ₁₀ H ₁₁ O	10 CO ₂ , 11 HO	10,188	3,353	Favre and Selbermann.
Acetone,	C ₃ H ₃ O	3 CO ₂ , 3 HO	7,320	3,317	Favre and Selbermann.
Rock oil,	C H	CO ₂ , HO	7,335	2,139	Rumford.
			4,500	1,339	Dalton.
Oil of turpentine,	C ₅ H ₄	5 CO ₂ , 4 HO	10,496	3,187	Grassi.
			10,874	3,301	Favre and Selbermann.
Oil of lemons,	C ₁₀ H ₈	10 CO ₂ , 8 HO	10,663	3,237	Favre and Selbermann.
Terebene,	C ₁₀ H ₈	10 CO ₂ , 8 HO	10,959	3,327	Favre and Selbermann.
Camphor,	C ₁₀ H ₈ O	10 CO ₂ , 8 HO	5,250	1,847	Dalton.

Name of Combustible.	Symbol.	Symbol of product of combustion.	Pounds of water raised 1° by one pound of substance or units of heat.	Pounds of water raised 1° when one pound of oxygen combines with the combustible.	Authorities.
Olive oil,	$C_{10}H_8O$	$10CO_2, 8HO$	6,675	—	Crawford.
			7,800	—	Dalton.
			9,045	—	Rumford.
			9,862	—	Dulong.
			11,100	—	Lavoisier.
			9,300	—	Rumford.
			7,800	—	Dalton.
			8,370	—	Rumford.
			7,273	—	Crawford.
			7,800	—	Dalton.
			9,472	—	Rumford.
			9,975	—	Lavoisier.
			2,105	—	Dalton.

The fifth column in the preceding table has been given, as having reference to a law propounded by WELTER, namely, that all combustible bodies disengage the same amount of heat during their combination with the same weight of oxygen; or, in other words, that the caloric developed was proportionate to the amount of oxygen assimilated during the combustion. WELTER founded this theory upon the results of LAPLACE, LAVOISIER, DESPRETZ, RUMFORD, and others, which must be admitted to be less trustworthy than those obtained by DULONG, GRASSI, ANDREWS, and other modern investigators; and it will be seen that when the numbers of the latter are adopted, the relation sought to be established does not hold good. To give one instance: hydrogen combines exactly with three times the quantity of oxygen that carbon takes up, and so from WELTER's theory the heat developed should be three times greater when hydrogen is burned, than when an equal weight of pure carbon is subjected to the same process; but from the results of the last-mentioned chemists, the ratio is between one to four and one to five. This wide difference is only observable, however, with combustibles very dissimilar in their nature, for when they approach to identity in physical appearance, as wood, peat, and coal, the estimation of the oxygen taken up gives an average indication of the heating power of the substance, which, without being absolutely correct, will answer most purposes.

BERTHIER has founded a system of analysis upon this theory, by which the oxygen is estimated, and therefrom the heating power of the fuel deduced. It is easy and expeditious, and may, under the foregoing circumstances, be occasionally adopted. He mixes a weighed portion of the finely-powdered fuel with thirty to forty times its weight of oxide of lead—litharge—and introduces the compound into a fireclay crucible, pressing it gently, and covering the whole with a thick layer of the litharge. The crucible is then carefully closed, and placed on the fire, where it is gently heated till the whole of the carbon and hydrogen is burned. During this process, the mass, being semifluid, is considerably distended by the carbonic acid and water, resulting from the combination of the elements of the fuel with the oxygen of the metallic oxide; towards the end of the operation, therefore, the fire should be quickened, and as soon as the crucible has attained a bright redness, it should be taken out, and its bottom struck gently against a stone or piece of iron, so as to cause the particles of reduced metal to accumulate and form a button. As soon as cold the crucible is broken,

and the metal, coated with oxide of lead and slags from the ashes of the fuel, is abstracted. It is cleaned from the adhering impurities by a few blows of a hammer upon the anvil, and subsequent brushing, after which it is weighed. From the number thus found, the oxygen required for the combustion of the fuel is calculated, since it is derived from the oxide of lead—a definite compound of equivalent proportions of lead and oxygen. When pure carbon is operated upon in this way, it has been found that about thirty-four and a half times the weight of the sample of metallic lead has been obtained. This amount of metal stands in a definite relation to the oxygen entering into the combustion, and, consequently, according to the law propounded, to the heating power of the fuel also; for, supposing a certain weight of metal to be produced, the following ratio will give the heating power of the fuel: namely, as the metal obtained when operating with pure charcoal is to that reduced by the substance under experiment, so is the number expressing the units of heat of carbon to that of the fuel. For instance, the weight of metal obtained with pure charcoal is 34·5; allowing that with the subject of the experiment to be twenty; and taking ANDREWS' determination, or seven thousand nine hundred, to represent the heating power of the charcoal, while x represents the unknown heating power of the fuel; then,—

$$34\cdot5 : 20 :: 7900 : x.$$

$$\text{Or, the heating power } x = \frac{20 \times 7900}{34\cdot5} = 4580$$

nearly. If in a substance of a complex nature, such as wood, peat, coal, *et cetera*, the hydrogen and oxygen are in such a ratio as to form water by their combination, it is evident that the average result of the lead assay will approximate to the truth; but where this is not the case, and a quantity of hydrogen is present without oxygen to combine with it, the accuracy of the experiment is less to be depended on, because the heating equivalent of the former element is taken as if it were carbon, whereas it is shown by the foregoing table to be much higher. When great exactness is required, it is evident that the heating power must be determined from the elementary analysis of the substance and the estimated calorific power of the constituents. This may be done with considerable accuracy, since it does not alter the amount of heat developed, whether the combustion be effected under the influence of a concentrated stream of oxygen gas, or in ordinary

air. The method of performing the calculation is very simple. Supposing the elementary composition of the fuel examined to be as follows:—

	Per cent.
Carbon,	86.48
Hydrogen,	3.04
Oxygen,	7.10
Ashes,	3.38
	100.00

it would be necessary to deduct from these numbers the oxygen, and the equivalent of hydrogen which combines with it, and to account as available for raising the temperature only the remaining hydrogen and carbon. In the above analysis the equivalent of hydrogen which will unite with the oxygen of the substance, will

be $\frac{7.10}{8} = 0.8875$, which, when deducted from 3.04,

leaves 2.1525 as the weight of hydrogen which goes to generate heat. According to ANDREWS' numbers in the foregoing table, the units of heat which this

would produce may be expressed thus: $\frac{2.1525}{100} \times 33808 = 727.7$, and in like manner the carbon may

be valued, $\frac{86.48}{100} \times 7900 = 6833.9$; making together

$727.7 + 6833.9 = 7559.6$ as the heating power of the fuel. In the same way may the value of any other kind of fuel be found.

Having the expression of the units of heat generated, it is easy to find the thermometric temperature which it produces; to do this, however, involves the necessity of knowing the quantity of air required for consuming the matter, and likewise the specific heat of the products. It is well known that air is composed of seventy-seven parts of nitrogen and twenty-three of oxygen, of which constituents only the latter is available in combustion. Having a knowledge of the proportionate quantity of oxygen required to burn the combustible elements, the volume of air containing this proportion may be readily found. Thus, every part of carbon combines with 2.66 of oxygen, which is yielded by 11.59 of atmospheric air; upon similar grounds, the air required for the combustion of hydrogen is 34.78 parts. In both cases, the products are carbonic acid, water, and nitrogen, the weight of which may be ascertained from the data given. Now the heat produced by the combinations of these distributes itself among the gases, so that they all indicate the same temperature, and which can be estimated, since the specific heat of these bodies is known. The number thus obtained, and which represents the temperature of combustion, varies, however, with the nature of the fuel; and still, owing, perhaps, to the specific heat of the gases at a high temperature, the results should be viewed only as an approximation.

As an example of the calculation of the pyrometrical heating power of a fuel, that already submitted may be again taken. It has been shown that the absolute heating effect of this specimen is 7559.6 units of heat, and that 0.8875 of the hydrogen contained in it is taken up by the oxygen, leaving 2.1525 of that element to undergo combustion with extraneous oxygen. It has been likewise stated that 11.59 parts of atmo-

spheric air are required for the complete combustion of one of carbon, and, upon the same grounds, that hydrogen requires 34.78; hence the weight of air required to convert the carbon and hydrogen of the fuel into carbonic acid and water would be—

$11.59 \times 86.48 = 1002.3$ parts for the carbon, and
 $34.78 \times 2.1525 = 74.8$ „ hydrogen;

making a total of 1077.1.

From these } 326.5 parts of carbonic acid,
 are produced }

19.37 „ water, and

819.88 „ nitrogen, to which it

is necessary to } 8.00 „ water, formed by the
 add }

union of the oxygen of the fuel with a portion of its hydrogen; thus making a total of $27.37 = 19.37 + 8.0$ parts of water. The specific heat of carbonic acid being 0.221, the amount of caloric required to raise 326.5 parts 1° would be $326.5 \times 0.221 = 62.16^\circ$

The specific heat of aque- } $27.37 \times .847 = 23.18^\circ$
 ous vapor is 0.847; hence, }
 the coefficient for nitro- } $819.88 \times 0.273 = 223.80^\circ$
 gen is 0.273; therefore, }

309.14

This number expresses the total amount of heat carried off by the products of the combustion of one hundred parts of the fuel; hence,

$$7559.6 \div \frac{309.14}{100} \text{ or } \frac{7559.6 \times 100}{309.14} = 2445.3;$$

which number represents the thermometrical heating effect of one part. In this calculation the specific heat of the ash has not been taken into account; but the quantity of caloric lost in this way is so insignificant, that the results are but very slightly affected by it.

Pursuing the same course, the pyrometrical heating effect of any other kind of fuel or combustible, however numerous its ingredients, may be ascertained; that is, by finding the absolute heating power by the formula already given for the purpose, and dividing it by the sum of the specific heat of the products multiplied by their total weight, the quotient will be the available heat for any particular work when the fuel is burned.

It may here be remarked, that when a fuel is consumed in oxygen gas, the pyrometrical effect is much greater than when the combustion takes place in ordinary air, although the units of heat are the same in both cases. The difference of effect arises from the fact, that the nitrogen of the air passing through the fire in considerable quantities, renders latent a large amount of heat—the difference between the indication in oxygen and air.

The following table shows the heating effect of a few combustibles, as well when burned in oxygen gas as in air, calculated according to the above formula:—

Pyrometrical Heating Power.			
Name.	Symbol.	In Oxygen.	In Atmospheric Air.
Carbon,	C	9753°	2450°
Carbide of hydrogen,	C H	4944	2286
Ether,	C ₄ H ₆ O	4035	2070
Light carbide of hydrogen,	C H ₂	4703	2273
Alcohol,	C ₂ H ₅ O, H O	3407	1870
Hydrogen,	H	3491	2248

		Heating Effect.			
COAL.		Absolute.	Specific.	Pyrometrical.	
Sand coal, ..	} with five per cent. of moisture and five per cent. of ash,	0.79	1.06	2200	
Sinter,		0.89	1.16	2250	
Caking,		0.93	1.17	2300	
Anthracite, ..		0.96	1.44	2350	
WOOD CHARCOAL.					
Air-dried black charcoal, with twelve per cent. of moisture and three per cent. of ash,		0.97	—	2450	
Perfectly dried black charcoal, with three per cent. of ash,		0.84	—	2350	
Air-dried red charcoal, with ten per cent. moisture and one and a-half per cent. ash, ..		0.72	—	2200	
Perfectly dry red charcoal,		0.64	—	2100	
Birch,	} no moisture, and three per cent. of ash,	—	0.20	—	
Ash, wild service,		—	0.19	—	
Red beech, white beech, elm,		—	0.18	—	
Red fir,		—	0.17	—	
Maple,		—	0.16	—	
Oak, pear tree,		—	0.15	—	
Alder,		—	0.13	—	
Lime,		—	0.10	—	
PEAT CHARCOAL.					
Worst description of air-dried peat charcoal, with ten per cent. moisture and fifty-six per cent. ash,		0.85	—	2050	
Best air-dried peat charcoal, with ten per cent. moisture and four per cent. ash,		0.83	—	2350	
COKE.					
Good coke, with ten per cent. moisture and five per cent. ash,		0.84	—	2350	
Best " five " three per cent. ash,		0.92	—	2400	
Ditto, with no moisture and three per cent. ash,		0.97	—	2450	
Sand coal coke,	} no moisture and five per cent. of ash,	—	0.46	—	
Sinter coal " ..		—	0.41	—	
Caking " " ..		—	0.33	—	
GASEOUS COMBUSTIBLES.—FURNACE GASES.					
Gases from wood charcoal, A,		0.108	0.000140	1675	
" " B,		0.080	0.000104	1450	
Gases from coke,		0.107	0.000139	1750	
" coal,		0.205	0.000267	1850	
GENERATOR GASES.					
Gases from wood charcoal,		0.115	0.000150	1775	
Gas from wood, I,		0.136	0.000177	1850	
" " II,		0.124	0.000161	1575	
Gas from turf,		0.092	0.000120	1525	
Gas from coke,		0.110	0.000143	1775	

It is assumed that the whole of the combustibles named in this table are consumed, but in practice this never happens; hence, the heating effects given are higher than would be found to result when performing actual service; further, it is taken for granted that the combustion takes place in the shortest possible period of time, and that whilst it lasts, an equal amount of caloric is evolved each instant, a condition never fulfilled in the furnace. The discrepancy produced by both these sources of error, between the practical results and theoretical calculations, is to some extent

counteracted by the high temperature required to commence the combustion.

Having alluded to the process published by BERTHIER for the determination of the heating power of a fuel, the following tables are submitted as the results of his investigation; and although it will appear from what has been said in reference to WELTER's theory, that these results, from being founded upon it, are not quite correct, yet they may be useful as a close approximation to the pyrometric values of the substances mentioned:—

I.—WOOD.

Species of Wood.	Dried in the ordinary manner. Berthier.		Containing nine per cent. of water. Winkler.		Perfectly dried. Schodler and Peterson.		
	Pounds of lead reduced by one pound of wood.	Pounds of water which one pound can heat from 32° to 212°.	Pounds of lead reduced by one pound of wood.	Pounds of water heated from 32° to 212° by one pound of wood.	Pounds or oxygen required for the complete combustion of one pound of wood.	Pounds of water heated from 32° to 212° by one pound.	Air at 66° Fahr. required to consume one pound of wood.
							in pounds. Hessian. in C. F.
Oak,	12.5	28.3	14.05	31.82	1.358	39.82	5.83 154.4
Ash,	—	—	14.96	33.89	1.356	39.76	5.82 154.2
Sycamore,	13.1	29.7	14.16	32.07	1.394	40.85	5.98 148.4
Beech,	13.7	31.0	14.00	31.71	1.346	39.44	5.78 152.9
Birch,	14.0	31.7	14.08	31.90	1.356	39.73	5.82 153.0
Elm,	—	—	14.50	32.84	1.418	41.55	6.08 161.1
Poplar,	—	—	13.04	29.54	1.390	40.72	5.96 157.9
Lime-tree,	—	—	14.48	32.80	1.429	41.87	6.13 162.3
Willow,	—	—	13.10	29.67	1.352	39.61	5.80 153.6
Fir,	14.5	32.8	13.86	31.39	1.408	41.25	6.04 160.0
Pine,	13.7	31.0	13.88	31.44	1.392	40.82	5.98 158.2
Scotch fir,	—	—	13.27	30.06	1.393	40.85	5.98 158.3
Hornbeam,	12.5	28.3	—	—	—	—	—
Alder,	13.7	31.0	—	—	—	—	—
Larch,	—	—	—	—	1.408	41.25	6.04 160.0

II.—CHARCOAL.

Species of Charcoal.	Berthier.		Winkler.		Air required for perfect combustion.
	Pounds of lead reduced by one pound of charcoal.	Pounds of water heated from 32° to 212° by one pound of charcoal.	Pounds of lead reduced by one pound of charcoal.	Pounds of water heated from 32° to 212° by one pound of charcoal.	
Commercial.	Poplar charcoal,.....	30.60	On an average 68	33.50	On an average of 293.5 C. F. Air at 66° Fahr.
	Sycamore ".....	30.60		33.23	
	Ash,.....	29.60		33.23	
Enclosed in bottles immediately after being made.	Aspen,.....	29.50	On an average 72	—	
	Fir,.....	32.30		33.51	
	Alder,.....	32.40		—	
	Birch,.....	31.40	On an average of 75.7	33.71	
	Oak,.....	31.30		33.74	
	Beech,.....	—		33.57	
	Elm,.....	—		33.26	
	Lime-tree,.....	—		32.79	
	Willow,.....	—		33.49	
	Pine,.....	—		33.53	
	Scotch fir,.....	—		33.62	

III.—PEAT.

Source of Peat.	Pounds of lead reduced by one pound of peat.	Pounds of water heated from 32° to 212° by one pound of peat.	
Peat from Troyes,.....	8.0	18.1	
" Ham, dép. de la Somme,....	12.3	27.9	Berthier.
" Passy, dép. de la Marne,....	13.0	29.2	
" Framont, dép. de la Vosges,...	15.4	34.9	Winkler.
" Ischoux, dép. Landes,.....	15.3	34.6	
" Königsbrunn, Wirtemberg,...	14.3	32.4	Griffiths.
Among twenty-four sorts from Hartz } Mountain, the worst gave.....	11.9	26.9	
The best gave.....	18.8	42.6	
From Allen in Ireland.			
Upper peat,.....	27.7	62.7	
Lower peat,.....	25.0	56.6	
Pressed peat,.....	13.7	28.0	

IV.—PEAT CHARCOAL.

Source.	Pounds of lead reduced by one pound of charcoal.	Pounds of water heated from 32° to 212° by one pound of charcoal.	
Crouy sur l'Ourocq, depart. Seine et Marne,.....	17.7	40.1	
Seine et Ham,.....	18.4	41.7	Berthier.
Essone, much used in Paris,.....	22.4	50.7	
Framont, and peat from Champ de Fue,...	26.0	58.9	

V.—BROWN COAL.

Locality.	Pounds of lead reduced by one pound of coal.	Pounds of water heated from 32° to 212° by one pound of coal.	
Gemünde Dauphin, Basses Alpes,....	25.3	57.3	
St. Martin de Vaud, Canton de Vaud,...	22.6	51.2	Berthier.
Minerme, département de l'Aude,....	22.8	51.6	
Gardanne, Bouches du Rhône,.....	22.0	49.8	Winkler.
Fuveau,.....	21.0	47.6	
Enfant Dort,.....	21.0	47.6	Griffiths.
Koep Fuarch, lake of Zurich,.....	20.7	46.9	
St. Lon, Basses Pyrenees,.....	20.3	46.0	Berthier.
Val. Pineau, dép. Sarthe,.....	19.25	43.6	
Common German,.....	18.40	41.7	Winkler.
Edon, dép. de la Charente,.....	17.0	38.5	
Alpheus, Greece,.....	16.3	36.9	Berthier.
Triphilis, ".....	16.3	36.9	
Kum, ".....	15.8	38.8	Winkler.
Elbogen, Bohemia,.....	18.2	41.2	
Brown coal from Meissner,.....	20.1	58.9	Kühnert.
Pitch coal ".....	15.9	46.6	
" Ringkuhl,.....	16.9	49.5	Berthier.
" Habichtswald,.....	16.0	46.9	
Glance coal from Ringkuhl,.....	19.3	56.5	Winkler.
Pitch coal from Habichtswald,.....	19.0	43.6	
Lowest stratum, Ringkuhl,.....	19.0	43.6	Berthier.
Middle stratum,.....	10.0	43.9	
Stillberger coal,.....	14.1	41.3	Winkler.
Lignite from Meissner,.....	14.7	43.1	
" Laubauch,.....	17.5	51.3	

Locality.	Pounds of lead reduced by one pound of coal.	Pounds of water heated from 32° to 212° by one pound of coal.	
Earthy coal from Dax,.....	21.38	62.6	
" " Bouches du Rhône, ..	18.89	55.3	Regnault.
" " Lower Alps,	16.69	48.9	
" " Greece,.....	17.84	52.3	Varentrapp.
" " Cologne,.....	18.24	53.4	
" " Usnach,.....	15.90	46.6	Griffiths.
Helmstadt, Prinz Wilhelm's mine,....	20.17	59.1	
" " other mines,.....	21.83	63.9	Winkler.
Schöningen, Gr. Irene,.....	18.76	54.9	
" " other mines,.....	18.60	54.5	

VI.—MINERAL COAL.

Locality and Species of Coal.	Pounds of lead reduced by one pound of coal.	Pounds of water heated from 32° to 212° by one pound of coal.	
Coal from Dowlais, Wales,.....	31.8	72.0	
Glamorgan,.....	31.2	70.7	Berthier.
Eschwiller, near Aix-la-Chapelle,....	31.0	70.2	
Lippe-Schaumburg,.....	30.9	70.0	Winkler.
Newcastle,.....	30.9	70.0	
Carneau, near Alby,.....	30.1	68.2	Griffiths.
Rive-de-Gier, Grand Croix,.....	29.6	67.0	
Mons, Boulevard-Fontaine-Madame,....	29.0	65.7	Berthier.
Canal coal, Wigan,.....	28.3	64.1	
Mons, Grand-Gaillet,.....	28.1	63.6	Winkler.
Rochebelle, near Alais,.....	27.6	62.5	
Bonchamp, Haute Saône,.....	27.3	61.8	Berthier.
Bessèges, Aveyron,.....	27.0	61.1	
St. Pierre la Cour, near Meyenne, ...	27.0	61.1	Winkler.
Epinac, Saône and Loire,.....	26.8	60.7	
From Oviedo in Asturia,.....	26.1	59.1	Berthier.
Freuil mine, near St. Etienne,.....	25.4	57.5	
Bellestat, Aude—called jet,.....	24.4	55.2	Winkler.
Jet—locality unknown,.....	23.3	52.8	

SINTER COAL.

Locality and Species of Coal.	Pounds of lead reduced by one pound of coal.	Pounds of water heated from 32° to 212° by one pound of coal.	
Cherry coal, Derbyshire,.....	27.2	61.6	
Soft coal,.....	26.3	59.5	Berthier.
Oviedo in Asturia,.....	26.1	59.1	
Cannel coal from Glasgow,.....	24.9	56.4	Winkler.
St. George's de Lavencas, Aveyron,...	24.0	54.5	
Cannel coal from Lancashire,.....	23.5	53.2	Berthier.
Ombrowa, Silesia,.....	21.2	48.0	
Salin, Jura,.....	21.0	47.5	Winkler.
Vagas, Slavonia,.....	19.4	43.9	

VII.—COKE.

Species of Coke.	Pounds of lead reduced by one pound of coke.	Pounds of water heated from 32° to 212° by one pound of coke.	
A la Garre, from coal of St. Etienne,...	28.5	65.6	
From coal of Bessèges,.....	28.4	64.3	Berthier.
" " Rive-de-Gier,.....	26.0	58.9	
Gas coke from Paris,.....	22.0	50.3	Winkler.

VIII.—ANTHRACITE.

Locality.	Pounds of lead reduced by one pound of anthracite.	Pounds of water heated from 34° to 212° by one pound of anthracite.	Berthier.
Anthracite, from Lamure, near Gre-	31.6	71.5	
noble,.....	30.5	69.1	
Anthracite from Pennsylvania,.....	33.0	74.7	
From Laval, { la Chaumière,.....	26.6	60.2	
“ { la Baconière,.....	26.7	60.5	
“ Corbattière in Savoy,.....			

The numbers cited in some of the preceding tables, as indicating the heating power of many kinds of fuel, appear at first sight contradictory to the known results obtained with such materials in the furnace. Thus considerably more heat is produced, judging from the work performed, when hard woods are burned than with the softer varieties; but numbers stated in the tables assign the greater heating power to the softer woods. SCHÖDLER and PETERSEN account for this apparent inconsistency by the difference in the amount of hydrogen producing unequal intensity of combustion in the two cases. They show that whilst woody fibre contains oxygen and hydrogen in the proportion in which they unite in water—that is, in the ratio of eight to one—all woods have the hydrogen in greater or less excess of the oxygen, and this excess acting at the temperature of combustion upon the carbon of the substance, produces a quantity of hydrocarbon gases, which are rapidly consumed. The residuary charcoal becomes in this case more porous, and, therefore, presents a larger surface to the oxygen of the air; the consequence of which is, that it is much more speedily consumed than if it remained a dense compact body. Hard woods have less hydrogen than the soft ones, and this fact accounts for the difference in the amount of heat produced. The annexed table gives the excess in one thousand parts after the oxygen has been assimilated:—

	Excess of hydrogen.
Ash,.....	5.05
Oak-wood,.....	5.08
Beech-wood,.....	6.50
Willow,.....	7.00
Birch,.....	7.50
Scotch fir,.....	7.70
Poplar-wood,.....	8.20
Maple,.....	8.30
Pine-wood,.....	8.80
Deal,.....	9.50
Elm,.....	10.00
Lime-wood,.....	13.90

In the other tables above given, it will be seen that the highest place is assigned to lime-wood in point of heating power; but, in practical application, the oak produces a better result. The difference of the time required for the combustion of the two accounts for the inequality. In the case of lime-wood, a considerable quantity of its carbon is taken up by the large excess of hydrogen, and is given off in the shape of inflammable gas, which presents an extended surface to the oxygen, and is consequently speedily consumed; the residuary charcoal burns rapidly on account of its porous nature, arising from the evolution of the particles of hydrogen and carbon. Now, oak-wood not having so large a per centage of hydrogen to react upon its carbon, of course a greater weight of the latter remains, and this being denser than in the case of lime-wood, a

less surface is undergoing combustion in the fire, and a longer time will be occupied in its burning. It rarely happens that the arrangements for the application of caloric in the arts are of such a nature as to allow of the entire economization of the heat produced, more especially when it is developed intensely and in a short space of time; hence, when soft woods are employed as fuel, there is a considerable amount of heat lost, by which the working effect is lessened. On the contrary, with woods which burn slowly, the loss is not so great, since it is nearly wholly absorbed in proportion as it is developed by the combustion. The same remark applies to coals; and this is the reason why particular kinds are employed for steam-generating purposes, for glass and porcelain works, *et cetera*; but although there appears a very great difference arising from this cause, yet it does not follow that the pyrometric effect of the one is less than that of the other. If, for instance, two equal weights of oak-wood be consumed—one in the form of chips or shavings, and the other in a compact mass—it will be seen that the former will burn in a much shorter period than the latter, and that the practical heating effect produced by the one will be much less than by the other. It is evident that the pyrometric heat is the same in both, only that the evolution of caloric from the divided portion is so rapid as to cause the dissipation of a large part of it. Where a high temperature is necessary, it is evident that a fuel capable of giving off its caloric in a comparatively short space of time is required; and hence the preference given to soft wood, or finely cleft hard wood, in the glass furnace and porcelain kiln. The facility which minute division affords for rapidity of combustion has, however, its limit, which, when exceeded, instead of expediting, retards, and when carried to extremes, actually arrests combustion entirely, as may be observed with coal, coke, wood, and peat charcoal, when crushed to a powder. In this case the air has no access to the combustible except at the surface, so that the area of contact is very limited when compared to the bulk, and, consequently, ignition is arrested. When it happens that fuel in this minutely divided state is the only kind available, the combustion is assisted by piling blocks of limestone, sandstone, or other material upon the grate, and placing the fuel—such as sawdust, slack, bres, *et cetera*—upon them, in which case the currents, ascending through the interstices, supply the requisite oxygen to the fuel. If the grate does not admit of this arrangement, the finely-divided combustible is converted into a valuable compact fuel by blending it with tar, pitch, or some such binding material, as described under Patent Fuels.

In consequence of the defective furnace arrangements in most manufacturing establishments, the quantity of heat absorbed and utilized bears, in general, no definite relation to the quantity produced, without taking into account the proportion of the fuel, which is either not at all, or only partially burned. The loss from these two causes alone has been estimated to be equivalent to the one-half of the coals consumed under the imperfect systems generally followed. Of late years considerable attention has been directed to discover some means whereby the cause of the first loss might be

removed by an improved construction of the furnaces or fire-places, with a view to their better retention of the heat, and marked benefits have arisen to many branches of trade, but more especially to those making extensive use of steam, from the various investigations instituted. Although the waste of caloric from both the causes mentioned—namely, the non-retention of the heat and the imperfect combustion of the material—is very great; yet a considerable waste of fuel is occasioned by other circumstances which attend ordinary combustion, and which require investigation as much as the others. To enter into a minute discussion of all these would be tedious; but a short examination of the principal ones will be necessary, to point out the sources of the difference between the calculated value of fuel in heating power, estimated from experiments controlled in such a way as is not possible when the materials are burned in the ordinary furnace or grate, and that which results in practical operation.

In the first place, it will be evident that the mere maintaining of a fuel in a state of combustion, whether in a grate or furnace, involves, and is dependent upon, a certain loss of caloric, as well latent as sensible, in the production and expansion of the gases resulting from the change, whereby they ascend from the substance and admit the fresh air to keep up the chemical action. It is well known that, under the provision made for burning fuel of any description, the air which is admitted must always be greater than the amount which theory assigns as sufficient, otherwise the combustion would be imperfect, and a heavy loss sustained. Admitting, however, that no more than is absolutely necessary passes through the fire, it will be seen, on reflection, that still a great amount of heat is rendered useless by the draught in the chimney. From the tables already given, it appears that for the complete combustion of one pound of dry wood an average of 5.94, or in whole numbers, six pounds weight of air at 32°—equal one hundred and forty-eight cubic feet—are required. Admitting that this volume of gaseous matter passes off from the fire to the chimney at a temperature of 300°, the whole heat lost will be $1620^\circ - (6 \times 270) = 06$, or six per cent. It seldom happens, however, that the temperature of the escaping gases is so low as that assumed in this instance; and where their heat is greater, of course, the loss will be proportionally increased; and the same effect will follow when the quantity of air passing through the furnace is greater than the theoretical amount.

Another cause of the reduction of the heat, and the prevention of a due effect resulting from combustion in the furnace, is the water which is usually present in fuels in greater or less abundance. The loss suffered from this alone is twofold: firstly, inasmuch as the amount of real combustible is diminished by it, whe-

ther it be large or small; and, secondly, because by its conversion into steam, in which state it passes off with the products of combustion, it unites with a large amount of caloric, which becomes latent.

When the proportion of water is appreciable, the quantity of caloric which is given off is very great. Wood, for instance, contains, after being dried in air, about one-fifth of its weight of moisture, so that when employed in this state as a fuel, only four-fifths of the weight taken is capable of generating heat. Supposing that 40.6 pounds of water are heated from 32° to 212° by one pound of wood perfectly free from moisture, it is evident that only 32.5 pounds would be brought to the same degree by the available fuel in the pound of common air-dried wood. Further, the one-fifth of moisture is expelled in steam, and this takes up as much caloric as would bring 5.5 pounds of water from the freezing to the boiling point. Founding a calculation upon this fact, the one-fifth of a pound of water present would assimilate as much heat as would raise 1.1 pound of water to the boiling point. By adding both, the total loss will be $9.2 - 8.1 + 1.1 = 22.5$ per cent. less than if dry wood were employed. This example shows, in a striking manner, the great advantages which the employment of wood, peat, lignite, or such fuel as is liable to be more or less saturated with hygroscopic matter affords, when they are thoroughly exsiccated, over the same when containing ten, fifteen, or twenty per cent. of moisture. Where wood is much employed, care is taken to submit it to a preliminary drying operation, so that its combustion may be rapid, and that the loss described may be avoided.

It may be remarked, however, that water does not, under all circumstances, diminish the calorific effect of a fuel; but on the contrary, when judiciously managed, adds to it in a high degree. BUNSEN and FYFE have shown that aqueous vapor passed over incandescent fuel suffers decomposition; its oxygen is abstracted by the highly heated carbon, and carbonic oxide results, while the hydrogen passes off partly uncombined, and partly associated as carbide of hydrogen. These three products in the presence of sufficient oxygen, and the high temperature of the furnace, are capable of undergoing further combustion, and yield a large amount of heat by being converted into carbonic acid and water. In numerous experiments it was shown that the caloric developed in this manner, more than compensated for the fuel employed in producing the gases. The application of aqueous vapor, however, demands caution; for when used in too great an excess, it reduces, rather than increases the temperature of the fire. Its effect is to diminish the heat, unless used sparingly, and with a free admission of air to promote the combustion of the inflammable gases.

The method in which water is utilized for raising the temperature, is to place a vessel of this liquid beneath the bars, so that the heat radiated downwards may have the effect of producing the steam without further trouble; where steam-engines are employed, a jet of the waste vapor is allowed to issue under the furnace. A mistaken inference from this fact leads many to moisten the coals before throwing them on the fire,

with a view to the increase of the heat; but that the contrary effect is produced, is evident from what has been already detailed; the water in this case serves only to slacken the combustion, and render a considerable amount of heat latent. It is the practice, especially, to moisten small coals and slack, when it is required to burn them on the furnace bars, and in this case the loss in heat from the presence of the water may to a certain extent be compensated by the advantage of the adhesion produced between the particles of the fuel, whereby it is prevented from falling into the ash or stoke-hole. Clay, plaster, or bituminous substances would serve better.

Besides the loss of caloric which results from the gases or products of combustion passing in a superheated state into the chimney, as well as from the presence of an excess of moisture, there is another source of loss which is of far greater importance, and which is much more generally felt. It is necessary for keeping up the ignition that the column of air in the chimney be expanded by heat, and thus rendered specifically lighter than the surrounding atmosphere, to produce a constant current through the fire. The moisture in a fuel may be removed by a preliminary desiccation, the extent of the heat-absorbing surface may, under certain circumstances, be augmented, so as to arrest and economize a large amount of caloric which might otherwise be lost; but to effect a complete combustion of the fuel, with the least possible volume of air, demands a thorough knowledge of the scientific principles involved in this change, as well as of the products resulting therefrom, together with the strictest attention on the part of the *stoker*. It is evident that a definite relation must exist between the weight of combustible elements in a fuel, and the oxygen which is required to convert these into carbonic acid and water, and that to effect the latter change within the limits of this relation requires the most favorable circumstances, such as properly arranged furnaces, the adjustment of the fuel and draught of air passing through the fire, with skill and constant attention on the part of the fireman.

In a grate of any given dimensions, and burning a given weight of fuel in a determinate period, the quantity of air to be supplied can be easily deduced with the aid of known experimental results, as well as from theoretical calculations. Thus, according to the determinations and analyses quoted at page 112, one pound of peat requires for complete combustion from seventy to one hundred and thirty-four cubic feet of air at 66.2°; medium kinds of this fuel, one hundred and forty-nine cubic feet; one pound of peat charcoal requires one hundred and fifty-five to two hundred and twenty-eight cubic feet; one pound of brown coal, according to the lead test, one hundred and thirty-nine to two hundred and twenty-two cubic feet, and by analysis, one hundred and sixty to two hundred and forty-eight; one pound of coal requires, by the lead test, one hundred and seventy to two hundred and seventy-nine, average qualities two hundred and twenty-eight cubic feet; according to RICHARDSON'S analysis, from two hundred and forty-eight to three hundred and three; by REGNAULT'S, average qualities, from the coal formation, take three hundred and twenty to three hundred and

thirty-two—those from the secondary formation, two hundred and ninety-three to three hundred and twenty-six cubic feet; one pound of coke requires one hundred and ninety-four to two hundred and fifty cubic feet; one pound of anthracite, according to the lead experiment, demands two hundred and thirty-three to two hundred and seventy-seven—according to REGNAULT'S analysis, three hundred and twelve cubic feet. A cubic foot of air weighs 0.03794 pound Hessian—0.07500 English—at the above temperature.—*Richardson and Ronalds*.

Now, in these calculations, it is presumed that the oxygen of the air is in contact with every particle of the fuel during ignition. Could the same condition be insured in the furnace, it is evident that the great desideratum required in combustion would be attained; no escape of combustible gas could then ensue, nor of the carbonaceous particles which give to the gases passing up the chimney the character of smoke; and the greatest possible heat arising from the burning of the substance in air would be developed. Indeed, nothing would be wanting to extract from the fuel the benefit of its total theoretical heating power, but such an arrangement of the furnace as would perfectly utilize the caloric so produced. No one, however, who has any experience as to the manner in which the fire is managed in the ordinary kinds of furnaces, will hesitate to assert that the above conditions are never supplied. The coals are thrown in thick layers upon the grate, by which the existing temperature for a time is greatly depressed, being absorbed in part by the cold fuel, and by the dispersion of its hygroscopic matter. In addition to the reduction of the heat temporarily, the thick bed of fuel impedes the draught, and sufficient air cannot enter to effect a consumption of coals, adequate to the generation of the amount of heat required. The portion of air which traverses the fire is deoxidized by the ignited fuel on the bars, and no oxygen, for a considerable period, can come into contact with the mass lying upon that which is burning; but although in this way it does not contribute to the pyrometrical effect, the temperature of the ignited mass, and the heated gases permeating it from below, cause a distillatory change, by which the whole of the available hydrogen, together with a large percentage of the carbon, is expelled as hydrocarbon gases, which escape combustion. This decomposition, occasioned by the undue fuelling, does not only waste the combustible matter in the way alluded to, but it diminishes the heat which is produced by the portion that burns, since the gases in passing off carry with them a considerable portion of caloric as latent and sensible heat. Further, after the distillation of the gaseous matter is effected, and the residuary coke has acquired incandescence, an additional loss is sustained in consequence of the carbonic acid in which the combustion of the carbon in the base of the fire terminates, being, by the deoxidizing power of the overlying glowing combustible, transformed into carbonic oxide, the abstracted oxygen taking as much again of the carbon as it would do if perfect combustion had occurred. The double volume of gas produced under these circumstances renders a large quantity of heat ineffectual for useful application.

It is thus that three radical and distinct sources of loss arise out of the profligate system of stoking usually practised; namely, waste of the volatile inflammable hydrocarbon gases of the substance; loss of the fixed carbon by the deoxidation of the carbonic acid; and, lastly, loss of the caloric with which the combustible and non-combustible gases combine and carry off, as well in the state of latent as of sensible heat.

Independently of such gross waste in the application of fuel, another of no little moment exists—namely, the rapidity of the draught in the flues. Experiments have shown that in those cases where the flue has been lengthened with the view of affording a greater heating surface, the effect produced was materially affected by having the damper entirely withdrawn, or only partially so. Such a result is a natural one, considering the imperfect conducting power of air, and also of water, when it is on the point of passing into the state of elastic vapor; for the one does not transmit the caloric to the fluid, nor does the latter combine with it so readily as to sufficiently abstract this principle from the gases when they rapidly circulate around the boiler and pass away. URE illustrates this non-conducting quality of gases passing rapidly over a conducting surface by the slight elevation of temperature which is experienced in guns, cannon, *et cetera*, notwithstanding that the temperature produced by the combustion of the powder is very high. The reason is, that the rapid evolution of the gases prevents the absorption of the caloric by the metal. In the case of a furnace, the barrel of the gun may be represented by the flue; the force of the explosion, and the products therefrom, by the draught and vapors produced in an ordinary furnace; and the effect of non-absorption in the latter instance, will be as marked as in the former if the draught be too great. Hence it will be readily inferred, that to absorb the whole or the greater part of caloric, time must form an important consideration to afford a more or less prolonged contact of the heated gases with the material of the boiler; consequently, where the draught is increased rather than checked within proper limits, the pyrometrical effect is, to a considerable extent, lost.

The causes of these losses in the production of heating effect, and, consequently, of mechanical power, have of late years engaged much attention, as well in America as in this country; and although the investigations, which have been conducted with a view to ascertain the conditions by which the largest amount of work might be performed by the fuel, have added materially to the knowledge of those circumstances that affect the heating power, they have scarcely touched upon those which relate to the economizing of fuel. Several modifications of furnaces have been patented of late years for the prevention of smoke, while, at the same time, it is alleged that the heat of the fire is increased; but it is to be feared that many of these arrangements, while ostensibly obviating one evil, produce others quite as injurious. This arises for the most part from the injudicious introduction of cold air at a part where the temperature is too low to cause combustion of the inflammable vapors and portions of carbon; or the quantity of air admitted is too great, and

the heat rendered latent by it amounts to as much or perhaps more than in the ordinary fire. Much benefit will doubtless accrue from those improvements in the furnace by which the supply of fuel upon the grate is regulated, and rendered more or less independent of the stoker. By these the loss arising from imperfect combustion, as already explained, is to a great degree avoided. To enter into a discussion and notice of the several improvements would be, in some degree, foreign to the subject of this article; but the reader who may be desirous of information on this matter, is referred to a work by Mr. W. WYE WILLIAMS, to the *Dictionnaire des Arts et de Manufactures*, published by LABOULAYE, and to KNAPP, RONALDS, and RICHARDSON on *Fuel*.

Regarding the investigations above alluded to, the chief object with which they were undertaken was to find the best coal for steam navigation. As already mentioned, there are many kinds of coal, which, though capable of producing a high temperature during combustion, yet are not economical for the purposes of the navy or other boiler furnaces. The reasons have been already stated. To find the best among the numerous varieties of coal extracted even from the same pits, and still more from different fields, the Government of the United States intrusted Professor W. R. JOHNSON with the investigation. This example was soon followed by Great Britain, whose manufacturing and naval interests, depending so much on steam, rendered such an inquiry most urgent. Dr. LYON PLAYFAIR and Sir HENRY DE LA BECHE were appointed as the principals in this research. In both the American and British investigations, the experiments were made with reference to the following principles:—

Firstly. The fuel should burn so that steam may be raised in a short period, if this be desired; in other words, it should be able to produce a quick action.

Secondly. It should possess high evaporating power—that is, be capable of converting much water into steam with a small consumption of coal.

Thirdly. It should not be bituminous, lest so much smoke be generated as to betray the position of vessels of war when it is desirable that this should be concealed.

Fourthly. It should possess considerable cohesion of its particles, so that it may not be broken into small fragments by the constant attrition which it may experience in the ship.

Fifthly. It should combine a considerable density with such mechanical structure that it may be easily stowed away into small space—a condition which, in coals of equal evaporative values, often involves a difference of more than twenty per cent.

Sixthly. It should be free from any considerable quantity of sulphur, and it should not progressively decay, both of which circumstances render it liable to spontaneous combustion.

The boiler employed by JOHNSON in his trials of the evaporating power of coals, was thirty feet long, and three and a half in diameter; this was set over a furnace, and the heated gases, after passing through two interior return flues, each one foot in diameter, escaped by the side flues exterior to the boiler to the chimney, making the entire length of circuit for

the products of combustion one hundred and twenty-one feet. The grate surface was sixteen feet and a quarter, and the area of heat-absorbing surface three hundred and seventy-seven and a half square feet, so that the ratio of both surfaces was as one to 23·2. The chimney was sixty-three feet high, and had a cross section of three hundred and twenty-four square inches.

On the other hand, a Cornish boiler was employed in the English investigation, the length of which was twelve feet, with an external diameter of four feet. The furnace, as usual with this class of steam boilers, was constructed in a flue two feet in diameter passing through the middle of the vessel. After the products of combustion traversed the central flue, they returned by two other external side ones to the front, and thence entered a main under the boiler, and which led to the chimney, thus making a course of thirty-six feet. A grate five feet square was employed, and the absorbing surface amounted to 197·6 square feet, so that the latter was to that of the fire as 1 to 39·5. In this case the height of the chimney was 35·5 feet, and its cross section presented an area of 182·25 square inches.

The amount of coals consumed in the hundred and forty-four trials made by JOHNSON at Washington was sixty-two and a half tons; and, in the eighty-two experiments conducted at London by PLAYFAIR and DE LA BECHE, about fourteen tons six hundred. The average weight of coals burned in the American inquiry at once was eight hundred two quarters twenty-six pounds, and in the English, three hundred two quarters.

The results of these experiments were published by Professor JOHNSON in a Report to Congress in 1844, and by Sir HENRY DE LA BECHE and DR. LYON

PLAYFAIR in a series of Reports to the British Government, concluded in 1851; but the relation between the composition of the coal, as ascertained by analysis, and its value for producing steam, is not by any means very clearly brought out even by these experiments. They prove, indeed, by the very differences which they exhibit, as compared with the results of experience, that the only trustworthy method of determining the value of a fuel, especially for steam purposes, is that of practical experiment under the boiler, where several tons and not pounds are consumed. It appears, therefore, to be unnecessary to transcribe the voluminous and elaborate tables embraced in the American and English reports, which the few readers who may be desirous to inspect them will find in RONALDS and RICHARDSON'S *Chemical Technology*. It may be stated, however, that in JOHNSON'S experiments the weight of water evaporated at 212° from one cubic foot of coal was found to vary from 440·8 to 556·1 pounds with different specimens of anthracite; from 350·2 to 478·7, with bituminous coking coal; and from 353·8 with Scotch, to 439·6 with English bituminous coal. In the English experiments, the Newcastle coal varies from 325·24 to 529·34; and Scotch coals from 352·58 to 460·82. The following may be given as a summary of the latter series of experiments, where A represents the evaporating power, or number of pounds of water evaporated at and above 212° by one pound of coal; B, rate of evaporation, or number of pounds evaporated per hour; C, weight in pounds of one cubic foot of coal, as used for fuel; D, space occupied by one ton in cubic feet; E, results obtained in experiments on cohesive power of coals, or, in other words, the per centage of large coals; and F, the per centage amount of sulphur contained in the coals:—

	A.	B.	C.	D.	E.	F.
Average of thirty-seven samples from Wales,.....	9·05	448·2	53·1	42·71	60·9	1·42
“ seventeen samples from Newcastle,	8·37	411·1	49·8	45·3	67·5	0·94
“ twenty-eight samples from Lancashire,..	7·94	447·6	49·7	45·15	73·5	1·42
“ eight samples from Scotland,.....	7·70	431·4	50·0	49·99	73·4	1·45
“ eight samples from Derbyshire,.....	7·58	432·7	47·2	47·45	80·9	1·01

The volume of the coals with reference to their respective qualities as a solid compact fuel was tested by JOHNSON, in the state in which they come to market, but in the English inquiry the several varieties were broken up into fragments not exceeding one pound in weight; hence the results in the latter were necessarily more uniform than in the former, and, therefore, the quantity of steam raised by equal bulks of the coal would from this, if from no other circumstance, be in favor of the English coals. Where the specific bulk of a fuel becomes a matter of consideration, as it must do when required for shipping, attention should be devoted to the size of the lumps, for even with the same coal there is great difference in the weights of two given volumes, one of which is in large and the other in smaller pieces.

The moisture present in the British coals was not deducted in calculating their evaporative value, as it was considered of greater practical importance to esti-

mate this in the state in which they were found in the market.

The British commission, besides employing the direct practical method—that of burning a portion of the coal under the boiler—had recourse for the calculation of the value of the fuel to the lead test, as also to the ultimate analysis. Between the results of these three methods there is often to be found in their tables a considerable difference, amounting even to a virtual contradiction. This has been shown to arise from the almost utter impossibility of economizing the heat under the boiler in the practical test, and from the fact of the oxygen derived from the litharge being made the basis for calculating the pyrometrical effect of the fuel in the lead test, an assumption that has been shown to be erroneous.

It is at least certain that very different quantities of steam were found to be raised by coals capable of reducing the same amount of lead, and hence it is evi-

dent that the lead test cannot be relied on as an exact measure of the value of a fuel, although it may afford an approximation. The same observation applies to the method of testing by the estimation of the coke or fixed carbon, the amount of which does not present a sure guide in the determination of the value of coal, since a wide difference was found between the steam generated or work done by different coals possessing an equal average amount of carbon.

With respect to the value which ought to be attached to the experimental results obtained by actually burning a portion of coals under the boiler, the information which even this method affords for practical guidance is not so reliable as might appear at first sight. This arises from the circumstance, that the effect of the fire depends to a great extent on the form and setting of the boiler; and as marine boilers differ from the Cornish ones in these particulars, the numbers found in the course of the experimental investigation do not present the actual equivalent of work to be expected in steamships. Even from the smallness of the boiler employed in the experiments, the results fell short by twenty per cent. of the maximum amount of work which the same fuels could perform when applied to larger boilers constructed and set on the same principles. The inquiry is rendered less efficient from another cause, namely, the want of a thorough control and measurement of the air passing through the furnace; for, doubtless, a knowledge of this would be of immense service in the application of fuel, so as to develop its entire pyrometrical effect under the most favorable circumstances.

The Editor concludes this article by acknowledging his obligations for much assistance to the very able work of RICHARDSON and RONALDS already referred to, as likewise to MILLER'S *Chemistry*, DUMAS' *Traité de Chimie Appliquée aux Arts*, and Dr. URE'S *Dictionary*.

GAS.—*Gas*, French; *Gaz*, German.—A recent writer appositely remarks, that in the present era, when the creative faculty of man seems to be more than ever busy in its obedience to the primitive injunction to subdue the earth, it seems but to be consistent with the harmony and order of the world that the production of light should have been one of the earliest aims of British industry. For the daily experience of social as well as of organic life, declares light to be one of the chief necessities of man, no less than of every other living thing; and sense and science alike at once accept as truth, that light was the first material force that worked in the embryo universe.

From the tallow dips of the last generation, powerless and void of everything save smell, to the bright stearic acid that cheers the drawing-room now-a-days, what a development! In the iron arteries under towns, in the constellations of burners that rule the nights of favored days, rising over the chaotic oil-lamps of old, what a creation! And can any one doubt that the same voice which first bade light to be, has summoned gas to the service of man, and pronounced the light from it to be good?

The discovery and earliest observation of elastic æriform fluids, capable of being inflamed and of imparting light and heat, must, according to HUGHES,

undoubtedly have been of great antiquity. The most ancient writings contain notices of inflammable vapors springing from fissures and cavities in the earth. It is evident, therefore, that gas being a natural production, no such individual as the discoverer and inventor of gas ever existed. Modern chemistry will have no difficulty in showing that all inflammable gases, whether arising naturally from rocks, or produced artificially by combustion or otherwise, are composed of simple elements, which present a remarkable analogy to the common bihydride of carbon, the gas chiefly consumed in our street lamps and houses at the present day.

Inflammable gas may be truly said to be as old as the first creation of organic matter, for wherever animal or vegetal substances have existed, by the immutable laws of nature they have been subject to eremacausis, and wherever decomposition has taken place, a variety of gases has been produced, some of them combustible, and others not. Whether the change be that engendered by the slow combustion of decay, or that more speedy process caused by the application of sensible heat, the effect is the same—the gases are equally produced in the two cases.

Gas may, in one sense, be called a more natural production than steam, although the latter has existed from the first creation of water, and in its palpable state, as proceeding from boiling water, must have been observed in all ages.

The *discoveries* of man in respect to gas and steam, ought rather to be called *applications*; they are conquests over the elements, the subjugation of great powers in nature to his use and convenience. So it is with nearly all great inventions, in which is found one power of nature after another, chained, confined, bound down, stored, and then let loose when required, and made to work machines, to propel ships across the ocean, to supply the place of human exertion itself in a thousand different ways; nay, to pass far beyond the actual powers of the combined labor of multitudes, and to effect that by a single effort which the manual strength of a world could scarcely accomplish.

If such astonishing applications of steam and gas had been made in the days of ancient Greece, what magnificent, expressive, and high-sounding names would have been found to convey their meaning! Instead of such contemptible little monosyllables as *gas* and *steam*, one might have heard of the spirit of coal and the spirit of water, with some superlative adjective to stamp the vast importance of each. In such an age these wonderful conquests would have thrown all meaner efforts into the shade; for them alone would poetry have strung its harp, and the grandest epic productions of genius might have commemorated the victory of man over the inanimate matter of nature, instead of dedicating her loftiest songs to the art of war.

As already stated, jets of flaming gases bursting out from the ground have attracted notice from a very early date, so that savage tribes, owing to the grandeur of the spectacle, apparently unsupported by fuel, considered the spots whence such emanated as the abodes of their gods. The well-known holy fires of Baku still burn, and are due to the ignition of light carbide of hydrogen with some naphtha vapor. They

are worshipped by the savages in the neighborhood of the Caspian Sea. In China, the borers for salt water often meet with streams of combustible gases, which they employ for illuminating factories and evaporating brines; consequently, the Chinese were acquainted with the use of coal-gas, long before the knowledge of its application was acquired by Europeans. The most familiar instance of the elimination of inflammable gases from the earth in this country, is the fire-damp of the miners; but it is not of such a good quality as that artificially produced.

Some of the earlier nations considered fire as a type of divinity, and one can scarcely wonder at the feelings of veneration occasioned by mysterious outbursts of flame, the origin of which appeared utterly incomprehensible. Hence superstition erected her altars over such flames, and claimed the interference of the gods to sustain the perpetual miracle. But all that had been observed with reference to inflammable vapors in olden times, was very far indeed from leading to any attempt to collect and use them. Their very nature and composition were unknown, and the most mistaken ideas prevailed as to their real elements. It was not until modern chemistry had exploded volumes of ancient dogmas, had traced the so-called elements to far simpler forms, and had taught the laws according to which simple bodies are combined in order to constitute all forms of matter—it was not till then that it began to be seen that the inflammable vapor of coal, wood, oils, and other fatty substances, was analogous with the marsh gas which arises in bubbles from the decomposition of vegetables under water; that it was of the same nature as the *ignis fatuus* or *Will-o'-the-wisp*, which on the wild moor or bog has lighted many a traveller to destruction; finally, that it was nearly the same as the gas which arises from the decomposition of water, however effected; and that, in fact, one of the constituents of water, the greatest antagonist and extinguisher of flame, was itself the most inflammable substance in nature, namely, hydrogen gas; while oxygen, the other element, is the greatest supporter of combustion.

Various opinions have been hazarded to account for the almost perpetual fires which were kept burning on the ancient altars. These are mentioned by STRABO and PLUTARCH, who add that when they happened to be extinguished, they were lighted by invisible means. The altar in the temple of Ægina may be mentioned as affording a good explanation of the mystery. Here a round hole, about thirteen inches in diameter, is observed in a block of stone. The circular orifice opens into a square one, which passes down through solid stone to a depth of several feet. The lower extremity of the square hole communicates with a cavity in which Mr. DODWELL supposes a fire to have been constantly kept burning, so that the flame did not appear above the surface of the fissure. He says, nothing more would be necessary than to pour oil into the orifice, when the flames would immediately burst forth, and appear to have a miraculous origin.—*Hughes*.

Although the application of the gases produced by the destructive distillation of pit-coal, as a means of obtaining artificial light, appertains to modern times, yet the germ of it may be traced back nearly two cen-

turies. In the year 1659, THOMAS SHIRLEY is said to have attributed the exhalations from the burning well of Wigan, in Lancashire, to the subjacent coal beds; and in 1664, the observation was made by Dr. CLAYTON, that combustible illuminating gas was formed during the decomposition of coal by heat, and that this could be collected.

One hundred years afterwards application was made of the fact, but by mere accident. In 1787, Lord DUNDONALD, of Culross Abbey, in Scotland, took out a patent for making coal-tar, and erected near the Abbey a series of ovens for this purpose. The tar was conducted by pipes from the condensers into cylinders of brickwork, each of which had a small opening at the top for the escape of the incondensable part of the products. To these openings the workmen were in the habit of attaching a cast-iron pipe by means of a mass of soft clay, and lighting the gas at the other end to give them light during the darkness. His lordship, also, was in the habit of burning the gas in the Abbey as a curiosity; and, for this purpose, he had a vessel constructed resembling a large tea-urn, which he frequently caused to be filled and carried up to the Abbey to light the hall with, especially when he had company with him.

But the true discoverer of the practical application of coal-gas for lighting purposes was Mr. MURDOCH, a Scotchman, who, in the year 1792, while at Redruth in Cornwall, made a series of experiments on the quantity and qualities of the gases produced by distillation from different mineral and vegetal substances. He was induced, by some observations which he had previously made on the burning of coal, to try the combustible properties of the gases produced from it, as well as from peat, wood, and other inflammable substances; and was struck with the great quantities of gas which they afforded, as well as with the brilliancy of the light, and the facilities of its production. He continued his experiments till 1798, when he removed from Cornwall to a situation of importance in BOULTON and WATT's works at Soho, and there he constructed an apparatus which, during many successive nights, was applied to the lighting of their principal building. In the meantime he tried various methods for washing and purifying the gas, and these experiments were continued with some interruptions till the peace of 1802, when a public display of the gas-light was made by him in the illumination of the manufactory at Soho on that occasion. He afterwards extended the same apparatus, so as to give light to all the principal shops in the neighborhood, where it was in regular use to the exclusion of other artificial light; and, finally, in 1808, he fitted up the gas apparatus in Messrs. PHILLIPS and LEE's cotton mill; from which time it gradually extended to all the cotton mills in the kingdom.

At the same time, much credit is due to Mr. WIN-SOR, who took out a patent for a similar process in 1806, delivered lectures on the subject, and endeavored to get up a joint-stock company for street-illumination. In this object he did not succeed till 1812, when some of the streets of London were first lighted with gas. Oil-gas was first prepared on a large scale by PHILIP

TAYLOR, who erected the gas-works at Paris soon after the peace of 1815.

NATURE OF ILLUMINATING GAS.—KNAPP justly remarks that the lighting properties of a gas, or mixture of gases, must depend upon the relation which the carbon in it bears to the hydrogen, and that it can only be turned to a useful purpose when there is more of the former of the two elements present than in fire-damp, and when the proportion of both approaches that of olefiant gas. Light carbide of hydrogen— CH_2 —contains 75.4 carbon to 24.6 hydrogen; olefiant gas— C_2H_2 —consists of 86 carbon to 12 hydrogen.

The illuminating power of different carbides of hydrogen varies considerably. Fire-damp contains one part by weight of hydrogen to three of carbon; but one part of hydrogen requires eight, and one part of carbon 2.666 parts of oxygen for combustion; now, supposing the oxygen of the air, which performs an important part in combustion, to combine with both simultaneously—then, as eight parts of oxygen consume one of hydrogen, just eight parts of oxygen would unite with the carbon, and consume three parts, or exactly the whole quantity. In olefiant gas, there is one part of hydrogen to six of carbon; therefore, under the same supposition, one part of hydrogen and three parts of carbon will be consumed together, whilst as much carbon, or three parts, will be set free. Although in reality the hydrogen is always consumed first, yet it is obvious that olefiant gas is capable, under similar circumstances, of supplying more carbon to the flame, and, consequently, of producing more light, and it would have a decided preference above all others, if it could be procured sufficiently cheap. This, however, is not the case, and one must be satisfied, from economical motives, with a mixture of gases, or, in other words, a compound gas, produced by the decomposition of certain substances of organic origin, and containing so much olefiant gas that it far exceeds carbide of hydrogen in illuminating power. When these organic substances are exposed to a certain temperature, the following process results. Certain volatile products escape, which partly condense on cooling into tar and aqueous fluid, whilst the rest is a mixture of gases, but contains likewise no small portion of the volatile vapors of different compounds, which remain dissolved in the cooled gases, without being condensed into liquids. A coaly residue which is termed *colce* is left.

The researches of numerous chemists upon coal tar, have led to the discovery of oily volatile products of very different chemical character, and which are chiefly carbides of hydrogen, with a very large proportion of carbon. To this class belong *anilin*, *leucolin*, *pyrrol*, *rosolic*, *brunolic*, and *carbolic acids*, and *naphthalin*. Most of these contain ninety per cent. of carbon, naphthalin as much as ninety-four; and in burning they deposit it in still greater quantity than olefiant gas. It is, therefore, easily conceived why the vapors of these substances remaining with the gas, so very much enhance its value. Such mixtures of gas and vapor are termed illuminating gas, without reference to the separation of noxious and useless impurities before it is used. Gas, consequently, is not a definite compound of light carbide of hydrogen or olefiant gas, but more

properly a mechanical mixture of very various bodies, some being only slightly or not at all luminous, whilst others are exceedingly so, as olefiant gas and the other carbides of hydrogen which possess similar properties, and to which the whole is indebted for its illuminating power. It is a remarkable circumstance, that carbon and hydrogen are capable of uniting in the same proportions by weight to form a series of gases and liquids, which only vary on account of the different amount of contraction of volume which their elements undergo in the moment of combination; and this alone can explain the great multiplicity of solid, liquid, and gaseous carbides of hydrogen which are known to exist.

It may be conceived that different substances, as wood, fat, and coal, must be suited in different degrees for the production of light-gas. Coal, fats, or oils, resin and tar, asphaltum, soap-water, and the refuse of animal bodies, are all practically employed, according to the locality, in the production of gas. The different nature of these bodies requires that different modes of preparing the gas from them should be adopted, and these will be considered separately further on.

The amount of gas from a given quantity of coal depends greatly upon its quality, and the manner in which its distillation is conducted; it is, therefore, very variable.

Experience has proved that English cannel is the best gas-coal, both as regards the quantity and quality of the gas which it yields. Scotch parrot coal comes next. Even the Berlin gas-works use cannel coal from England. In France, where cannel is not to be met with, highly caking coal of a similar character is selected, and on the East coast of England, caking coal is generally employed for the production of gas.

ACCUM found that one hundred cubic feet of coal gave from eighteen thousand seven hundred to nine thousand two hundred cubic feet of gas, according as the best kinds of Scotch or Lancashire coal were used, or the inferior sorts of Staffordshire. At the hospital at St. Louis, at Paris, the yearly average, from the same amount of coal, was twelve thousand three hundred cubic feet of gas, which is equal to four hundred and ninety-three cubic feet of gas to the hundredweight of coal. PRECHTL estimates the produce at seven hundred cubic feet; so that the statements as regards the weight of gas vary from twelve to seventeen per cent.

The decomposition of the coal begins with the incipient red heat of the enclosing vessels, and continues, if large quantities are employed, several hours, the quantity of gas gradually decreasing towards the end. PECKSTON found that, in an eight hours' distillation, when the fire was uniform, and the vessels constantly red hot, the relative quantities of gas given off were, in the first hour, twenty; in the second, fifteen; in the third, fourteen; in the fourth, nearly thirteen; in the fifth, twelve; in the sixth, ten; in the seventh, nine; and in the eighth, about eight per cent. of the whole quantity. The cubic foot at the end, therefore, costs two and a half times as much as at the commencement. The quality of the gas, at the different periods of the distillation, however, must also be taken into consideration. For this purpose, it will be proper to glance at the ingredients of the gaseous mixture in

general, which, after the separation of the aqueous fluid and the tar, consists of—

Hydrogen,.....	H
Bihydride of carbon,.....	C H ₂
Olefiant gas,.....	C ₂ H ₂ , or C ₄ H ₄
Volatile hydrocarbon,.....	C ₆ H ₆
Benzol,.....	C ₁₂ H ₆
Carbonic oxide,.....	C O
Cyanogen,.....	C ₂ N
Sulphide of hydrogen,.....	H S
Ammonia,.....	N H ₃
Carbonic acid,.....	C O ₂
Sulphurous acid,.....	S O ₂
Bisulphide of carbon,.....	C S ₂
Nitrogen,.....	N

The carbonic oxide and a part of the free hydrogen, doubtless, have the same origin, being formed from the moisture in the coal, or from the first portions of aqueous vapor generated, which, passing over the incandescent coke, are converted into these gases. The nitrogen of the coal is obtained entirely as cyanogen and ammonia, partly in combination, and the latter is also found with the sulpho-cyanogen and the other acids, forming volatile salts; *free* nitrogen, on the contrary, is the residue of atmospheric air contained in the retort. Sulphide of hydrogen and sul-

phurous acid arise from iron pyrites, eviscerated by the coal.

The first four of the ingredients named, with the illuminating vapors of tar oil, form the proper bulk of the gas; the others are small quantities of impurities which should have been separated with the tar. Experiment has proved that the relative proportions of the four principal ingredients vary with the duration of the distillation. When chlorine is added to light-gas and the vapors of tar oil, a fluid compound separates, and the original volume is consequently lessened. The diminution which the volume of the gas suffers when mixed with chlorine is, therefore, in direct proportion to its illuminating power and to the value of the gas—the amount of olefiant gas and tar oil vapors which it contains. This explains the following results of a series of elaborate experiments by Dr. HENRY, who followed analytically, step by step, the whole course of the evolution of gas. He found that, at incipient redness, scarcely anything but hydrogen, atmospheric air, and some tar passed off, with hardly any illuminating gas; but that, after attaining that temperature, illuminating gas alone appeared, and this was composed of a mixture of gases in the following relative proportions:—

Time of collection.	Specific gravity.	Out of a hundred parts of gas from Wigan canal coal.				
		Chlorine absorbed	Carbide of hydrogen absorbed	Carbonic oxide absorbed	Hydrogen absorbed	Nitrogen absorbed
In the first hour,.....	0·650	13	82·5	3·2	0	1·3
.....	0·620	12	72	1·9	8·8	5·3
.....	0·630	12	58	12·3	16	1·7
Five hours after the commencement,.....	0·500	7	56	11	21·3	4·7
Ten do. do.	0·345	0	20	10	60	10

Consequently, as a general result, carbide of hydrogen is formed in decided excess, and the most luminous portion of this, which is condensable by chlorine, comprises only about one-fifth of the whole. These numbers also prove distinctly, that after about the fifth hour the quantity only increases, but the quality does not improve; indeed, this deteriorates so rapidly, that at the expiration of ten hours, the gas which passes over is hardly luminous when ignited, but burns with a very faint flame. The specific gravity, as will be seen, keeps pace with the quality of the gas, diminishing as the latter improves, and can thus far be taken as a test for its value. As pure olefiant gas has about the specific gravity of common air, 0·98, the density of the illuminating gas must increase with the quantity of olefiant gas contained in it; yet an extraordinary amount of carbonic oxide, specific gravity 0·97, or of carbonic acid, specific gravity 1·52, may give rise to errors of some magnitude.

The great increase of hydrogen, which at the last period amounts to sixty per cent., is remarkable, and important to the manufacturer—an augmentation which is no longer due to the decomposition of aqueous vapors, but to that of the carbides of hydrogen. It was long ago observed that these are decomposed at a bright red heat, and deposit a portion of their carbon on the sides of the vessels. MARCHAND's recent experiments show very clearly the progress of this decomposition. When olefiant gas was conducted through a red-hot

tube, and the heat constantly elevated, the gas passing off, collected in successive portions, contained the following quantities of carbon to one hundred of hydrogen:—

Hydrogen.	Carbon.	Nature and temperature of the gas.
100	614	Olefiant gas.
100	580	Red heat.
100	533	—
100	472	—
100	367	—
100	325	Intense white heat.
100	307	Light carbide of hydrogen.
100	7	Continued white heat, nearly pure hydrogen.

The Editor will now give a short account of each gas, with its preparation and properties.

HYDROGEN.—First in the table of the constituents of coal-gas is this element, which in its pure state is a colorless transparent gas, possessing a very low specific gravity. It may be obtained by the action of weak sulphuric acid upon iron or zinc. Some nails, or pieces of iron wire, or granulated zinc, may be introduced into a tubulated flask, and covered with sulphuric acid, diluted with six or eight times its bulk of water; an effervescence ensues, heat is evolved, and the gas escapes, which may be collected in the hydro-pneumatic trough. The hydrogen, however, which is thus eliminated, is never perfectly pure. When procured from iron, its smell is peculiar and disagreeable, in consequence, according to BERZELIUS, of its

containing a portion of volatile oil, formed by its union with a minute quantity of carbon, which all common iron contains. When such gas is passed through alcohol, much of the odor is absorbed by it, and on diluting it with water, it becomes milky. Obtained by means of zinc, the gas is perhaps somewhat more pure, but appears to hold a trace of zinc and of carbon in solution, and perhaps, in some cases, traces of sulphur and of arsenic. For the purposes of delicate experiments, hydrogen must be passed through a solution of potassa, and then exsiccated by conducting it over fragments of fused chloride of calcium; it should also be collected over mercury, and procured from *purified zinc*, and *pure* sulphuric acid, so far diluted as to act but slowly upon the metal.

Hydrogen is an uncondensable aeriform fluid; it is not absorbable by water, unless that liquid has previously been deprived, by long boiling, of common air, in which case a hundred cubic inches dissolve about 1.5 of the gas. It has no taste, and when perfectly pure is inodorous. It has great power of refracting light. It may be respired for a short time, though it is instantly fatal to small animals. M. MAUNOIR, after having breathed a quantity of this gas, found that his voice had become remarkably shrill. The intensity of sound is greatly diminished in an atmosphere of hydrogen; LESLIE, indeed, ascertained it to be more feeble than its rarity, compared with air, would have led him to expect. He placed a piece of clockwork, by which a bell was struck every half minute under the receiver of the air-pump, and after exhausting the air, filled the receiver with hydrogen; but the sound was then even feebler than in the highly rarefied atmosphere.

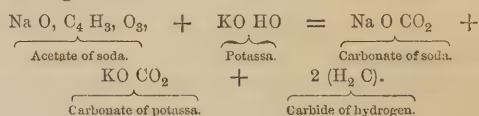
Hydrogen gas, says BRANDE, is the lightest known form of matter, and its equivalent, combining, or atomic weight, is below that of all other substances; it is, therefore, conveniently assumed as *unity* in reference to the *atomic weights* of all other bodies. In consequence of its extreme lightness, it is difficult directly to determine its weight with accuracy by the common process; but the researches of BERZELIUS and DULONG, and of Dr. PROUT, lead one to infer that its specific gravity, compared with oxygen, is as one to sixteen; one hundred cubic inches, therefore, of pure hydrogen gas at mean temperature and pressure, weigh only 2.1483 grains, and compared with air, its specific gravity would be nearly as seven to one hundred, or, more correctly, as 0.0694 to unity.

The low specific gravity of this gas is well and interestingly illustrated, by substituting it for common air in soap bubbles, which then rapidly ascend in the atmosphere, and may be kindled by the flame of a taper. The same circumstance also leads to its employment for the inflation of balloons, which, however, have of late years been generally filled with coal-gas. Small balloons may be purchased made of gold-beater's skin, or the lining membrane of the crop of a turkey, which, when filled with pure hydrogen, rise to the ceiling, their specific gravity being inferior to that of the surrounding air. Some of these, when filled with hydrogen, do not weigh more than forty-two grains, while the same bulk of air would weigh fifty-two, so that their buoyant power is about ten grains.

Hydrogen is inflammable, and extinguishes flame. When pure, it burns quietly, with a pale yellowish flame at the surface in contact with air.—*Brande*.

BIHYDRIDE OF CARBON—light carbide of hydrogen—is produced collaterally with carbonic acid, in the putrefaction of vegetal substances under water—hence its name, *marsh-gas*. It burns with a pale bluish light, rather stronger than hydrogen.

This gas is best obtained for experimental purposes by the decomposition of *certain acetates*, under the following conditions, first pointed out by PERSOZ, and described by DUMAS: forty parts of crystallized acetate of soda, forty of caustic potassa, and sixty of powdered quicklime, are well mixed and heated in a glass retort; the use of the lime being to prevent the action of the alkali upon the glass; at a heat approaching dull redness, the gas is abundantly evolved, and may be collected over water. The action is determined by the affinity of the alkaline bases for carbonic acid, and the instability of the acetic acid at high temperatures, an equivalent of acetic acid and one of water producing carbonic acid, which combines with the soda and potassa, while, at the same time, light carbide of hydrogen is formed, and passes off, as shown by the following formula:—



A mixture of one equivalent of fused hydrate of baryta, and one of anhydrous acetate of soda, similarly treated, also yield a pure gas.

Sir H. DAVY found the specific gravity of this gas to be 0.555, and, compared with hydrogen, as eight to one. One hundred cubic inches weigh 17.4 grains. According to FARADAY, its refractive power is 2.097, air being 1.000. When pure, it is of course unrespirable, but it is not very noxious when mixed with air. It is sparingly soluble in water, fourteen cubic inches of which take up about one of the gas. It is hardly sensibly soluble in alcohol or ether, and in oil of turpentine the proportion dissolved is not probably one-fifteenth of the volume of the fluid employed. It is inflammable, burning with a yellow flame, and producing carbonic acid and water; it has, when quite pure, scarcely any odor. It is not decomposed by electric sparks, but, when passed through a white-hot tube, deposits a portion of its carbon.

A hundred volumes of this gas require two hundred of oxygen for perfect combustion, which produces *water* and a hundred volumes of *carbonic acid*. One hundred volumes of carbonic acid contain a hundred of oxygen, or half the quantity consumed; the remaining hundred volumes, therefore, must have united with two hundred of hydrogen to form water; hence, this gas is composed of—

	Atomic weight.	Per cent.
1 Eq. of Carbon,	6	75
2 Eqs. of Hydrogen,	2	25
1 Eq. of Bicarbide of hydrogen,...	8	100

DAVY made several experiments on the combusti-

bility and explosive nature of this gas. He observed that when one volume was mixed with one of air, they burned by the approach of a lighted taper, but did not explode; two of air and three of the latter to one of gas manifested similar results. When four of air and one of the gas were exposed to a lighted candle, the mixture being in the quantity of six to seven cubic inches in a narrow-necked bottle, a flame descended through the mixture, but no noise was produced; one volume of gas, burned with six of air in a similar bottle, made a slight whistling sound; one of gas with eight of air, rather a louder sound; one with ten, eleven, twelve, thirteen, and fourteen still inflamed, but the violence of the combustion decreased. A candle burned in a mixture of one of gas and fifteen of air, with a greatly enlarged flame, without producing explosion. The compound which appeared to be of the greatest explosive power, was that of seven or eight volumes of air to one of gas; but the report produced by fifty cubic inches of this mixture was less than that resulting from one-tenth of the quantity of a mixture of two parts of atmospheric air and one of hydrogen.

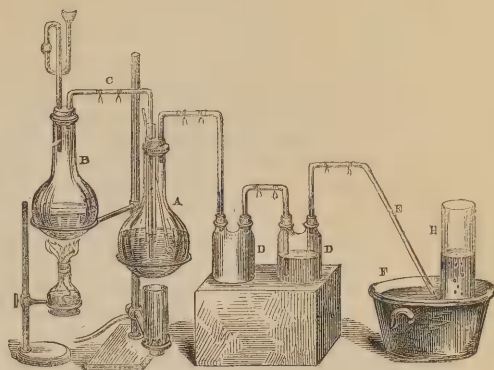
In reference to the *degree of heat* required to explode this gas mixed with its proper proportion of air, it was found that a common electrical spark would not explode five parts of air and one of the gas, though it exploded six parts of air and one of the gas; but very strong sparks from the discharge of a Leyden jar seemed to have the same power of exploding different mixtures of the gas as the flame of the taper. Well-burned charcoal, ignited to the strongest red heat, did not explode any mixture of air and of the fire-damp; and a fire made of well-burned charcoal, that is, charcoal that burned without flame, was blown up to whiteness, by an explosive mixture containing the fire-damp, without producing its inflammation. An iron rod at the highest degree of red heat, and at the common degree of white heat, did not inflame explosive mixtures of the gas; but when in brilliant combustion, it produced the effect. The flame of gaseous oxide of carbon, as well as that of olefiant gas, exploded the same mixtures.—*Brande*.

OLEFIANT GAS.—Next in order is the chief constituent of coal-gas—namely, olefiant gas, a name derived from its property of producing, when in contact with chlorine at the common temperature, a peculiar aromatic oil resembling chloroform.

This gas burns with a beautiful brilliant flame, constituting the true illuminating principle of coal-gas. It is generally obtained by decomposing alcohol by sulphuric acid; for which purpose, two parts by measure of the acid, and one of alcohol, are put into a retort, and heat applied; soon after the mixture boils, the gas is evolved. It may be collected over water, and should be well washed with lime water, or with a solution of potassa, to abstract sulphurous and carbonic acids; it also retains a little ethereal vapor, which may be removed by agitating it with weak alcohol, and afterwards with water. A more refined process for the production of olefiant gas is that of *MITSCHERLICH*, which consists in passing the vapor of alcohol into sulphuric acid, so far diluted as to have its boiling point reduced 325°—namely, about two parts vitriol,

specific gravity 1·8, and one of water. The acid is heated to the boiling point, or nearly so, and is then put into the receiver, A, Fig. 89. The flask, or tubulated retort, B, contains alcohol. On the application

Fig. 89.



of heat to the latter, its vapor passes, by means of the tube, C, into the hot acid, and is converted—catalytically—into olefiant gas and aqueous vapor, which, after passing through a Woulfe's apparatus, D D, escape by the tube, E, together with a little alcohol and ether, into the pneumatic trough, F. The gas continues its course upwards into its recipient, H, while the accompanying bodies just mentioned are condensed in the trough. By this process the acid is not discolored, and no sulphurous acid is formed.

The apparatus may be variously modified. Thus, when it is required that the whole of the alcoholic vapor should be transformed into the olefiant gas, the ebullition of the acid must be continued by means of a spirit or gas lamp placed under the receiver. When the acid is merely heated in the first place, decomposition proceeds only till the acid is cold. Still, for preparing a *small quantity* of gas, this condition is quite sufficient.

The specific gravity of olefiant gas, as usually prepared, is about 0·980, or, compared with hydrogen, as fourteen to one, and a hundred cubic inches weigh about thirty grains. According to *THOMSON*, its specific gravity is 0·9722—the same as that of nitrogen and carbonic oxide—and a hundred cubic inches at the temperature of 32° weigh 31·879 grains. Its refractive power is 1·818, air being one; and its specific heat, compared with that of air, is, according to *DULONG*, 1·53, and according to *DE LA ROCHE* and *BERARD*, 1·55, being greater than that of any other gas.

Under the combined influence of intense cold and pressure, *FARADAY* succeeded in condensing olefiant gas into a clear, colorless, transparent liquid, not solidifiable: its vapor exerts a pressure of 26·9 atmospheres at 0°.

Olefiant gas, when carefully purified, has little odor, though it is very difficult to get rid of traces of ether; it is inflammable, burning with a bright and highly luminous flame. It extinguishes a taper, and is quite irrespirable. Water absorbs about one-eighth its volume of olefiant gas, leaving an insoluble residue, which burns like light carbide of hydrogen.

MARCHAND states that one volume of olefiant gas requires, for perfect combustion, three of oxygen. When sulphur is heated in one volume of this gas, charcoal separates, and two volumes of sulphide of hydrogen result. As hydrogen suffers no change of volume by combining with sulphur, it follows that olefiant gas contains two volumes of hydrogen condensed into one; hence the quantity of oxygen required for its combustion. This compound is also decomposed by heat alone, as by passing and repassing it through a red-hot tube of earthenware or metal; it then gradually deposits its carbon, and is ultimately expanded into twice its original volume of pure hydrogen. An analogous transformation of the olefiant gas generated in the retorts of the gas-works is observed, and is connected with the deposition of several interesting forms of carbon.

When *one* volume of olefiant gas is detonated by the electric spark in a proper tube—which, on account of the violence of the explosion, should be very strong—with three volumes of oxygen, *two* of carbonic acid are formed, and water is deposited. Now two volumes of carbonic acid contain two of oxygen, so that the other volume of oxygen must have condensed two of hydrogen to form water. Hence *one* equivalent or volume of olefiant gas must contain *two* equivalents of carbon and *two* of hydrogen.—*Brande*.

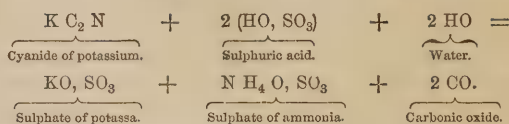
VOLATILE HYDROCARBONS.—Next in order, among the constituents of coal-gas, are the volatile hydrocarbons, portions of which vaporize at a heat much below that of boiling water; consequently, parts of them are carried off by the coal-gas—the quantity found in the gas varying with the distance from the works in which it is generated.

BENZOL contains ninety-two per cent. of carbon, a far greater amount than even olefiant gas. When it is burned with an insufficient supply of oxygen, large deposits of carbon ensue. With a proper quantity of oxygen, this hydrocarbon affords a beautiful light, as may be observed when a stream of atmospheric air is transmitted through it during ignition. The peculiarly rich and illuminating power of the vapor of benzol, may be seen by passing it through the pale and almost invisible flame of hydrogen. This substance has been fully described in Vol. I., page 285, *et sequitur*.

CARBONIC OXIDE, which is rather an impurity than a proper constituent of coal-gas, may be very readily obtained, as *BRANDE* remarks, by *DUMAS'* process, which consists in gently heating oxalic acid with five or six times its weight of sulphuric acid; the mixture effervesces in consequence of the evolution of equal volumes of carbonic oxide and carbonic acid gas; the latter may be abstracted by a caustic alkaline solution, and pure carbonic oxide gas remains. In this case, the evolution of the two gases is caused by the abstraction of water from oxalic acid, which contains, in its anhydrous state, the elements of one equivalent of carbonic oxide, and one of carbonic acid; but these can only exist as oxalic acid when in union with water, or with a base, anhydrous oxalic acid not having been isolated. Crystallized oxalic acid is $C_2O_3, 3HO$, which, acted upon by three equivalents of sulphuric acid, $3(HO, SO_3)$, becomes $3(2HO, SO_3) + CO_2 + CO$;

the hydrated sulphuric acid remains in the retort, the carbonic acid is abstracted by passing the gases through a solution of caustic potassa, and the carbonic oxide passes off. Another source of carbonic oxide, suggested by *FOWNES*, is the action of ten parts of concentrated sulphuric acid on one part of pulverized crystals of ferrocyanide of potassium; the gas thus obtained is pure, and is evolved in the proportion of three hundred cubic inches from half an ounce of the salt.

Ferrocyanide of potassium contains cyanide of potassium, $K C_2 N$, and cyanide of iron, $Fe C_2 N$; they are converted by the sulphuric acid into sulphates of iron and potassa, sulphate of ammonia, and carbonic oxide; thus, in regard to the cyanide of potassium,



It not unfrequently happens that carbonic oxide is formed by the combustion of carbon when the supply of oxygen is inadequate to the production of carbonic acid; hence the lambent blue flame which sometimes plays upon a coke or charcoal fire, or is seen to issue from certain furnaces: this is, in fact, equivalent to passing carbonic acid over red-hot charcoal; so that $C O_2 + C$ becomes $2 CO$.

The specific gravity of this gas compared to hydrogen is as fourteen to one; and to atmospheric air as 0.9706 to 1.0000; a hundred cubic inches weighing 29.0979 grains. It is very fatal to animals, causing giddiness and fainting when respired mixed with atmospheric air. When breathed pure, it almost immediately produces profound coma. It extinguishes flame, and burns with a peculiar blue light when mixed with, or exposed to, atmospheric air. *DAVY* found that the temperature of an iron wire heated to dull redness was sufficient to inflame it. It has no taste and little odor; it does not affect vegetal colors, occasions no precipitate in lime water, and is very sparingly absorbed by water which has been deprived of air. When burned in dry air or oxygen under a bell-glass, no moisture whatever is deposited, showing that hydrogen is not contained in this gas. Carbonic acid is the only result of this combustion.—*Brande*.

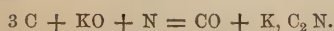
No change is effected in carbonic oxide when it is passed and repassed through a red-hot porcelain tube; nor is it altered at high temperatures by phosphorus, sulphur, nor even, according to the experiments of *SAUSSURE*, by hydrogen, though it is stated upon other authorities, that at elevated temperatures hydrogen does decompose it.

CYANOGEN.—There is no class of organic bodies, remarks *SIR ROBERT KANE*, of which there is more extensive and exact knowledge, than those which have cyanogen as their basis. The powerful affinities which this radical exerts, the simplicity of its constitution, and above all, the circumstance that one is able to prepare it in an isolated state, and to generate its compounds directly from it, as from those of a truly simple body, renders its history the most advanced portion of organic chemistry, and that to which the

analogy of mineral bodies, and the theory of compound organic radicals, is most undeniably applicable.

Cyanogen does not exist in nature ready formed; the kernels of peaches, plums, bitter almonds, *et cetera*, and the leaves of the cherry-laurel, yield, by distillation, abundance of hydrocyanic acid, but it is only then produced by the decomposition of other substances containing nitrogen.

This body may, however, be formed abundantly, and in a simple manner, by bringing its elements together at a high temperature, in contact with substances with which it may unite. Thus, when any organic matter containing nitrogen is calcined with potassa, the nascent carbon and hydrogen unite, and cyanide of potassium is produced; even with pure charcoal this occurs, nitrogen being derived from the air; and FOWNES has shown, that when a mixture of pure charcoal and potassa is ignited in a tube, and a current of nitrogen passed through it, the latter is absorbed, and carbonic acid gas being given off, cyanide of potassium is produced—



This mode of forming cyanogen has been made the basis of manufacturing processes on the great scale, and at present much ferrocyanide of potassium so formed is sent into commerce. By the action of ammonia also on ignited charcoal, cyanogen is generated in abundance; it combines with hydrogen and the excess of ammonia, and produces ferrocyanide of ammonium. It is by virtue of these processes, that cyanogen is obtained for its various applications in the arts.

Cyanide of silver, or cyanide of mercury, is to be introduced into a small glass retort, and heated to just below redness; a gas is evolved which must be collected over the mercurial trough; the cyanide of silver separates simply into metal and cyanogen; but when cyanide of mercury is used, a brown powder appears, the quantity of which is less as the temperature of its decomposition has been lower. The gas which comes over is, however, cyanogen absolutely pure. If a large supply of this gas be required, but not of absolute purity, it may be prepared by mixing boiling solutions of two parts of chloride of mercury, and three parts of ferrocyanide of potassium, and evaporating down the liquor; the dry mass, which is a mixture of cyanide of mercury, chloride of potassium, and cyanide of iron, gives out on the application of heat a very large quantity of cyanogen, nearly pure.

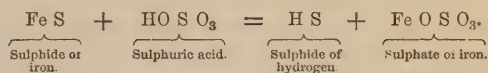
The properties of this gas are very distinct. It is colorless, has a sharp smell, which irritates the eyes. It

collects at the other end, *b*, as a colorless liquid. It is combustible, burning with a beautiful rose-colored flame, and producing two volumes of carbonic acid and one of nitrogen. It is constituted, therefore, of equal volumes of carbon vapor and nitrogen, the two volumes being condensed to one; hence, $0.836 + 0.976 = 1.812$, is its specific gravity. It dissolves abundantly in alcohol and water, but these solutions soon undergo very complex decompositions; the liquor being found to contain carbonic acid, hydrocyanic acid, ammonia, urea, and oxalic acid, besides a brown insoluble matter. A similar decomposition is produced much more rapidly by contact with aqueous ammonia. The composition of this brown matter appears to be C_4N_2HO . It dissolves in alkalies, and gives precipitates with the metallic salts; it has been hence termed *azulmic acid*. When heated it gives off cyanogen, which has been termed *paracyanogen*. This may be also formed by heating cyanide of mercury very strongly. It dissolves in hot nitric acid, and the solution gives, with water, a yellow precipitate, which combines with bases.

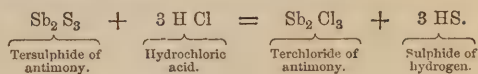
Cyanogen unites directly with hydrogen and with the metals, but its oxygen combinations require to be indirectly formed; there are three compounds of cyanogen and oxygen, which are all acids, and are polymeric bodies. It combines also with sulphur, and its compounds with this element have a remarkable tendency to form double and triple combinations.

The formula of cyanogen is indifferently written C_2N or Cy . Its equivalent number is 26.—*Kane*.

SULPHIDE OF HYDROGEN is best prepared by acting upon the sulphide of iron with dilute sulphuric acid. A lively effervescence ensues from the escape of this gas, and the solution contains protosulphate of iron; a gentle heat may be applied to facilitate the decomposition. In this process water is decomposed, its oxygen uniting with the iron, and its hydrogen with the sulphur; the change may be represented by the following—



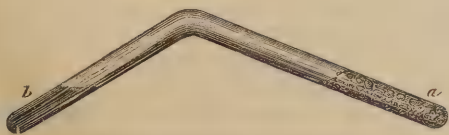
This gas may also be obtained by acting on sulphide of potassium by dilute sulphuric or hydrochloric acid, in which case the result is similar to that already given. Sulphide of antimony and hydrochloric acid produce, when heated, very pure sulphide of hydrogen, the reaction being—



As sulphide of hydrogen is absorbed by water, it cannot well be collected over this liquid, except it be saturated with chloride of sodium, or be heated to above 90° , in which case its solvent power is very much diminished. It cannot be kept long over the mercurial trough, for the lead and tin, always present in the mercury of commerce, gradually decompose it, combining with the sulphur, and leaving the hydrogen free; the volume of the gas remains the same during this chemical reaction.

This gas is colorless and transparent; it is charac-

Fig. 90.

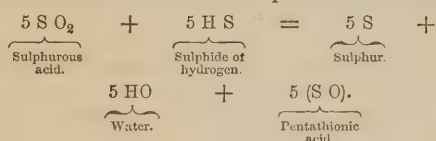


specific gravity is 1.819. If a quantity of cyanide of silver be sealed up in a strong tube, bent as in Fig. 90, and then heated at one end, *a*, the cyanogen is evolved and condensed by a pressure of about four atmospheres, and

terized by the fetid odor of rotten eggs, which, in fact, owe their peculiar smell to the production of this gas during their putrefaction. Its specific gravity is 1.177.

Sulphide of hydrogen gas dissolves in water, forming a solution used extensively as a reagent for most of the metals, from the solutions of which it precipitates metallic sulphides of various colors, by which many metals are distinguished.

When aqueous sulphide of hydrogen is exposed to the air, oxygen is absorbed, which combines with the hydrogen of the sulphur compound, water being produced, while the sulphur is set free, and appears as a milky precipitate. The nascent sulphur, however, in part absorbs also oxygen, and sulphuric acid is formed; hence the presence of this acid, free, in volcanic springs, as in the Rio Vinaigre in New Spain. If a solution of sulphurous acid be mixed with sulphide of hydrogen, half of the whole quantity of sulphur is precipitated, and the remainder is converted into pentathionic acid—



Sulphide of hydrogen is highly inflammable; if burned in a limited quantity of air, the hydrogen is consumed, whilst most of the sulphur is deposited. By means of chlorine or nitric acid, it may be completely decomposed; hence, chlorine acts as a disinfectant and purifier of sewers or rooms impregnated with the odor of sulphide of hydrogen. The annexed represents the decomposition:—



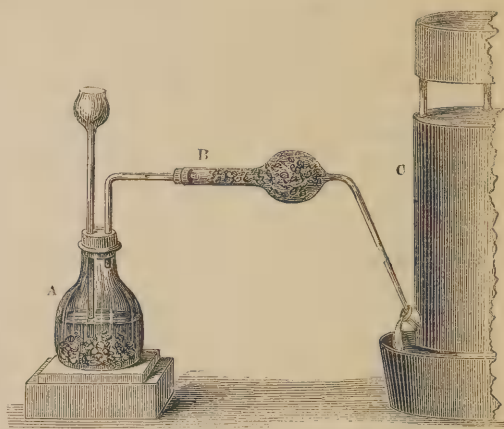
This gas is very poisonous; air containing only one eight-hundredth part producing death. Many of the metals decompose sulphide of hydrogen, particularly when heated in this compound, combining with the sulphur, and setting free the hydrogen. This occurs slowly, even at common temperatures; hence metals, as gold and silver, which are not oxidized by the air, are gradually tarnished by sulphide of hydrogen, which, exhaled from decomposing animal matter, is always present in the atmosphere. This gas, evolved probably by the action of water on the native sulphides of iron, at high temperatures, is a frequent constituent of mineral springs, and forms the class of spas termed sulphurous, such as those of Harrowgate, Lucan, and Golden-bridge. They are easily recognised by the fetid odor, by blackening a silver spoon, or by giving a black or brown precipitate with a solution of a lead salt.—*Kane*.

AMMONIA.—A full description of this volatile alkali is given in Vol. I., page 177, *et sequitur*.

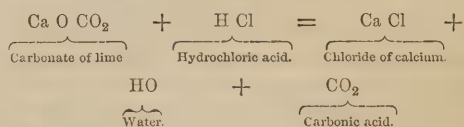
CARBONIC ACID exists in the atmosphere as a product of combustion, and of the respiration of animals. Combined with metallic oxides, it forms the numerous class of native earthy and metallic carbonates, of which the carbonate of lime is much the most important.

It is a result, also, of the slow decomposition of vegetable substances, and is evolved in great quantity from the ground in volcanic countries. In the fermentation of sugar, it is produced in abundance along with alcohol. For the purposes of the chemist, it is generally prepared by decomposing marble, or calc-spar, by means of any strong acid; from its cheapness, and the solubility of the residual salt, hydrochloric acid is generally employed. Some fragments of carbonate of lime being placed in a wide-necked bottle, A—Fig. 91—the acid diluted with its own volume of water, is

Fig. 91.



poured in by means of a funnel, as represented in the figure, and the gas which is evolved is conducted through the tube, B, filled with fragments of recently fused chloride of calcium to remove any moisture. It then passes into the gasometer, C, to be made use of as required. The decomposition is as follows:—



The gas, owing to its gravity, may be received in a wide-mouthed bottle, which in this case is ascertained to be full by applying a lighted taper to the mouth, when it is immediately extinguished.

The properties of this gas are exceedingly striking; it is entirely void of color, and invisible; it is irrespirable, producing, when an attempt is made to breathe it, violent spasms of the glottis. If it be inhaled with air, even in the proportion of one to ten, it gradually produces stupor and death, acting as a narcotic poison. Its specific gravity is 1.511; hence, when disengaged in large quantity, whether by natural operations, or in the process of manufacture, it accumulates in all cavities within its reach, and may cause fatal accidents to animals which enter inadvertently. Workmen engaged in cleaning out dry wells or vaults, or the large vats from which fermenting liquors have been run off, should carefully observe whether a candle can remain for some time burning brightly at the bottom. In volcanic countries, chasms are frequently occupied to the

level of their surface by this gas, exhaled from the ground; and an experiment often shown, to amuse the traveller, consists in walking into such a cavern with a dog, which, holding the head near the floor, is almost instantly asphyxiated by the inferior layer of carbonic acid, whilst men, whose heads are above the level, breathe pure air; the dog, on being thrown into a neighboring pond, recovers from the stupor. Carbonic acid does not support combustion, a burning taper held in a jar of it being instantly extinguished; and the high specific gravity of the gas may be easily illustrated by placing a lighted taper at the bottom of a vessel holding air, and taking in the hand another containing carbonic acid; on inclining the latter, the heavy gas can be poured into that which contains the lighted taper—just as water may be emptied from one vessel to another—and falling to the bottom, extinguishes it.

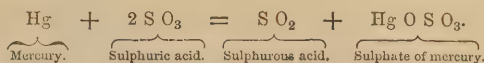
Water absorbs its own volume of carbonic acid gas, forming a solution possessing an agreeably acid taste, and which sparkles when agitated. It changes blue litmus into a wine-red, which, by exposure to the air or heat, disappears. By means of pressure, water can be made to retain a large quantity of this gas, which escapes with effervescence when the pressure is removed, and is thus the basis of a variety of agreeable effervescing beverages. Carbonic acid dissolved in water precipitates solutions of lime and baryta white, forming carbonates, which redissolve in an excess of this acid.

Under a pressure of thirty-six atmospheres, carbonic acid may be liquefied. It then forms a colorless, exceedingly mobile liquid, having a specific gravity 0.83 at 32°, which is remarkable for its excessive expansibility by heat—this being four times that of air, or nearly one per cent. for each degree of Fahrenheit. When the pressure is suddenly removed from the liquid acid, it regains the elastic form with such rapidity, that, in consequence of the amount of latent heat with which the vapor combines, and which is abstracted from the liquid portion, part of it is frozen to a solid. Solid carbonic acid can thus be obtained in large quantity by an apparatus contrived by THILORIER. It is a white body in filamentous masses, like asbestos; it evaporates but slowly; it is very soluble in alcohol and ether; the latter solution produces by its evaporation the most intense cold known, estimated at *minus* 166°.—*Kane.*

SULPHUROUS ACID exists at ordinary temperatures and pressures in the gaseous form, but is one of the most easily condensable gases. It is always produced when sulphur is burnt in the atmosphere, or in pure oxygen, sulphur being incapable of passing directly into a higher degree of oxidation. In the burning of sulphur, the volume of sulphurous acid gas produced equals exactly that of the oxygen consumed.

When desired pure, it is usually prepared by decomposing sulphuric acid, by means of a metal not very easily oxidized, as mercury or copper. The metal combines with one equivalent of the oxygen of the sulphuric acid, and the sulphur with the remaining two equivalents of oxygen pass off as sulphurous acid gas; the oxide obtained unites with the sulphuric

acid to form a salt. Thus, taking mercury for an instance:—



If the temperature be not elevated beyond 200° in this process, it is black or suboxide of mercury which is produced— $\text{Hg}_2 \text{O}$ —but above that degree the red oxide— Hg O —alone is formed.

Sulphurous acid gas is absorbed by water; and hence, in order to examine its properties in that state, it must be collected over mercury. It is colorless and transparent, having a peculiar irritating odor, and cannot be respired. It is neither combustible, nor a supporter of combustion. It possesses bleaching properties, owing to which it is used in the arts to whiten straw bonnets, corn, silk, sponges, and other substances; if a red rose be exposed to the flame of burning sulphur, it becomes completely white.

When this gas is exposed to a temperature at zero, it condenses into a liquid, which boils at 14°, and produces by its evaporation intense cold.

Water dissolves about thirty-seven times its volume of this gas; the solution possesses the properties of sulphurous acid in a very high degree, and bleaches vegetal colors with great power; when kept for some time it gradually absorbs oxygen, and the sulphurous becomes converted into sulphuric acid.

Sulphurous acid is one of the most feeble acids known, and is expelled from its combinations by almost all acids but carbonic, to which the Editor has shown that it bears a most striking resemblance, and this even extends to the salts of both.

BISULPHIDE OF CARBON.—This remarkable substance is obtained whenever sulphur comes in contact with red-hot charcoal. Procured in this way, it contains an excess of sulphur dissolved in it, and must be purified by redistillation at a very moderate heat; when about nine-tenths have distilled over, by allowing the residue to evaporate spontaneously in a capsule, very fine right rhombic crystals of sulphur deposit.

The bisulphide of carbon is a colorless liquid possessing a very disagreeable alliaceous odor. It does not mix with water, but dissolves in alcohol and ether. Sulphur and phosphorus are soluble in it in large quantity. Its specific gravity is 1.272. It boils at 108°, and forms a colorless vapor, the specific gravity of which is 2.621. From its volatility, it obtained the name of *alcohol of sulphur*. While evaporating, it produces great cold; mercury may be frozen by suspending under the bell-glass a thermometer, the bulb of which is surrounded by cotton moistened with this fluid, and rapidly exhausting the air. It is very inflammable, burning with a blue flame, and producing carbonic and sulphurous acids. If a few drops of it be allowed to fall into a strong bottle containing oxygen, it detonates when touched with a lighted taper, like a mixture of oxygen and hydrogen. When the bisulphide of carbon is heated in contact with a metal, carbon is separated, and a metallic sulphide produced, which proves it to consist of one equivalent of carbon united with two of sulphur.

It is a powerful sulphur-acid, combining with the

sulphides of the alkaline metals, and yielding sulphur-salts, which are crystallizable; with the sulphides of lead, silver, copper, *et cetera*, it forms insoluble compounds, which correspond closely in composition to the ordinary carbonates. This substance, in fact, exactly corresponds to carbonic acid— CO_2 —the sulphur being replaced by oxygen, and hence it is often called sulpho-carbonic acid.—*Kane*.

NITROGEN is one of the two gases that constitute the atmosphere; it serves only to modify the effect of oxygen, and render the air fit and suitable for respiration: it is called nitrogen, from being the basis of nitric acid. It is also called by some chemists *azote*, from its incapability of supporting existence; but the former name is generally used, as a great many other gases have not the power of sustaining life.

Nitrogen exists in great quantity in the atmosphere;



Fig. 92.

it is readily procured by abstracting the oxygen from a confined portion of the air, when nitrogen remains almost entirely pure. Thus, if a small piece of phosphorus laid in a cup, *a*, floating in water, be set on fire, and a bell-glass, *a*, be inverted over it, the phosphorus, in burning, unites with the oxygen of the air, and forms white fumes of phosphoric acid. At first, from the great expansion of the air, caused by the high temperature of the flame, some bubbles escape from under the edge of the glass, but soon, even before the phosphorus ceases to burn, the water begins to rise in the bell, and finally, the clouds of phosphoric acid

gradually dissolving in the water, the residual gas will be found to occupy four-fifths of the original volume of the air, and to be colorless. Any combustible body would answer the same purpose, although not so perfectly as the phosphorus.

Independent of this source of nitrogen in atmospheric air, it may be obtained indirectly from other substances. Thus, most animal matters contain nitrogen in large quantity, united to carbon, hydrogen, and oxygen. If, therefore, some pieces of muscle, or albumen, or gelatin, be boiled in a retort with nitric acid, the oxygen of the latter combines with the carbon and hydrogen of the animal substance, forming different compounds, according to the temperature and the proportions, whilst the nitrogen of both is disengaged.

Nitrogen is a permanent gas, colorless, and transparent; it is absorbed by water only in very small quantity. It is lighter than atmospheric air, its specific gravity being 0.976, air being 1.000. It is characterized by the complete absence of the positive properties which distinguish other gases. Thus it does not support combustion or respiration; it extinguishes a taper, and animals are suffocated in it; but these effects appear to be due only to the absence of oxygen.—*Kane*.

AQUEOUS VAPOR.—It will be necessary merely to allude to the aqueous product of the distillation of coal, which is water holding in solution—

Carbonate of ammonia.
Sulphate of ammonia.
Sulphide of ammonium.
Chloride of ammonium.
Ferrocyanide of ammonium.

Most of these are fully described in Vol. I., page 183, *et sequitur*, and therefore, being only secondary products, need not be further dwelt upon.

OILY MATTERS.—The oily portion consists of—

Liquid.	{ Benzol, Toluol, Cumol, }	Neutral, {	$\text{C}_{12} \text{H}_6$	} Constituents of naphtha.
			.....	$\text{C}_{14} \text{H}_8$
			.....	$\text{C}_{18} \text{H}_{12}$
Liquid.	{ Anilin, Picolin, Leucolin, Hydrate of Phenyl-acid— }		$\text{C}_{12} \text{H}_7 \text{N}$	} Constituents of heavy oil of tar.
			.....	$\text{C}_{12} \text{H}_7 \text{N}$
			.....	$\text{C}_{18} \text{H}_8 \text{N}$
			.....	$\text{C}_{12} \text{H}_6 \text{O}_2$
Solid.	{ Naphthalin, Paranaphthalin, Pyren, Chrysen, }		$\text{C}_{20} \text{H}_8$	} Constituents of heavy oil of tar.
			.....	$\text{C}_{30} \text{H}_{12}$
			.....	$\text{C}_{30} \text{H}_{12}$

The Editor having learnt that the little information with reference to these ingredients, which is given in the treatises on gas hitherto published, has been felt as a want, will now refer to them individually; because, although secondary in point of importance, they are highly interesting, as being so intimately connected with the manufacture of coal-gas, which will constitute the principal subject of this article:—

Toluol.—When tolu balsam is distilled, there passes over a large quantity of benzoic, mixed with a little cinnamic acid, and a yellow liquid, which is a mixture of *toluol* and benzoic ether. By redistilling this, so as only to collect the portions which pass over between 265° and 285° , a distillate is obtained, which, when deprived of benzoic acid by distillation with solid caustic potassa, possesses the properties which belong to toluol.

It is a colorless limpid liquid, having an odor like benzol, volatile without residue, and boils at 226° ; the density of its vapor is 3.246. When it is acted on by concentrated nitric acid, and water afterwards added, an oily fluid is obtained, which is nitrotoluid, $\text{C}_{14} \text{H}_7 \text{NO}_4$, or, according to the Editor, toluol in which one equivalent of hydrogen is replaced by peroxide of nitrogen. By the action of sulphide of ammonium upon nitrotoluid, a yellow oil, which gradually solidifies into a crystalline mass, is obtained. To this substance, which acts as an *organic base*, the Editor gave the name of toluidin.

It crystallizes from its hot alcoholic solution in large broad plates. It is soluble in pyroxylic spirit, sulphide of carbon, and the fat and volatile oils, with the same facility as in spirit of wine; it is very sparingly soluble

in water; it has a vinous aromatic smell and burning taste; it has no action upon turmeric, but it changes red dahlia paper to green. With nitric acid it produces a fine scarlet color, whereas anilin, so treated, assumes a blue tinge. The extraordinary crystalline tendency which distinguishes the salt of anilin, belongs also to toluidin; its alcoholic solution almost immediately solidifies when mixed with an acid. Its salts are inodorous, and, with the exception of the platinum and palladium compounds, colorless. It gave on analysis the following:—

		Theory.	Editor.
14 Eqs. of carbon,	84	78.50	78.53
9 Eqs. of hydrogen, . . .	9	8.41	8.61
1 Eq. of nitrogen,	14	13.09	12.86
1 Eq. of toluidin,	107	100.00	100.00

Cumol occurs with hydrocyamid in Roman cumin oil, which, when distilled in an oil-bath, parts with a volatile acid, the hydrocyamid, at 165°, and in the residue the cumin oil remains as a colorless liquid, retaining a strong odor of Roman cumin oil, and a sharp burning taste; boils at 220°. By the action of cyanide of potassium, cumin oil is converted into a product resembling benzoin; in the air, and by the influence of oxidation, it yields cuminic acid. If cumin oil be boiled a long time with nitric acid, there is obtained nitrocuminic acid.

Anilin.—This base, which has the same constitution as picolin, exists in coal-tar oil, as well as in DIPPEL's oil; that which, by fractional distillation of the mixed bases, passes over at 182° is anilin. If sulphide of hydrogen be transmitted into an alcoholic solution of nitrobenzid, saturated with ammonia, sulphur is separated, and shortly the whole stiffens at 0° to a mass consisting of yellow crystalline needles; if this be heated to 212°, the solution filtered away from sulphur, and the filtrate distilled until the contents of the retort separate into layers, then is the lower one *anilin*, which is purified by distillation. It is a colorless fluid, strongly refracts light, has a penetrating odor, taste sharply burning, specific gravity 1.020, boiling point 182°; easily soluble in cold water, alcohol, and ether; if the aqueous solution be warmed it clouds, a portion of anilin being separated; it does not possess an alkaline reaction, but coagulates albumen; in contact with hydrochloric acid it forms a white vapor. When anilin is exposed to air it absorbs oxygen, and becomes yellow, brown, and resinous. A few drops of fuming nitric acid added to anhydrous anilin produce a fine blue color, which on slightly heating the mixture becomes yellow, and violent action ensues, sometimes followed by explosion; otherwise, the liquor passes through various hues, and crystals of nitropicric acid are ultimately formed. When anilin is added to a solution of hypermanganate of potassa, binoxide of manganese, oxalic acid, and ammonia are formed.

If to a solution of chloroxide of calcium—bleaching powder—anilin be added, a deep violet color is obtained, which in the presence of acids becomes red. By these reactions, anilin is distinguished from the other bases which have the same constitution. With the acids, anilin forms crystallizable inodorous salts, which are soluble in water and in alcohol, and which in the moist

air soon become rosy-red. Anilin precipitates the salts of the protoxide and sesquioxide of iron, alumina, and oxide of zinc. Cyanide, ferrocyanide, and sulphocyanide of potassium, do not react upon salts of anilin; tannin causes a brown precipitate.

Picolin occurs in DIPPEL's oil, as also in coal-tar, and in each part thereof, which, on distillation, goes over first, together with anilin. It is more volatile than anilin, and can, therefore, be separated by fractional distillation; what passes over at 133° is pure picolin. It is a flowing liquid of a strong, penetrating, somewhat aromatic smell, and sharp, burning, bitter taste; still fluid at 17°, boils at 133°, specific gravity 0.955; mixes with water, alcohol, and ether in all proportions; it is not precipitated by a solution of bleaching powder, does not coagulate albumen, reacts alkaline. Nitrate of silver, chlorides of barium and strontium, and sulphate of magnesia, are not apparently affected by picolin; tannin causes a white caseous precipitate. It combines with the chlorides of mercury, platinum, tin, and antimony. If picolin be added to a solution of chloride of gold, fine lemon crystals are obtained. The salts possess the property of crystallizing.

Leucolin or *Quinolin*.—This base is found in the least volatile portion of the basic oil of coal-tar, and is also formed when quin, cinchonin, strychnin, and thialdin, are heated with potassa. It has a disagreeable odor, and boils at 460°; its specific gravity is 1.081. It neutralizes acids, forming difficultly crystallizable salts. Its refractive and dispersive power is as high as that of bisulphide of carbon.

Hydrate of Phenyl, or *Carbolic acid*.—LAURENT obtained from that portion of the oil of tar which boils between 300° and 400°, *carbolic acid*, a compound which it has been found convenient to represent as the hydrated oxide of a radical which has been termed *phenyl*. It is obtained by agitating the oil with about twice its volume of *aqua potassæ*, pouring off the watery portion, and saturating it by hydrochloric acid. The carbolic acid separates in the form of a heavy oil, which may be purified by continuous distillation over a small quantity of caustic potassa.

Hydrate of phenyl is a colorless oily liquid, neutral to litmus paper, of a high refractive power, specific gravity 1.062. It has a penetrating odor, a pungent burning taste, and acts powerfully on the skin; it occasionally assumes the form of acicular crystals, which fuse at 94° and boil at 368°. It is slightly soluble in water. It forms crystallizable salts with the alkalis, which, however, retain an alkaline reaction; in many of its properties it resembles creasote. It unites with sulphuric acid to form sulphocarbolic or sulphophenic acid; with chlorine, bromine, and nitric acid, it yields various compounds.

Naphthalin is readily procured by the distillation of coal-tar, but its quantity is considerably enlarged if chlorine be transmitted into the menstruum, or if the latter be treated with bleaching powder, water, and sulphuric acid. Naphthalin always passes over last in the distillation of tar, mixed, however, with paranaphthalin, from which it is separated by treatment with alcohol, in which menstruum the latter is insoluble;

both bodies are deposited if the distillate be cooled to 10°. Naphthalin is purified by recrystallization from the hot alcoholic solution; it crystallizes by slow evaporation in thin, white, rhombic leaflets, and by slow sublimation in white, extremely light flakes of peculiar odor, and burning aromatic taste; insoluble in water, readily soluble in alcohol, ether, acetic acid, and a solution of oxalic acid; melts at 79°, boils at 212°; specific gravity 1.045. Easily distils with vapor of water is inflamed with difficulty, and burns with a sooty flame.

Paranaphthalin or *Anthracin*, which is found in coal-tar, is obtained by the method given in connection with naphthalin. It is procured pure by repeated distillation. Its properties are similar to those of naphthalin, but it does not fuse below 300°; completely sublimable; insoluble in water, scarcely soluble in alcohol or ether, but easily in oil of turpentine. If anthracin is boiled for a few minutes with nitric acid, it is converted into a yellow mass accompanied by evolution of nitrous acid; the mass stiffens after cooling, and if it be then washed with water and treated with ether, a substance remains which has not been thoroughly investigated. This body melts at a high temperature, and by cooling congeals to a mass consisting of long needles.

Pyren is isomeric with anthracin, and is found in tar from wood, coal, and oil. If the last be distilled until one-fourth remains, and the residue again submitted to distillation in a small retort until there is only carbon left, a reddish substance is obtained, which consists of pyren, chrysen, and empyreumatic oils; if this mixture be treated with ether, the chrysen remains, and if the ethereal extract be slowly evaporated, the pyren is then precipitated. It crystallizes from the boiling alcoholic solution in clear rhombohedral prisms; melts at 170° to 180°, and stiffens crystalline; inodorous, tasteless; insoluble in water, little soluble in ether and alcohol; on the contrary, readily soluble in oil of turpentine. Boiled with nitric acid it gives a combination, which consists of $C_{30} \left\{ \begin{smallmatrix} H_{10} \\ 2 NO_4 \end{smallmatrix} \right.$ *id est*, pyren, in which two equivalents of hydrogen are replaced by two of peroxide of nitrogen.

Chrysen.—The production of this body is stated in connection with the preceding; it appears as an inodorous and tasteless powder; insoluble in water and alcohol, and scarcely soluble in ether and oil of turpentine; fuses at 230° to 235°; solidifies crystalline. If it be boiled with nitric acid, it is completely dissolved, and a compound results, the composition of which is doubtful, but the Editor is of opinion that it must have the formula $C_{42} \left\{ \begin{smallmatrix} H_{12} \\ 2 NO_4 \end{smallmatrix} \right.$.

Besides these, there are various undescribed oils. Of these products, which are all contained in tar, it will be perceived that there is only oxygen in one, and this possesses acid properties. The first three are neutral, and constitute rectified coal naphtha. Three are alkaline, and contain nitrogen. The other four are solid and neutral. It is remarkable how few of the products of distillation have any oxygen, and how much they differ in this respect from those of wood; and that, where the oxygen does enter into combination, it

produces compounds having no illuminating properties, namely, carbonic oxide, carbonic acid, and water; and that, in one instance, it unites with a compound of carbon and hydrogen, producing an acid oil that is found in very small quantity in the tar.

The nitrogen of the coal forms ammonia, cyanogen, and a few alkaline oils; the latter is discovered in minute quantity in the tar. The products are nearly all compounds of carbon and hydrogen; and respecting these it is further to be observed, that when the hydrogen exists in greater quantity than the carbon, as in carbide of hydrogen, which contains two equivalents of hydrogen to one of carbon, the compound is permanently gaseous; this gas has been subjected to a pressure of thirty-two atmospheres, and to cold 166° below zero, without liquefying. Olefant gas, in which carbon and hydrogen exist in equal proportions, but in which two volumes of hydrogen and two of carbon are condensed into one volume, is durably gaseous; $C_{18} H_{12}$ is liquid; whilst naphthalin, $C_{20} H_8$; paranaphthalin, $C_{30} H_{12}$; pyren, $C_{15} H_3$; chrysen, $C_{12} H_4$, are solid. It may be safely asserted, that where the carbon and hydrogen exist in an equal number of equivalents, the compound will be gaseous, unless a very large number enters into the combination.

CHOICE OF GAS COAL.—What, then, are the practical inferences to be drawn from these statements? In the first place, it will be manifest that the greater the quantity of hydrogen, and the less oxygen and sulphur a cannel or coal may contain, the better it will be for gas-making; for the latter two rob the coal of a portion of its hydrogen, which is thereby prevented from uniting with a portion of carbon for the production of an illuminating gas. The coal should be selected as free from iron pyrites and sulphate of lime as possible, and lumps or masses of these should be thrown out, as they often occur in such a form in the coal.

EFFECTS OF WATER.—The coal should be moderately dried before being used, which can only be secured by its being stacked under cover, otherwise the rain would keep it saturated with moisture. The water, in its decomposition in the retorts, furnishes oxygen to the carbon of the coal, impoverishing the gas, whilst the hydrogen of the water does not combine with the carbon of the coal, but is liberated.

When the vapor of water is passed over red-hot coke and coal, and analysed, the resulting gas is found to consist, in a hundred volumes, of fifty-six of hydrogen, twenty-nine of carbonic oxide, 15.8 of carbonic acid, and light carbide of hydrogen only two-hundredths of one per cent. *It contains no olefant gas whatever*; this experiment is quite conclusive against the use of water or steam. It is evident that there are no products of the decomposition of water by red-hot coal or coke that possess any illuminating power. It has often been proposed to *pass steam into the retorts during the distillation of coal, but such a proceeding could have no good effect, but the contrary*. When it is considered that fifty per cent. of the whole of the gases proceeding from the decomposition of water by red-hot carbonaceous matter is hydrogen, it must be evident that this product would not only diminish the light of the gas with which it was mixed, but would give out such an

amount of heat during the burning of it as would render the use of such gas almost insupportable. The coal, then, should be dry; but it has been shown that air, passed between seams of coal, has been deprived of a portion of its oxygen, which must have combined with the carbon and hydrogen of the coal, and by so much have impaired its quality; further, it has been stated that coal and cannel are continually giving off gas—fire-damp—and this teaches that coal should be dried quickly and then used.

DISTILLATION OF COAL.—A few remarks may now be made on the changes which take place during the manufacture of gas by the distillation of coal in red-hot retorts. The nitrogen in gas is *entirely derived from atmospheric air*, admitted into the retorts during the charges, and by leakage in the apparatus, and is not a product of the decomposition of coal at all; it need not, therefore, be further dwelt upon.

The quality and illuminating power of the gas will be affected, not only by the quality, composition, and condition, wet or dry, old or recently obtained, of the coal or cannel, but by the degree of heat employed in its preparation, and the mode in which the operation is conducted. The chief products of the distillation are compounds of carbon and hydrogen, and these alone yield light; but of these, some are solids, others liquids, and some gaseous. The first two are of no value for the purpose of illumination, because their physical condition as solids and liquids precludes their use. The gaseous are three: one containing very little carbon—carbide of hydrogen—and, therefore, emitting very little light; the other two very rich in carbon—olefiant gas and volatile carbides of hydrogen—and giving light, though in small quantity. Mixed with these are found, besides the usual impurities—sulphide of hydrogen, ammonia, carbonic acid, *et cetera*—two gases, hydrogen and carbonic oxide, constituting the chief bulk of the mixed coal gas, which have been mentioned, but which are never evolved in natural operations. They are not necessary products of the process, but result from the mode of distillation.

The volatile hydrocarbons in coal gas, the exact nature of which has not yet been determined, and the proportions of which in the mixture are valuable, probably consist of propylene, C_3H_6 , FARADAY'S gas, C_4H_6 , and benzol, $C_{12}H_6$, with perhaps a portion of MANSFIELD'S allyl. In LEIGH'S earlier experiments on coal gas, which had been made from a different cannel to what is now employed at the Manchester Gas-Works, he found, pretty uniformly, that each volume of the gas, condensable by sulphuric acid or chlorine, required four and a half volumes of oxygen for combustion; subsequently, he ascertained that, when richer cannels were used, the condensable gases required a still larger proportion of oxygen for combustion. The fact, that a greater amount of carbonic acid is produced on exploding the gas with oxygen, than would proceed from a body of the series C_nH_n , shows that some other hydrocarbon, the carbon of which exists in a greater ratio to the hydrogen than in this series, is to be found in coal gas.

When the number of equivalents of carbon in a compound exceeds those of the hydrogen, it is, within cer-

tain limits, liquid: beyond these limits, solid: thus benzol, $C_{12}H_6$, in which the carbon is double the hydrogen; toluol, $C_{14}H_8$; and cumol, $C_{18}H_{12}$, are liquid;—whilst naphthalin, $C_{20}H_8$; paranaphthalin, $C_{30}H_{12}$; pyren, $C_{15}H_8$; and chrysen, $C_{12}H_4$, are solid.

The carbides of hydrogen may be conveniently divided into three classes. In the first, the number of equivalents exceeds that of the hydrogen; they are very rich in carbon, as benzol; these are either liquid or solid, and would give great light could they be burnt, but yield much smoke. In the second, the equivalents of carbon and hydrogen are equal in the compoundly as olefiant gas, volatile carbide of hydrogen; these are gaseous, but condensable by great pressure and intense cold, and give much light. In the third, the equivalents of hydrogen exceed those of carbon; these are altogether uncondensable, and give little light. When coal and similar organic matters are distilled at a comparatively low temperature, the carbon has a disposition to pass off with little hydrogen; the liquid carbides of hydrogen are formed; there is much tar and little gas, but the latter is rich. As the temperature rises, the liquid carbide of hydrogen diminishes in quantity and gaseous carbide of hydrogen increases; there is more gas and less tar. The heat still rising, the gaseous products become richer in hydrogen, and poorer in carbon; light carbide of hydrogen is formed in abundance; and at length, the temperature becoming still more elevated, pure hydrogen is evolved, as is always observed in the last hour's distillation in gas-making.

It is a well-known law of organic chemistry, that the higher the temperature, and the more advanced the decomposition of the substance, the simpler are the products.

When olefiant gas is passed through red-hot tubes, or lime, or, in fact, over any highly heated surface, it deposits a portion of carbon in a solid form, and escapes as a mixture of carbide of hydrogen and hydrogen. The same thing LEIGH has proved of naphtha, which deposits carbon in like circumstances, and is resolved into simple products.

The affinity between carbon and hydrogen seems to diminish with the temperature.

Is it not probable, that in the distillation of masses of coal, compounds rich in carbon are first formed, the carbon being in excess of the hydrogen? as the product rises in temperature, it deposits a portion of its carbon, the equivalents of hydrogen become equal, and a rich gas is formed; but this, getting still hotter, deposits more carbon; the hydrogen is now in excess, the gas is poor and gives little light; the heat still increasing, the affinity between the hydrogen and carbon is entirely disrupted, the remaining carbon is deposited, and pure hydrogen given off. Certainly all this can be effected artificially; and that it is so to a large extent in gas-making, is evident from the thick lining of almost pure carbon which soon forms in the interior of gas retorts, and which must proceed from the decomposition of the gas by the red-hot surface—must be deposited from it, in fact. Still there are, probably, three products at least of the decomposition of a liquid carbo-hydrogen: solid carbon, a gaseous product containing much hydrogen, and a solid hydro-

carbon having much carbon, the elements being divided amongst each other. When naphtha vapor is passed over red-hot quartz, it deposits carbon, gives off olefiant gas and light carbide of hydrogen, and forms a crystalline compound, naphthalin. With these facts, is it not reasonable to conclude, that there is a temperature at which, in the process of decomposition, olefiant gas and volatile hydrocarbon should be formed, and which yet should be unable to decompose these into compounds poorer in carbon, the intensity of decomposition being proportionate to that of the heat? The Editor agrees with LEIGH in thinking there cannot be a doubt that there is such a temperature, but it must be far below that at present employed for the manufacture of gas. Let the present system of gas-making be examined, says LEIGH, and the true source of the hydrogen and carbonic oxide, so invariably found in gas, and constituting so large a portion of its bulk, will be seen. It may be premised, that when carbonic acid is passed over red-hot coke, it is resolved into carbonic oxide, by taking up an additional equivalent of carbon.

When compact masses of coal are thrown in heaps, of a hundredweight and a half, into retorts heated to a bright redness, as is now done, they are exposed to two very different conditions: the surface of the mass, the exterior, in contact with the intensely hot retort, is instantly decomposed and charred; hydrocarbons, as olefiant gas, *et cetera*, are eliminated, which also, at this temperature, are partly decomposed and converted into light carbide of hydrogen and pure hydrogen, with deposition of carbon, which, with some undecomposed olefiant gas and volatile hydrocarbons, pass off from the retort. The interior of the mass, on the other hand, is for some time exposed to a very moderate heat, and a simple distillation is accomplished; those compounds that are formed at a comparatively low temperature, the heavy hydrocarbons, which would ordinarily be in a liquid state, are eliminated; a portion, rising into vapor as it reaches the hotter surface, passes off with the gases formed, and condenses again when it has left the retort in the form of tar; but that portion of the vapor which, in its passage, comes into contact with the red-hot surface of the exterior of the mass and of the sides of the retort, deposits a portion of its carbon, and is resolved into simple compounds, olefiant gas and volatile hydrocarbons, which themselves partly undergo the change already described. As the heat penetrates to the centre, and a red-hot mass of charred material of considerable thickness comes to surround the decomposing coal within, as happens towards the end of the distillation, the whole of the hydrocarbons, namely, light oils, volatile hydrocarbons, olefiant gas, and even light carbide of hydrogen itself, that are eliminated, are decomposed in passing over such an extent of heated surface, and pure hydrogen is almost alone evolved. The carbonic oxide, which is formed from the union of the oxygen of the coal, and of the air admitted with the carbon of the coal, is also partially decomposed during the whole of the process, but in an opposite direction; not by depositing carbon, but by taking up more, and being converted into carbonic oxide, which is evolved with the gas.

These are the true sources of the hydrogen and carbonic oxide in gas; they are not necessary results of the distillation, but products of the decomposition of the distilled matter. It has been perfectly ascertained by LEIGH and other chemists, that when olefiant gas is passed through a nearly white-hot porcelain tube, it is entirely decomposed, depositing the whole of its carbon, and giving off pure hydrogen.

The greater the heat employed, then, in the process of gas-making, above a certain limit—namely, that requisite for the decomposition of the liquid hydrocarbons—the greater will be the bulk of the gas, and the poorer its quality; the more light carbide of hydrogen, hydrogen, and carbonic oxide it will contain, and the less volatile hydrocarbon and olefiant gas. The analysis of the gas will, therefore, furnish a test of the excellence of the process employed in the manufacture, and a check on the workman, by exhibiting, in the relative amount of hydrogen, and of the illuminating hydrocarbon, whether the heat has been too great. A large quantity of gas may be made from coal, and very badly made. *The mere amount of gas produced is no proof of the excellence of the manufacture.*

Cannel yielding eleven thousand feet of gas per ton, of specific gravity 1.600, would furnish, for every hundred pounds distilled, about—

	Pounds.
Gas,	22.25
Tar,	8.50
Ammonia water,	9.50
Coke,	59.75
	100.00

These proportions will vary considerably, but still the numbers will represent a general average of produce. It has been shown above, that considerably more than one-third of the weight of the gas produced is distilled from the cannel in the form of tar, which contains, and is almost entirely composed of, the richest carbo-hydrogen, and very little oxygen; whilst the gas, as it contains only about forty-five per cent. of compounds of carbon and hydrogen by measure, amounting to about half its weight, has really only eleven pounds, or something near that number, of carbo-hydrogen, and of this only about four pounds will be olefiant and richly illuminating gases. So that the tar truly holds as much illuminating matter, or nearly so, as exists in the gas—not twice as much, as would appear from the numbers; for it must be borne in mind, that in the oils composing the tar the carbon exists in much greater proportion than the hydrogen—one of the lightest, benzol, being a compound of carbon, twelve; hydrogen, six—naphthalin and the solid carbides being represented by carbon, twenty; hydrogen, eight; and even higher proportions of carbon. So that, in the decomposition into illuminating gases, much of the weight must be lost in the form of deposited carbon. It will be now tolerably apparent, that in the form of distilled matters nearly one-half of the illuminating portion derivable from coal and cannel is lost to the gas. It is probable that a perfect system of gas-making would produce, from good cannel, a compound containing twenty per cent. of olefiant or other illuminating gases.

MANUFACTURE.—The process followed at the Liverpool gas-works, where the purest gas in the kingdom is produced, will first be cursorily described, so as to give the reader an insight into the manufacture; and, subsequently, the several parts of the apparatus will be treated of fully and separately.

The mode of decomposing the coal is a point of great importance; because, upon its successful results the advantages of gas-lighting, as far as respects economy and profit, principally depend.

The vessels employed for distilling or carbonizing the coal are called retorts, and may be either of cast-iron or fire-clay. Fig. 93 shows a general plan of the gas-works above-mentioned, and Fig. 94 a sectional view, in which A A represents the fire, and B B the retorts.

To introduce the coal into the retort a shovel is used; but in stations having small ones, the coal is placed in a long semicircular iron shovel, or scoop, which, being inverted, spreads it in thin layers, so that every portion of it may be exposed to the action of heat. In order that the required substances may be evolved in sufficient quantities, there must be the requisite amount of caloric; for if a piece of coal is to be extended to two hundred and seventy times its bulk, the heat applied must be equal to the force requisite to produce a separation and expansion of its equivalents.

The heat should be sufficient at the outset to extract the maximum quantity of gas. During the first two or three hours, the greatest proportion of tar is produced. This is accounted for on the principle, that the temperature in the retort is not high enough to maintain the material in a gaseous form, and hence the large amount of tar. If the retort should be too hot, some of the heavy gas will be decomposed, depositing part of its carbon, and forming light carbide of hydrogen; if, on the contrary, it is not sufficiently hot, there will be formed, as just stated, a large proportion of tar, and the gas will be light and of a bad quality. The charge should not be left in too long, as the last portions consist chiefly of hydrogen and carbonic oxide, both of which have a most injurious effect upon the quality of the products. The process requires five, six, or eight hours, according to the nature of the coal and the shape of the retort.

Previous to drawing the charge, the lid is loosened and a light applied; this precaution is necessary to prevent explosion, or what the stoker denominates a *rap*. At large establishments, the retorts are not suffered to lose their heat, but as soon as the incandescent coke has been taken out of them, are immediately replenished with fresh coal, and the operation renewed.

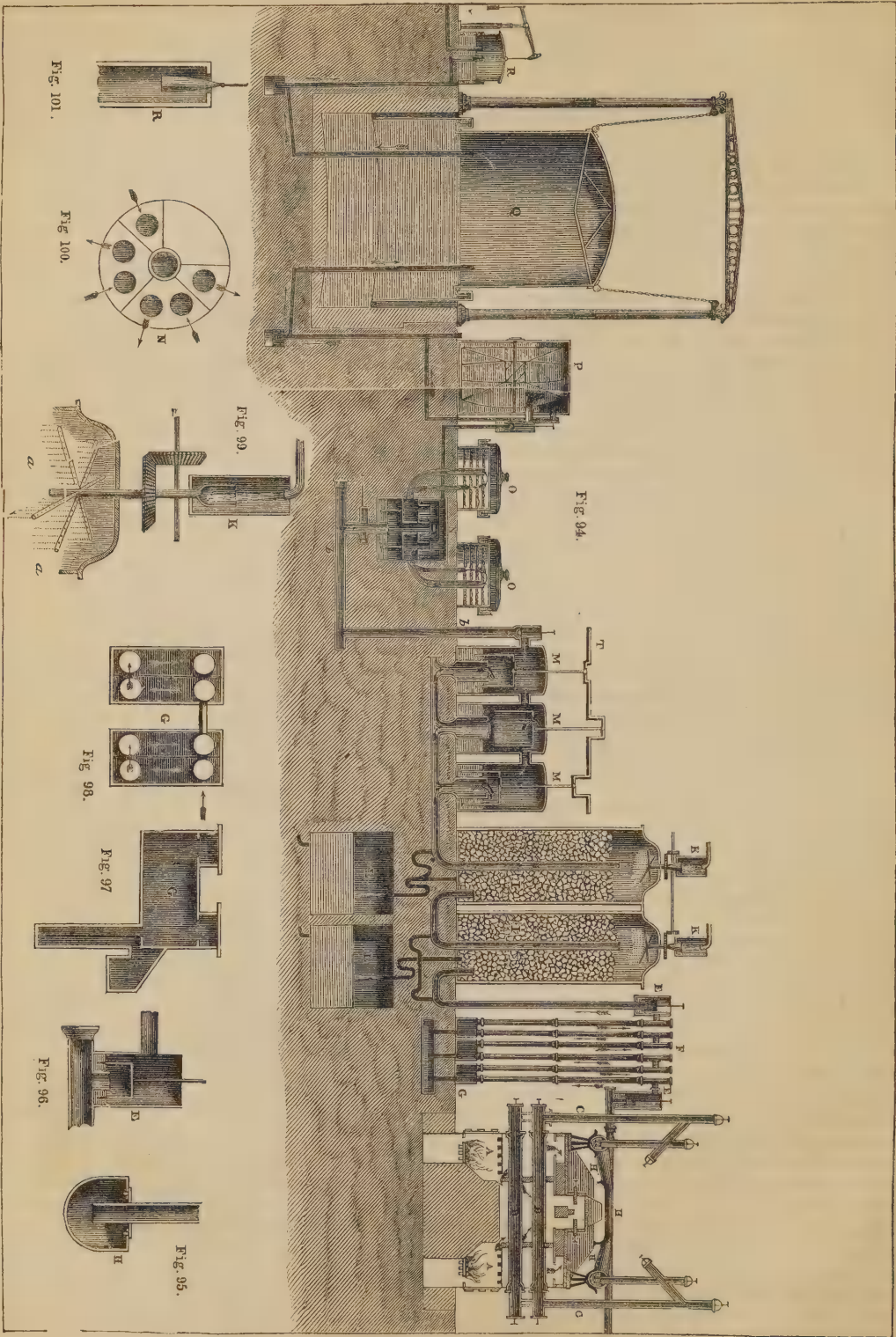
Inasmuch as the coke is withdrawn in a state of redness, the heat required to raise it to that temperature is lost. To remedy this, CROLL introduced the practice of burning the coke as fuel, immediately after its removal, and this plan is said to cause a saving of ten per cent.

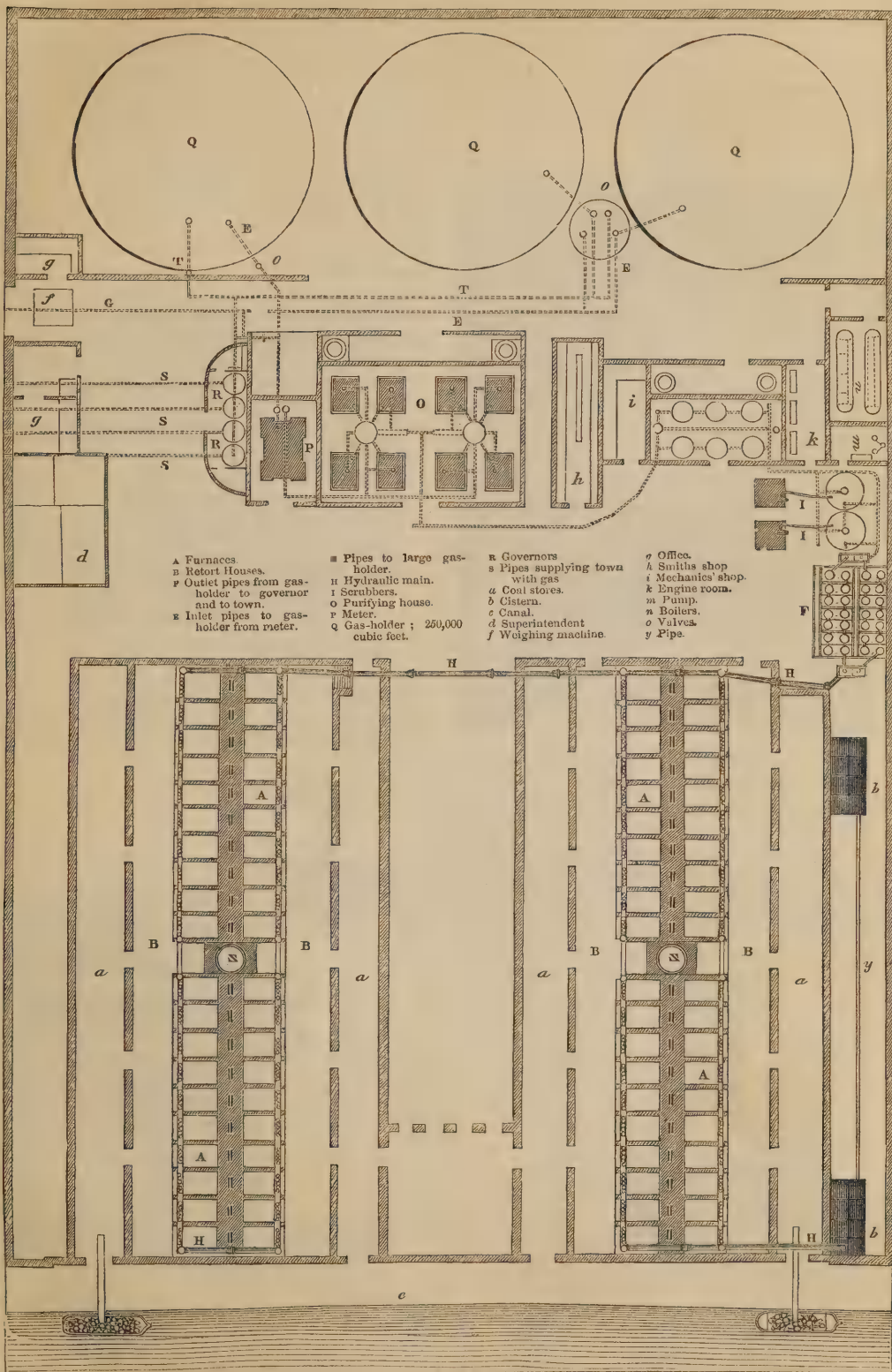
The dense vapors which pass from the retort are conveyed through the ascension pipes, c, Fig. 94, into the hydraulic main, H H, which runs the entire length of the house, and to which all the retorts are connected. Its position must be perfectly horizontal; it is used to cut off the communication between the retorts, when one

or more benches are charging or open. This is shown in Fig. 95. One end of it is perfectly closed by means of a flange, and the other has a similar one. On the top is attached a pipe, through which the gas passes to the condenser. In the outside of this end a piece of iron is placed, so that the water in the main is preserved at a certain height, and cannot sink below the proper level required for the operation. An enlarged view of this is shown at E, Fig. 96. The dip-pipes descend so far into the hydraulic main, D, as to be immersed in the water about three inches; by this means the gas is forced to pass through a quantity of liquid before it can enter the upper part of the main to escape, and becomes partly condensed, and deposits tar and ammonia, but, owing to its superheated state, portions of these products are still retained, and must be separated by further condensation. To effect this, the gas is conveyed into a double set of refrigerating pipes, F F—Fig. 94—closed at the top, and opening into a box, G, at the bottom, a section and plan of which are shown in Figs. 97 and 98. The latter receives two pipes, and constitutes one pair of the series which are united by a short connecting-pipe at the top, as seen in the drawing. The greater the quantity of cold surface the gas is exposed to, the more complete the condensation, and a state of stillness materially aids the deposition of the tar. Thence the gas passes through the scrubbers, I I—two large towers filled with paving-stones—and at the top of which one of the pipes, K K, for conducting water, which is kept continually percolating, is shown in the enlarged view of K—Fig. 99. The condensers and the scrubbers are relieved of their tar and ammonia by the cisterns, L L, which are conveniently placed under ground. The ammonia, being the lighter, floats at the top, and is therefore easily separated from the tar. In the articles AMMONIA and ASPHALT, the purposes to which both products are applied are enumerated. From the scrubbers the gas passes through the exhausters, M M M—a series of apparatus introduced into modern gas-works, for the purpose of drawing off the gas and relieving the pressure in the retorts. They are worked by a shaft, T, connected with the engine.

The gas then enters through a pipe, b b, into the chamber, N, a plan of which is given in Fig. 100. From this it is conducted, as shown by the arrows, through the dry lime purifiers, O O, where it parts with its carbonic acid and sulphide of hydrogen. It is next conveyed to the station-meter, P; thence to the gas-holder, Q; then into the governor, R, the principle of which is illustrated in Fig. 101; and, lastly, to the main, S, supplying the town with gas.

Whoever enters, says DODD, for the first time into a retort-house cannot fail to be struck with its appearance. The iron roof and floor—the absence of windows, machinery, and work-benches—the curious appearance of the walls, covered over with complicated iron-work—the darkness of the place—the appearance of the men,—all have an aspect of strangeness. But, at intervals of every hour or two, and especially at night, the visitor's attention is suddenly awakened to a startling scene going on within the building. A set of men are seen advancing to one part of the side apparatus; they turn the handles of what appear to be screws; several ex-





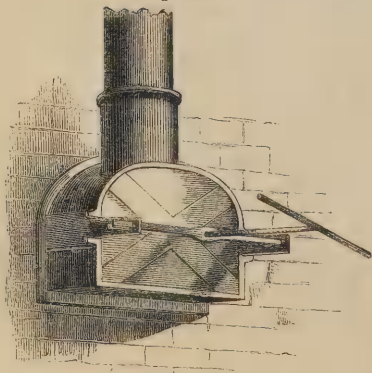
plosive reports are heard, followed by the removal of circular iron doors or covers, about a foot in diameter; a burst of flame then issues from each orifice from which a cover has been taken; and, on going in front of one of these openings, there will be perceived a mass of intensely burning coal, or rather coke, extending back to the depth of six or seven feet. Then will follow the

Fig. 102.



removal, by means of rakes, of all the burning materials from each aperture; then the hissing and steaming consequent on the wetting of the coke by buckets of water; and, lastly, the re-charging of the heated cavity with fresh coals. It is not until after witnessing this series of operations that a stranger can rightly understand the arrangements of such a place. Fig. 102 gives some idea of the retort-house.

Fig. 103.



Retorts.—As the form of the retorts in which the coal is distilled, and the material of which they are composed, are matters of paramount importance, it will

be desirable to enter fully into details with regard to them. They are usually of cast-iron, seven feet long, and one foot in diameter.

TOMLINSON states that, before being used, they are tested by being placed in water, and then forcing air through them; if any flaw exist, it is detected by the air escaping in bubbles. Each retort is generally in two pieces, which are connected by flanges and screws—namely, the *neck* or *mouth-piece*, and the *body* or *hinder part*, which, by constant exposure to the fire, soon wears out, and requires renewal, while the mouth-piece is but little affected. The retort is charged and discharged at the mouth, which is closed by a lid, and fixed by means of a screw and a holdfast, the joint being made tight by a luting of clay, or refuse lime from the purifier. The gases which are generated from the coal escape from the retort by a wide tube, cast into the mouth-piece, and shown in Fig. 103, rising up therefrom. The best form for the body of the retort for obtaining a large quantity of gas in the shortest time, was long a matter of discussion.—Tomlinson.

That shape of retort would be best which would bring the whole charge into connection with the red-

Fig. 106.

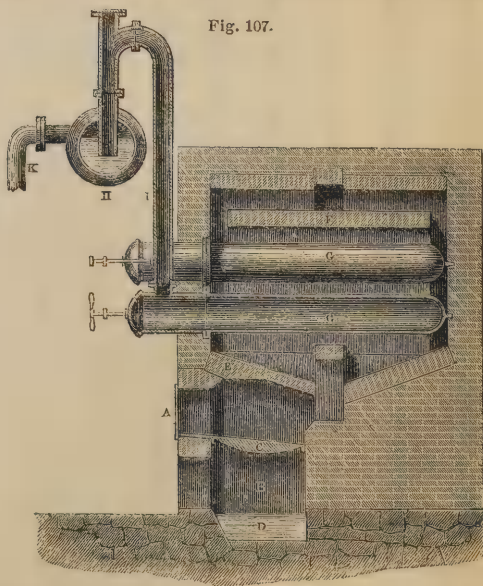
Fig. 105.

Fig. 104.



hot sides. Hence, at the suggestion of PRECHTL, the original circular form of retort—Fig. 104—was soon superseded by the elliptical one—Fig. 105—and this has been improved by bending in the lower surface—Fig. 106. With the same length of 6·5 feet, exposed to the

Fig. 107.

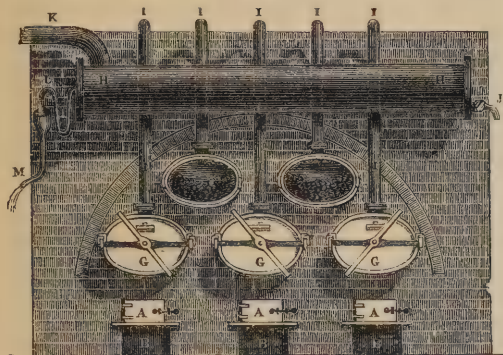


fire, one hundred and fifty pounds of coal, when they only half-fill the retort, will cover, in the round retort, a red-hot surface of ten inches in width; in the oval retort, a surface nearly of twelve inches. The layer

of coal, in the latter retort, is four inches thick, and about one-third nearer to the top of the retort than in the circular form. These advantages, which are self-evident, are strikingly shown in practice, the requisite time for heating being reduced to nearly one-half.—*Knapp.*

Fig. 107 shows the arrangement and position of the retorts, of which there are generally five placed pyramidally in one furnace. Fig 108 is a front view of the same. To the three fires of the furnace, A is the door, c the grate, and B the ash-pit, with a well, D—Fig. 107,

Fig. 108.



for occasionally drying lime-mud; E is one of the three arches which pass transversely over each fire and divide the flame, F is a large arch overspreading the retorts, G G, against which the flame breaks and escapes at the side. The conducting tubes, I I, rise side by side above the furnace, passing behind a large horizontal tube, H, called the hydraulic main, and lastly turning over above it, enter it, dipping down nearly to the bottom. As this main, H, is filled with tar, the mouths of the tubes, I I, are closed, and there is no connection established between the separate retorts. One may, therefore, be opened and charged, without in the least interfering with the process going on in the other. The greatest portion of the tar separates from the gas in H, which latter passes off through K, whilst the former is carried away by the tube, L, curved for the purpose of keeping H half-full, through M, to a tar cistern, which is shown at L, Fig. 94; H can be completely emptied by means of the tap, J.

A very hot flame, mixed with an excess of unconsumed air—oxidizing flame—is unnecessary for the evolution of gas, and deleterious, on account of the rapid destruction of the retorts which it occasions; everything, therefore, depends upon a uniform, steady fire. The destruction of the retorts is incredibly rapid, and dependent upon several circumstances; besides the combustion caused by the hot air of the fire, the sulphur in the coal converts the surface into sulphide of iron, which melts off, and, lastly, the deposit of carbon in the interior, is of no slight importance. This carbon is partly in the form of hair-like deposit, partly stalactitic, from the dropping of tar, but generally occurs as a coating, one or two inches thick, in concentric layers, and combined with iron to form graphite. The specific gravity of these layers increases rapidly from the inner-

most layer to those on the outside, from 1·7 to 2·3. The outermost contain 1·72 per cent. of iron, the inner layers less; sometimes they are so hard, that they will strike fire with steel, and can be polished like glass. Carbon, sulphur, and the oxygen of the air, are, therefore, conjointly destructive of the retort. The retorts suffer most from the air that enters at the door when the fire is poked, and attacks them whilst red-hot. To protect them from this, the stoking-hole is sometimes situated at the back of the furnace, in a continuation of the chimney, when the noxious draft passes away without attacking the retort.

Fire-clay retorts are now extensively used, especially in very large works; and, from all the Editor can learn, they are superior to cast-iron in every respect, as regards duration and the great quantity of gas they are able to produce. One great advantage which they possess over iron retorts, is the facility with which the carbon that accumulates on their interior can be scraped off. Retorts made of this material, which are charged and drawn at both ends, and are therefore termed *through* or double retorts, have been lately very largely introduced; their superiority over single or back-to-back retorts consists in the amount of space gained by leaving out the partition walls, and also the thickness of the ends of single ones. In addition to this, when iron retorts are employed, they become so choked up with carbon, that the charge of cannel has to be gradually reduced as the area of the interior of the retorts decreases. In *through*-clays this is obviated; and in order to remove the accumulated carbon, it is merely necessary to leave the retort mouths open, thus allowing a current of air to pass through, and the carbon will peel off in flakes if touched with a sharp bar; a portion may also be consumed. An iron retort will afford, according to various authorities, about seven hundred thousand feet of gas, whilst the same length of a through-retort of the same diameter has been known to produce six times that quantity. The amount of fuel required to heat the through-retorts efficiently, is as yet undecided: some engineers give it as their opinion that the amount requisite is the same as is necessary for iron retorts, whilst others affirm that they need a much larger quantity. Should the clay retorts become by any means cracked, a mixture, composed of the following ingredients, is found to be an excellent cement:—

	Per cent.
Fire-clay,	42·5
Loam-sand,	42·5
Glass,	10·0
Chloride of sodium,	5·0
	100·0

This compound is ground well together with water. The principle of sealing up the gas by a water lute, or hydraulic joint, is, however, the same in both cases, and affords another instance of those beautiful contrivances for using one fluid in the management and manipulation of another, which is much lighter and more elastic.

The Pipes for connecting the Retorts with the Main.—The pipes leading from the retort to the hydraulic main are not fitted in the retort itself, but into a sepa-

rate casting, termed the mouth-piece, which is commonly of the same size as the mouth of the retort, and is secured to it by a flange and bolts. The same kind of mouth-piece is used for clay retorts, which, instead of a flange, are provided with a ring, four inches in thickness and six in breadth, through which holes are cut to receive the bolts for securing the mouth-piece.

A bent pipe passes up from the mouth-piece to the hydraulic main, the straight part secured to it being called the stand-pipe, while the other straight part passing into the main is called the dip-pipe. The part connecting the dip and stand-pipe is named the bridge-pipe, and this part is usually provided with two bonnets, which can be removed when the pipe requires cleaning. The stand and dip-pipes vary in diameter from three to six inches, a very usual size being four inches. There are various modifications in the arrangement of pipes between the retorts and the hydraulic main. In England, the stand-pipe usually passes up to a height of four or five feet above the main, and is fitted at the top with a semicircular bridge, which connects it with the dip-pipe.

The Hydraulic Main.—This is a tube or trunk, H, Fig. 94, usually but not always of cast-iron, extending the entire length of the retort house, and varying from twelve to eighteen inches in diameter, and generally five-eighths to three-fourths of an inch in thickness, when made of cast-iron. Wrought-iron hydraulic mains are now beginning to be used, and will probably altogether supersede cast-iron, on account of their lightness and strength. These are usually made of larger diameter than the cast-iron, and put together in longer lengths. They are formed of three-eighths of an inch boiler plate. The ring forming the main is composed of two circular plates, and one flat piece on the top. These plates are made of two breadths, namely, about three and two feet, and about five feet six inches in length. They break joint with each other, by having their line of division alternately on opposite sides of the main, which is constructed in lengths of twenty-three feet, and at each end of this length, there is a flange three inches wide. At the end of each length, and also midway, is a division plate seven inches deep in the centre.

The cast-iron mains are generally of such a length as to reach over two benches, and the joints are made with bolts and nuts, and iron cement, in the usual manner. In old works, the hydraulic main is usually a circular tube; but of late years, D-shaped mains have been frequently employed, generally with the flat side downwards.

The hydraulic main, when first brought into action, is filled to about one-half with water, but the tar contained in the gas which passes into it is deposited, so that the sealing liquid changes its character, and becomes nearly all tar.

The hydraulic main being filled to the above height, the end of the dip-pipe passes through the water to a depth of three or four inches. The gas from the retorts is then conveyed through the dip-pipes, and bubbles up through the water, till it arrives in that part of the main above the surface of the liquid. The hydraulic

main, therefore, is the first receptacle in which the gas is collected, after its separation from the coal.

It perhaps will not be out of place to call attention, in passing, to the simple yet admirable contrivance exhibited in this apparatus, which is partly filled with a dense fluid for the purpose of forming a perfectly air-tight and gas-tight chamber, and cutting off all communication from this chamber to the retorts, while the passage of gas from the latter to the former is entirely free and open. Its *modus operandi* will be evident, if it be considered that the extreme lightness of the gas will always cause it to pass upwards through the tar, while, once arrived over its surface, it has no power whatever to displace the tar, and pass backwards. This exquisite contrivance is termed the water-joint, and the hydraulic main constitutes its first application in the gas manufacture. It is by this method that the chemist is enabled to store and confine his gases in the receivers of the pneumatic trough, and thus, by the use of denser fluids, such as water and mercury, to imprison the most volatile forms of gaseous matter in a mode which, for delicacy and subtlety, infinitely excels every scheme of mere mechanical fitting. It will be seen hereafter how largely this valuable principle of sealing up the aeriform fluids by denser ones, through which they can pass in one direction but not in the other, has been applied in the purifier, the gas-holder, and, in fact, in everything connected with the collection, storing, and distribution of the gas. At present, it may be sufficient to point attention to the value of this property, derived from the different densities of fluids, which gives both to the chemist and manufacturer a power over the aeriform bodies, which they could not hope to obtain by any other means.

Each of the pipes thus dipping into the tar of the hydraulic main freely delivers the gas produced in its own retort, and the liquid effectually prevents its return. However numerous may be the pipes entering into it, whether they contain gas or not, and whether the retorts are working or not, it is impossible that any gas delivered above the surface of the tar in the main can escape back.

The length of the dip-pipes should not be less than three feet, and is frequently made as much as five, in order to prevent the tar rising in the dip-pipes connected with the empty retorts as high as the bridge-piece. It is obvious that the pressure of gas from the working retorts will force the tar up a short distance into the empty dip-pipes, but this seldom equals three feet. As the hydraulic main is generally half filled with tar, its diameter must be so regulated that the latter forced up into the empty dip-pipes will not so far diminish the depth in the main as to uncover the ends of the former, because this would simultaneously unseal every one of them, and the gas would immediately escape.

The hydraulic main is sometimes placed in the solid structure of the brick-work over the retorts, but more frequently a little in advance of the ends, in which case it requires to be supported by columns. The hydraulic mains at the Great Central Gas-Works, London, are in the shape of a reversed D, eighteen inches in height and the same in width. There is one on each side of the stack

retorts. They are cast in lengths of nearly ten feet, so as to reach over one bench of retorts, and the joints are placed over the centre of the arches. Their thickness is five-eighths of an inch, with a two and three quarter flange at the ends of each length. The upright pillars to support the mains are hollow columns, seven inches at base, six inches at top, and five-eighths of an inch in thickness. A pillar is placed in the centre of each length, and the opposite pillars are tied together by bars of inch-round iron stretching entirely across the bench of the retorts.

Each length of the hydraulic main is usually provided with a partition, the top of which is level with the surface of the fluid, and the object of which is to keep it to the same height in every part of the main. Of course, where so much depends on the effective sealing-up of the ends of the dip-pipes, every care must be taken to fix the apparatus in a perfectly horizontal position, from end to end. When the hydraulic main is cast-iron, the holes to receive the ends of the dip-pipes are cast in it, and the flanges of the same are secured to the main by nuts and bolts, the joints being made with the usual cement, such as that employed for attaching the mouth-pieces to the retorts. When the main is of wrought-iron, the top is formed by a flat piece, to which the wrought-iron circular part of the main is attached by rivets, and in this flat piece the holes for the dip-pipes are cut by hand. One end of the hydraulic main is closed by a plate having the same section at the outside flange of the main, to which it is bolted and secured by iron cement. A similar plate is also bolted at the other end of the main, but this plate is provided with an orifice usually about half the diameter of the main itself. The lower part of this orifice is immediately above the level of the fluid in the hydraulic main, and the orifice itself corresponds with the exit-pipe, which conveys away the gas to the condenser. The flange of the exit-pipe is bolted on to the perforated end-plate of the main. It is usually provided, soon after leaving this apparatus, with a descending pipe to carry off the tar into the cistern below the condenser. The lower end of this descending pipe must be sealed either by its dipping several feet into the tar of the cistern, or into a small vessel which communicates with the latter. The descending pipe to carry off the tar is not absolutely necessary at this place, because the same office is sometimes performed by the siphon-pipe at the first bottom bend of the condenser.—*Hughes*.

Condenser and Scrubber.—A separate account of these is unnecessary, as the reader will fully understand their use and purpose from the description given of them at page 133, as well as by referring to them on the general section, F I K, page 135, and enlarged view, Fig. 99.

The Exhauster.—In describing this apparatus, which has been introduced into modern gas-works for the purpose of drawing off the gas and relieving the pressure in the retorts, Mr. HUGHES gives some interesting particulars, which are appended. The modern refinements insisted on with reference to the purity of the gas, all contribute to increase this pressure, as, every time the gas passes through a fluid of greater density

than itself, a resistance is occasioned, which adds to the pressure on the retorts, and this, at length, becomes so great, that means must be resorted to for diminishing it. In the first place, the contrivance of sealing the dip-pipes in the hydraulic main, requires the gas to force its way through several inches of tar before it can escape from the retort, and this is the first obstruction it meets with. In many works where dry lime is used in the purifiers, the gas is conveyed through water in the wash-vessel, where the gas is again resisted, and the pressure of course increased. In the dry lime purifiers and in the scrubbers, it is not considered that any sensible hindrance is opposed to the passage of the gas, but in some works both a washer and a series of wet lime purifiers are used, in which the force imposed becomes considerable, and an exhauster is found almost indispensable. The weight of the gas-holders also adds materially to the pressure in the retorts.

About twelve years ago it was ascertained by Mr. GRAFTON, in the course of some experiments at Cambridge, that the carbonaceous deposit in the retorts was due almost entirely to the pressure on the gas. Previously to this discovery, it was generally considered by the most scientific authorities that the carbon was due to high degrees of heat, and too great an extent of heating surface. In addition to the injury of this deposit to the retorts themselves, causing them to burn out with great rapidity, and the expense of frequently removing it, there is every reason to suspect that some of the very best constituents of the gas, namely, the volatile carbides of hydrogen, are decomposed and condensed in the deposit, and that the gas is thereby much impaired in quality. In addition to this, the pressure causes an increase in the quantity of tar, an effect which never takes place except at the expense of the gas. Mr. GRAFTON conducted his experiments in such a way as to show very practically the truth of the conclusion he had arrived at. By increasing the pressure till it became equal to a column of fourteen inches of water, he produced in a single week a layer of one inch thickness, and at the expiration of two months it had filled up nearly one-fourth of the retort. During this experiment an accumulation weighing ten hundredweight and twenty pounds was produced by the carbonisation of sixty-seven tons of Wall's End coal. Another trial, under entirely opposite conditions, was then made, all pressure being taken off except that arising from half-an-inch dip into the fluid of the hydraulic main. Under these circumstances, when the retort was again worked with the same description of coal for four months, scarcely any deposit had taken place.

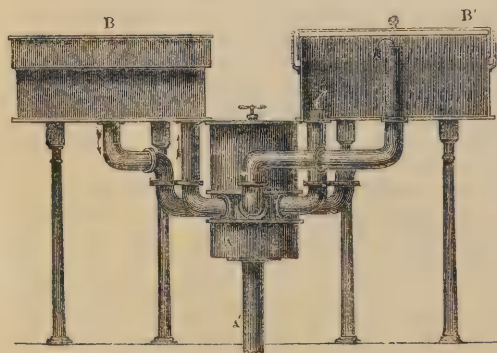
The earliest form of exhauster used was a pump on the principle of the Archimedian screw, which was used for pumping the gas from a higher to a lower point, level with the surface of a small reservoir of water. The screw revolves in an opposite direction to that required for pumping up or raising liquids, and, at each revolution, the upper mouth of the helicoidal canal takes in a certain quantity of gas, after which follows the water. The gas descends along the spiral canal of the screw, in proportion to the rate of revolution in the latter, and having reached the lower extremity of the canal, passes

off by a pipe, with an excess of pressure, measured by the height of the surface of the water above the lower extremity of the screw.

Another kind of extractor, which does not require so rapid a movement as the Archimedian screw, consists of a circular drum with four divisions, formed by curved plates proceeding from the centre to the circumference. The wheel revolves in a cistern filled with water to the height of three-fourths the diameter of the wheel; and each of the chambers, formed by the divisions, carries down below the surface of the water a certain portion of gas, which is delivered out of the drum into a pipe passing off at the level of the centre of the wheel. This pipe opens into a chamber containing water about an inch higher than the upper surface of the pipe, and the difference of level between the water in the cistern and in the chamber which the gas now occupies indicates the difference of the pressure. If the force be not sufficiently reduced by passing the gas through one drum of this kind, it goes on to a second or a third, till the required diminution has been attained.—*Hughes*.

Probably the most improved form of exhaustor is that used at the Liverpool works, of which there are two sets, of three each, in operation. Exhaustors become indispensable where clay retorts are employed, these being porous in their nature. They necessarily take up some space, but repay the outlay, as the oscillation shown on the inlet pipe does not alter more than half-an-inch, whilst other exhaustors are known to vary many inches. Their construction is very simple. A pipe from the scrubbers runs under the three exhaustor cylinders, with branches to reach to the height of three feet; at the top of the branch pipe there is a valve, and a holder of sheet-iron fits loosely over this, which has also a valve upon it. The space between the inlet pipe and outer cylinder is filled with water, in which the gas-holder works. When the latter ascends, the gas is drawn through the inlet valve, while that affixed to the gas-holder is closed by pressure from above; on its return the upper valve opens and the lower one closes. Each holder discharges at every revolution of the shaft about eighteen feet, and thus the gas is pumped from the retorts. Each cylinder is connected

Fig. 109.



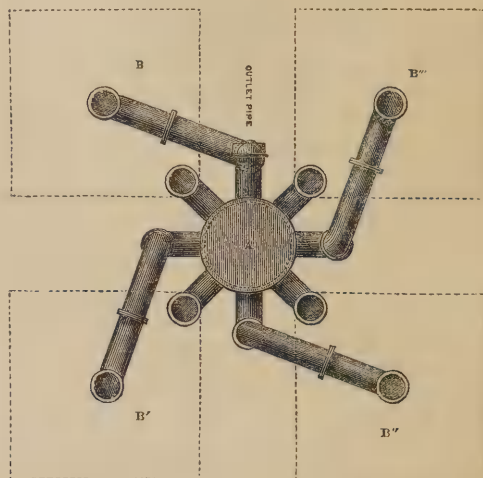
to the other by branches, placed near the top for the purpose of passing the gas through the purifiers, to which it is guided by the centre valve. They are

worked by a shaft, T, connected with a steam-engine, as shown in Fig. 94.

The Centre Valve of Purifiers.—At the majority of works as many as sixteen or even more valves are used for the purpose of guiding the gas into and out of the purifiers. But, by the adoption of one centre valve, as is done in the Liverpool works, the necessity for a number is obviated.

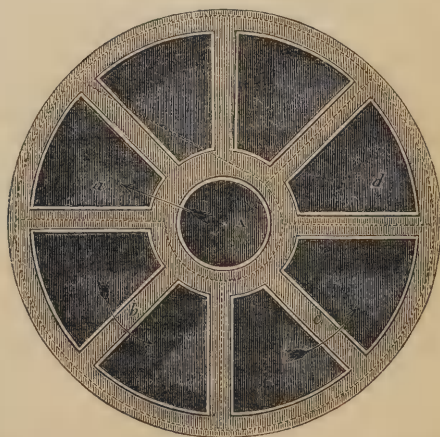
Fig. 109 represents a front view of this most important part of the role of the gas-making apparatus, in which one purifier, B, with which it is connected is shown in elevation, and another, B', in section. Fig. 110

Fig. 110.



is a plan of the same indicating the position of the four purifiers, B B' B'' B''', and the inlet and outlet pipes to and from each, by which the gas is made to traverse the

Fig. 111.



whole. In the general view—Fig. 94—this valve is seen in section, and Fig. 111 shows it more perfectly. In the elevation and plan, Figs. 109, 110, A is the valve, which is so constructed that the gas entering it by the inlet pipe, A', passes through an opening, as shown at a, Fig. 111, and thence flows through a conduit to

the first of three purifiers it has to traverse; the outlet which conducts it to division *b*, enclosed by the dotted line, causing it to pass into the inlet of the second purifier; the same arrangement answers for the outlet of second and inlet of third purifier. From that of the third, it enters through *d* to the division for one pipe, at the top of which there is an opening equal to the area of the pipe, through which the gas enters the upper part of the valve box. From this branches a duct which conveys the gas to the meter, as shown at *p*, Fig. 94. The blank division represented in the plan—Fig. 111—throws out of action the fourth purifier.

Circular pipes would answer all purposes as well as the rectilinear ones shown in the drawings, but a larger box would be required.

LIME PURIFIER.—Of all the substances which have been resorted to for the depuration of gas from sulphur compounds and carbonic acid, lime is the most universal, and the choice does not arise from its cheapness, but more on account of its superior effect in arresting those products which deteriorate illuminating gas.

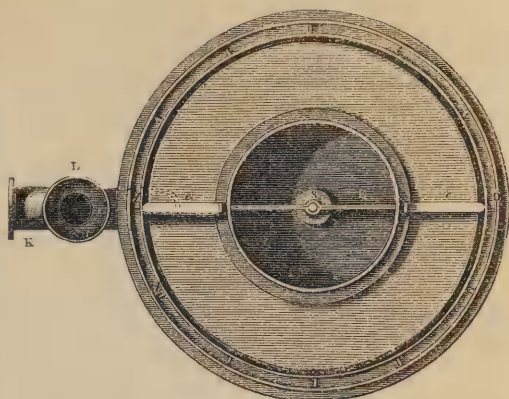
It is employed in two states: in the one case the apparatus is termed the wet lime purifier, from the lime being made into a cream with water, and used in this condition; the other is known as the dry lime purifier, in which quick lime, barely slaked, is resorted to. Their comparative efficiency is matter of dispute among gas-makers.

Both these have an unequal repute for efficiency among gas-makers; but their merits will be best made known to the reader by giving a few brief descriptive sentences upon each.

Wet Lime Purifier.—Fig. 112 is an elevational section of a lime machine, and Fig. 113 a plan through *dd* in Fig. 112. *A* is the inlet pipe, through which the gas passes into the chamber, *B*, which is four feet dia-

—after having overcome the pressure of the column of water in the tank, *plus* the pressure in the gas-holders—will pass, and bubble up through the lime-water.

Fig. 113.

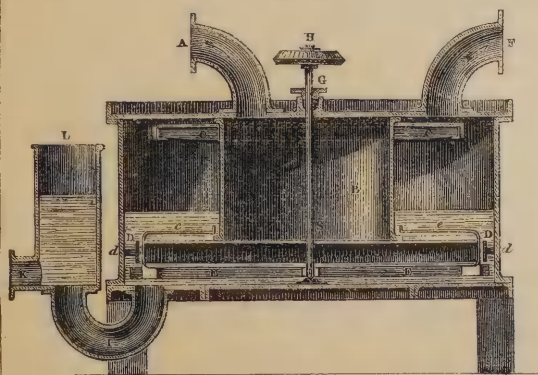


E is an arm made to revolve on the spindle, *s*; the parts *ee* of this arm continue through the aperture and over the ring, serving to keep the lime from settling, or obstructing the passage of the gas. *F* is the outlet for the purified gas. *G* is a stuffing-box, through which the spindle, *s*, passes. *H*, a mitre-wheel, connected to a water-wheel or steam-engine, for turning the spindle. *I* is a pipe, through which the lime-water is drawn off, when it has become saturated with the impurities of the gas. It will be observed, that by this contrivance the water can be completely drained off, by opening a slide-valve bolted to the flange of the pipe, *K*, without suffering the gas to escape along with it, because a column of water will remain in the tube, *I*, equal to the height of the bottom of the tank, measured from the inner radius of the curve of the tube, namely, twelve inches, which is always more than sufficient to overcome the pressure of the gas in the purifier, when the valve on the inlet-pipe, *A*, is closed, which should be done before that at *K* is opened. *L* is a cylindrical vessel, open at the top, for filling the purifier; it also serves to show the quantity of water required; when the machine is at work, the column contained in the vessel will be higher than that in the tank, by the pressure of gas in the gas-holders, usually about three inches.

At the end of 1813, an explosion of a serious nature took place at the Westminster station, owing to a volume of gas escaping from the purifier, which was placed in a building near the retort-house, coming in contact with the flues of the retorts. The windows of several houses in the neighborhood were shattered, and Mr. CLEGG was severely injured. The recurrence of such an event was afterwards guarded against, by drawing the refuse lime-water through a bent pipe, as shown above, always containing sufficient water to seal it.

The lime-water may be mixed in a cistern—having its bottom *above* the level of the water in the purifier when filled, and furnished with an agitator worked by hand—and drawn off by a hose into any of the ma-

Fig. 112.



meter, jointed to the lid of the purifier, and supported upon two cast-iron beams, *c*. On to the bottom flange of this chamber, a circular ring of thin wrought-iron plate is riveted, of such a diameter that its outside rim will be within five inches of the tank of the purifier. *D* is a hoop, supported from the tank by bolts, *d d*, *et cetera*, having its upper edge level with the before-named plate, and its lower edge four or five inches below it. The space left between this hoop and the ring is three-eighths of an inch, through which the gas

chines, care being taken to keep the mixture well agitated while passing. The proportions are one measure of paste-lime to three of water; that is, to every five bushels of paste-lime about one hundred and twenty gallons of water must be added. The size of the lime machines ought to be so regulated, that they will contain sufficient lime-water to purify the quantity of gas made in twenty-four hours, without having occasion to fill them higher than the water-line shown in the engraving.

Four lime machines are necessary, two being in action and two out, alternately. When that machine is spent through which the gas first passes, shut it off, and open a third, leaving the second to perform the duties of the first, and so on. The following extract from Mr. CLEGG's journal expresses his opinion on the construction and use of lime machines:—

The grand principle in the construction of a lime-water purifier, is to divide the gas as minutely as possible, at the same time avoiding unnecessary pressure. If the machine be well constructed, seven or eight inches pressure in the machine is quite sufficient. Two sets are necessary, in order to have a pair clean and ready for immediate use. The practice of working the contents of the vessel over again, by passing them from one to another, is mistaken economy.

The work performed by a lime-water purifier is generally computed by its contents in gallons, and the head of water or pressure opposed to the passage of the gas through it. Taking the latter at a constant quantity of eight inches, the computation is easy. Four thousand five hundred cubic inches of hydrate of lime—which, as has been before stated, is the quantity produced by reducing one bushel, or two thousand one hundred and fifty cubic inches of quicklime—mixed with forty-eight gallons of water, will purify ten thousand cubic feet of gas, if properly applied.

Notwithstanding, however, that the quantity of lime required may be well known, it is necessary to test the gas in its progress through the various purifiers. In some cases it is advisable to use the test every twelve hours, or oftener, in districts, for instance, where coal is of inferior and various qualities. Every morning, as soon as the superintendent arrives at the works, he ought to test the action of his purifiers, more especially if he has received a fresh supply of coal or lime. It is necessary only to drop a piece of paper into the plumbous solution, and hold it to the escape-hole of the purifier. The slightest coloration indicates impurity.

Dry lime purifier consists of a square iron box—two are shown at o o, Fig. 94—six feet long by five feet wide, and three deep. The inlet pipe is eight inches inside diameter, and enters at the bottom of the purifier. A few inches above its mouth is fixed a plate about two feet square, which serves the purpose of distributing the gas and preventing any of the lime falling into the inlet pipe. The purifier contains three trays or sieves placed six or eight inches apart, and resting on snuggs cast on the inside of the purifier: each tier contains four trays, each tray being about two feet eight inches by two feet four inches, so that one purifier contains in all twelve trays or sieves, the bottom of each being composed of round rods, five-tenths of an inch diameter, placed about half an inch apart. The top of

the purifier is an inverted box, six feet by five, and with sides and ends ten inches deep, fitting into a water lute twelve inches deep, so that the gas is enclosed by a seal of at least ten inches in depth of water; the outlet pipe passing out of the lid of the purifier is eight inches inside diameter, and is made in the form of a semicircle, the inside diameter of which is two feet; the other end of the semicircle joins another pipe that is fixed. Each end of the semicircle outlet pipe dips into an annular space containing ten or twelve inches depth of water, so as to form a water seal similar to that described for the cover of the purifier. These water joints greatly facilitate the removal of the semicircular pipe and the cover of the purifier whenever required for the purpose of cleaning out or otherwise, without breaking any solid joint or doing injury to any part of the machine. Mr. CLEGG states that two bushels of the hydrate of lime will spread over a surface of sieve equal to twenty-five square feet, with a depth of two and a half inches, which, in practice, is found about the best thickness; and that this quantity, which is equal to one bushel of quick-lime, will, in some places, purify ten thousand cubic feet of gas, while in other places double the quantity of lime will be required.

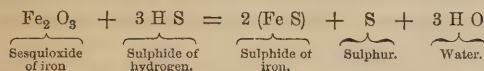
In most of the French gas-works the hydrate of lime is placed upon beds of moss, which are first spread on the trays, or the latter contain alternately a layer of moss and one of lime. The use of the moss is to subdivide the gas into the thinnest possible sheets and streams, so that every particle of it may be brought into contact with the lime.

The purifiers generally used in the French gas-works are from three to four and a half feet in depth, and they are generally made circular, from four to eight feet in diameter, according to the size of the works; in these are placed three or four trays, which contain layers of lime and moss. When the lime is spread upon moss, it is usual to employ rather less than a bushel of lime per square yard of purifier. In most of the French gas-works the quantity of lime used for purification is at the rate of two and a half bushels per ton of coal, which yield, on an average, less than seven thousand cubic feet of gas per ton. The usual calculations with them is, that a purifier with an area of one square metre, or ten and three-quarters feet, is required for every ten hectolitres—two thousand eight hundred pounds—of coal distilled. This proportion is nearly at the rate of one square yard of purifier for each ton of coal distilled. The calculation is made on the quantity of coal distilled in twenty-four hours, this being the interval at which the lime in the purifiers requires to be renewed. It is also made on the supposition that the purifiers contain three layers of lime, so that the proportion becomes three square yards of screen containing lime for every ton of coal distilled in twenty-four hours. The cover of the purifier is made of light boiler plate, provided with a border or rim, which dips into a ring surrounding the purifier, and filled with water, so as to make a perfectly hydraulic joint. The cover is also fitted with handles, by means of which it can be removed when the lime requires to be renewed.

The lime removes from the gas carbonic acid about two per cent., and sulphide of hydrogen about one per

cent. If the gas be properly purified, a paper dropped in a solution of acetate of lead, and held in the gas, will turn black if sulphide of hydrogen be present; if the gas be passed through lime-water, a milkiness will be produced with carbonic acid.

The dry lime purifier is generally preferred as being more handy, less noxious, and offering but little resistance to the gas, *et cetera*. Sesquioxide of iron has lately been introduced into the trays of the dry lime purifier. It ought to answer well, removing the sulphide of hydrogen completely in the following manner:



The resulting sulphide of iron would be of value to the manufacturer of sulphuric acid.

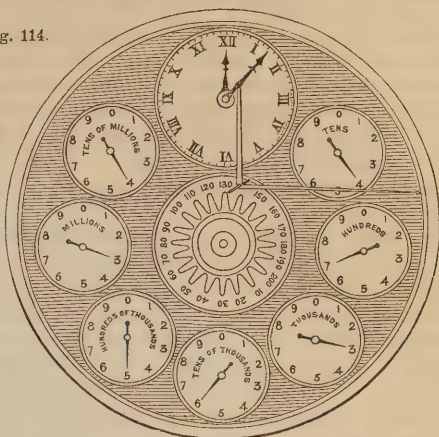
Station Meter, or Measurer, is used for the purpose of ascertaining the quantity of gas produced from the coal; likewise as a check upon the men's work; and also for comparing the gas sold through the consumer's meter with that delivered from the works. The principle upon which it is constructed is as follows:—The part of the meter by which the gas is measured is called the drum, shown at P, Fig. 94; it is a cylindrical vessel, supported at the front and back by an axis, and divided into four separate compartments. These are so contrived, that whilst the gas is entering on one side through the inlet-pipe, it is passing out at the same time from another compartment at the opposite end, and, in its attempt to escape through the water, imparts a rotatory motion to the drum proportioned to its capacity and the quantity of gas allowed to pass through in a given time. The primary cause of this motion is the impulse communicated to the gas from the retort, technically called pressure. The action of the meter depends on its being filled to a certain height with water, over the surface of which the gas is transmitted; the use of the water is to close the aperture through which the gas enters the drum, and it also gives the latter a steadier motion.

At the front of the meter a series of wheels are worked by a shaft communicating with the axis of the drum, which, by means of the index, are registered in cubic feet—from ten to ten millions feet of gas manufactured during any period. The station meter employed at Athol Street, Liverpool, is constructed to register seventy thousand cubic feet per hour—one revolution of the drum will pass about six hundred and fifty. It is the largest of the kind ever made. Fig. 114 is a front view of it. On the face is a *tell-tale*, which serves the purpose of pointing out every irregularity in the production of gas during the twenty-four hours.

The following accurate description is given by TOMLINSON:—In the centre of the *dial-field*—Fig. 114—is fixed a circular plate connected with a train of wheel-work, set in motion by an enclosed drum, through which the gas passes, indicating tens of thousands, hundreds of thousands, millions, and tens of millions of cubic feet of gas. Upon this round plate is fixed a disc of paper, divided into twenty-four parts, with subdivisions. Suppose the meter to register three hundred thousand cubic feet in twenty-four

hours, and the plate to be connected by wheels in the ratio of three to one to that index, which marks one

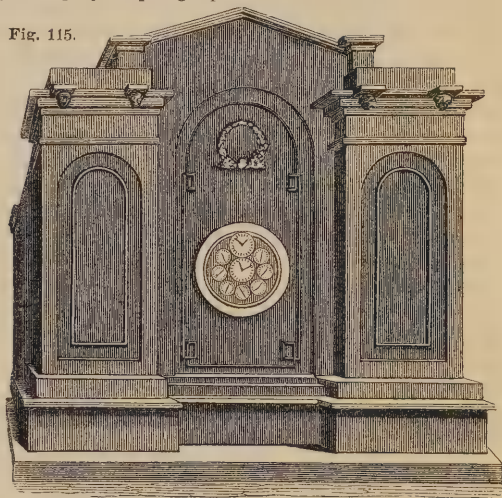
Fig. 114.



hundred thousand in one revolution; it is evident that the distance travelled by one of the twenty-four divisions of the plate from a certain fixed point, will indicate the quantity of gas made in one hour, or $\frac{300,000}{24}$

= twelve thousand five hundred cubic feet. Above this divided disc is a timepiece, to the minute-hand of which is attached a detent, furnished with a pencil, pressing by a spring upon the disc. As the minute-

Fig. 115.



hand of the timepiece revolves, the pencil, by means of a guide fixed to the meter-case, is regulated, so that in the first half-hour it will make a vertical line upon the paper, in length equal to the diameter of the circle formed by the minute-hand, measured from the centre to the point at which the detent is fixed; in the second half-hour the line will be retraced by the hand rising again. This arrangement supposes the divided disc to be stationary; but, as it is made to revolve on an axis, which is also the axis of the internal drum, set in motion by the gas, the pencil will make a series of curved lines, meeting the divided circle of the disc every hour, and the distance travelled from point to point will mark the number of cubic feet of gas made during every hour

of the twenty-four. If the production of gas is regular, the figures formed by the pencil will be so also; if, on the contrary, any neglect has occurred, the irregularity of the figure will detect it, and point out the hour and the amount of difference; because, if the speed of the revolving disc be decreased, the figure formed will approach nearer to the straight line; if increased, the points of intersection upon the divided circle will be further apart. The case of the station-meter is usually greatly ornamented, and bears an appropriate inscription.—*Tomlinson.*

Gas-Holder.—The next subject for consideration is the gas-holders, or vessels in which the gas is stored ready for delivery into the mains, which distribute it throughout the districts to be lighted. These vessels were originally termed gasometers, which name is even sometimes now applied to them; but as they have nothing whatever to do with the measurement of gas, but are merely vessels of capacity, the simple name of gas-holder appears more expressive and appropriate.

The earliest gas-holders were made in the form of cubes or parallelopipeds; but there were disadvantages in this shape, independently of the waste of material required to construct them of this form, as compared with that for a circular one of the same capacity. The corners and angles of the square figures were also found to need bracing, and other precautions were necessary, in order to render the resistance uniform. Wooden tanks were also at one time made for the lifting part of the gas-holder to work in, but this was at a time when they scarcely exceeded in size some of the large vats or backs in use at the great porter breweries. The construction of these wooden tanks was, in fact, entrusted to the back makers, who used to guarantee the duration of the vessel for some period of time agreed on. They were, in consequence, generally constructed in a substantial manner, but it is evident that the rapid increase which took place in the size of gas-holders required the adoption of a different material than wood. When a deputation from the Royal Society, with Sir JOSEPH BANKS at its head, visited the gas-works of the chartered company in Westminster, about the year 1814, they strongly recommended government to restrict the company from constructing gas-holders exceeding six thousand feet in capacity, to be confined in very strong buildings. When Mr. CLEGG published his work in 1841, he says *gas-holders are now constructed to contain two hundred and fifty thousand feet*. In 1853 all the new gas-holders of the Great Central Gas Consumers' Company contained four hundred and twelve thousand feet, and there is one in Philadelphia one hundred and forty feet in diameter, and seventy feet high, capable of containing more than a million cubic feet.

The modern gas-holder is a cylinder of plate-iron, made of sufficient capacity to contain the maximum quantity of gas produced in twenty-four hours; and in very large works, where several gas-holders are used, the joint capacity of all should be equal to this maximum production. In many gas-works the capacity of all the gas-holders somewhat exceeds the consumption of the longest night, but it is believed this excess in capacity is unnecessary. The cylinder which contains the gas has no bottom, or it may be described as a cylinder inverted

over a cistern of water, both the inlet and outlet pipes having their orifices above the surface of the water, so that the gas is hermetically sealed up within the holder, and can only escape through the outlet pipe. The mode in which gas is stored in the gas-holder bears a very exact analogy to that of collecting and storing pursued by the chemist in the laboratory, where the jar to be filled is inverted over a trough containing water, and the gas admitted into it by a bent pipe passing up through the water. In the chemist's method, however, the jar or gas-holder remains fixed, while the water is displaced by the gas; in the gas manufactory, on the other hand, the water is not displaced, but the gas-holder is raised by the gas flowing in.—*Hughes.*

The Editor deems a further explanation of this apparatus unnecessary. The reader will have a very good idea of the mode in which it is suspended by referring to Q, Fig. 94. Mr. ALFRED KING states that the pressure on the gas-holders varies from three to five inches—columns of water—but the distributing pressure, which is regulated by an instrument called a governor, about to be described, alters, according to the elevation of the district supplied, and the hour of the day or night, from four-tenths of an inch to two inches.

The Governor.—This is one of those ingenious self-acting machines which are equally admirable for their efficiency and simplicity. It is placed between the gas-holder and the principal main pipe, in order to regulate the pressure of gas admitted into the latter, and acts quite independently of any irregularity due to the unequal action of the gas-holder, or to other causes. The governor is important in another point of view, namely, where a town has several different stages of elevation, and where, without some contrivance, the pressure of gas passing through the mains would vary very much on each different stage. It has been found by experiment that the pressure in a main varies at the rate of one hundredth of an inch for every foot of rise or fall.

In the case of a district being below the works, a governor is seldom necessary, the works being generally, as a matter of convenience, placed at a tolerably low level; and it is found practically that a district lying even thirty feet below the works may be lighted without the intervention of a governor to increase the pressure, as the diminution due to the difference of level would be only three-tenths of an inch of pressure. But governors are especially necessary in towns, such as Bristol, Bath, Edinburgh, Liverpool, Lincoln, Nottingham, Exeter, and many others which have different stages of elevation; because the gas, as it reaches the higher part of the town, will act with so great a pressure as to produce very serious leakage in the pipes, besides the disadvantage of giving the upper districts an undue proportion of light at the expense of the lower. Separate governors for the regulation of pressure at different stages of elevation are not considered necessary, unless the ground has a rise of about thirty feet; and in order to carry out the principle of uniform pressure to the utmost advantage, there ought to be as many governors as the quotient of the whole elevation in feet divided by thirty. Every gas-work for lighting a town should have at least one governor, to regulate the pressure of gas passing from the gas-holders into the first main. Many towns

in flat situations, which have no elevations much exceeding thirty feet, will require only this one, but in other very hilly towns it would be advantageous to have several smaller governors to regulate the pressure for their different levels.

The governor is merely a miniature single-lift gas-holder—shown at R, Fig. 94—suspended from the centre, and furnished with an inlet and outlet pipe, the former having a conical piston suspended in it—Fig. 101—which regulates the admission of the gas in the reverse ratio of its pressure. The lifting part is usually a cylinder of very thin sheet-iron, about five times the diameter of the inlet pipe, so as to give plenty of room for the two pipes to stand inside, and leave a space above for the gas to occupy in passing through the governor. The tank is made of cast-iron plates, of a circular form, usually somewhat less in depth than the diameter, and with the capacity of about two cubic feet for every ten thousand feet of gas required to be passed through in twenty-four hours. Thus, a tank about five feet four inches diameter, and four feet six inches deep, will be sufficient for a governor to pass three hundred thousand cubic feet of gas in twenty-four hours. The lifting part or invert cylinder, R, is about the same depth, and about four inches less in diameter. The inlet pipe, which may be about twelve inches or less in diameter, is provided with a flange at the base, and is screwed to the bottom of the tank, where it passes up the centre through the water contained in the tank. The top of the inlet pipe is also provided with a flange, on which is screwed an annular casting, which contracts the opening to eight inches. In this inlet pipe is suspended a solid cone of iron, varying from six to fifteen inches in diameter at base, and about two at top. This cone is suspended from and attached to the centre of the roof of the lifting cylinder, R, so that the cylinder and cone rise and fall together. To the centre of the roof, on the outside, is attached a chain passing over a pulley, which sustains, at its other extremity, a weight so adjusted as nearly to balance the weight of the conical piston. It is evident that, when the pressure of gas is very small, the cone descends, and allows a large escape from the top of the inlet pipe; and, on the other hand, when the pressure increases, the cone will rise and contract the openings, so as to cause a diminished quantity of gas to enter. Of course the perfection of this action depends on an accurate adjustment of the weight, and when once this is effected, the regulation of pressure is so perfect as to leave nothing to be desired. The gas, when once admitted into the space above the inlet pipe, finds no impediment to its progress, and passes off by the outlet pipe without further hindrance. The cone is usually made of cast-iron, and is turned true in the lathe. The orifice at the top of the inlet pipe is also bored true, and of a conical form, so as to fit the base of the cone. The regulation of the weight and counterbalancing chain is very simple, and needs no further description.—*Hughes.*

The House-Meter.—This meter, by which the consumer registers his consumption, consists of one hollow drum or cylinder, revolving about a horizontal axis within another hollow drum or cylinder, the inner drum being divided into compartments for measuring the gas,

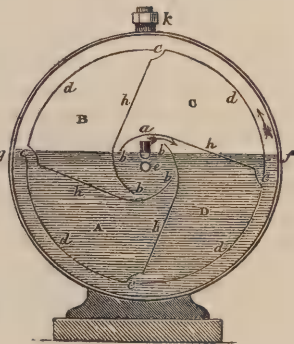
and revolving in water which occupies the lower part of the outer cylinder to a height above the axis, about which the inner drum revolves. The details of the construction may be varied, but the wet gas meters have this common feature, that the gas is measured in the compartments of a drum, which compartments are occupied successively by gas and water, the drum being made to revolve by the pressure or elastic force of the gas acting on the compartments of the drum in succession. The revolutions of the drum being registered by suitable apparatus, the quantity of gas which has passed through the meter, by so filling the compartments in succession, will be accurately measured.

In Fig. 116, the outer circle represents the outer case or drum of the meter, within which a drum divided into compartments, A, B, C, D, revolves about an horizontal axis, *e*. The gas to be measured is brought into the meter by a pipe passing horizontally in the direction of the axis of the inner and outer cylinder, and turned up at the end, so that its

orifice, *a*, may stand above the water level, *f, g*. The four compartments, A, B, C, D, are similar in every respect, each having an inlet, *b*, by which the gas enters the compartment, and an outlet, *c*, by which it passes out of the compartment into the upper part of the outer case, whence it may pass by a pipe, *k*, in any convenient

direction. The gas being admitted into the meter, will pass the inlet, *b*, into the part of the compartment, D, which is just rising out of the water; the gas presses equally on the surface of the water and on the side, *h*, of the compartment, D; the effect of this pressure on the side, *h*, is to cause the inner drum to revolve, whereby the compartment, D, is raised more and more out of the water, and, as it rises, it fills with gas, until it occupies, by the revolution of the drum, the position in space of the compartment C, as to which it will be observed that the inlet, *b*, has just dipped below the surface of the water, and the outlet, *c*, is just coming to the surface of the water. The outlet, *c*, having risen above the surface, the gas will escape into the upper portion of the outer case. As the gas passes out of a compartment in the situation of C, by the outlet, *c*, water will enter by the inlet, *b*, and as the drum revolves the compartment D having occupied the position in space of C and B, comes into the position A, when it is entirely emptied of gas and filled with water, until, by further revolution of the drum, the compartment having come again into the position of D begins to fill with gas, as already described. That which has been described for one compartment takes place for the other three, and it will be seen that there will always be two compartments discharging their gas into the outer case above the water level, one compartment

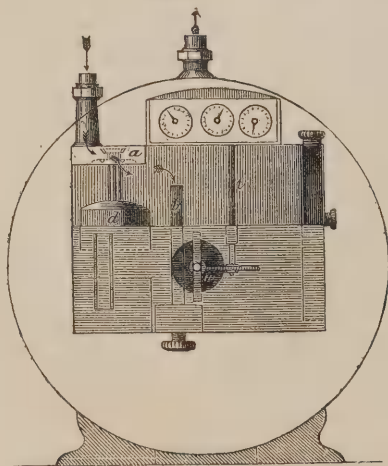
Fig. 116.



filling with gas, and as it fills causing the inner drum to revolve, and one compartment full of water. The motive power causing the inner drum to revolve, is the pressure of the gas in the mains as transmitted from the gas-holder at the gas works, and the quantity of gas will be ascertained from the number of compartments which have filled and emptied, that is, from the number of revolutions of the inner drum, which are registered by a train of wheel work and a dial plate in the usual manner. The gas so measured and passed through the meter is conveyed to the lights by a pipe communicating in any convenient manner with the outer case, and the action of the meter is suspended when the gas does not pass away. It will be observed that the quantity of gas measured will be affected by the height of the water in the meter, the portion of the compartment which is occupied by gas being greater or less, according to the level of the water, whereas the inner drum will revolve whatever the height of the water, within certain limits. If the water rises above the top of the supply pipe, *a*, the entrance of the gas may be stopped altogether, and if it sinks so low that the orifices *b* and *c* are not sealed or closed and opened simultaneously, the gas may pass through the meter without causing the inner drum to revolve. Hence every gas meter is or ought to be adjusted to a certain water level; if the water rise above this level each compartment will measure too little gas, and since the number of revolutions is the same whatever the available space in the compartment for holding gas, the consumer will be defrauded; on the other hand, if the water sink below this level, since the available space in each compartment is larger than was calculated on, the manufacturer will be defrauded. Various causes are in operation to occasion a variation in the water level, and the necessity of preserving it has given rise to several ingenious contrivances for discharging any excess or supplying any deficiency of water.

All this may be further illustrated by Figs. 117, 118,

Fig. 117.



and 119. In Fig. 117, the direction of the gas is marked by arrows. The box *a*, in which the inlet pipe valve is contained, is soldered tightly, having no communica-

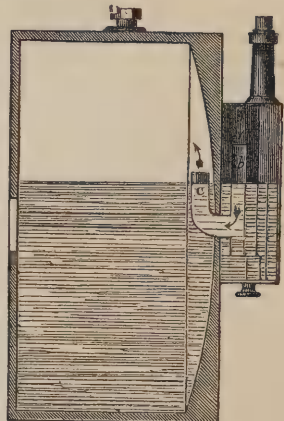
tion with the rest of the case, except through the valve, the position of which is shown by the arrows: *b* is the inlet pipe projecting above the water line, conveying

Fig. 118.



the gas into the meter by the bent arm *c*—Figs. 118 and 119—rising above the water between the convex cover and the inlet hoods. *d* is a float attached to the inlet valve, fixed so that when the water falls below the centre opening the valve will close, and the gas cease to enter the meter. Motion is communicated to the train of wheel-work behind the index from a spiral worm, *u*,—Fig. 118—fixed on to the axis of the drum, working into a wheel, the spindle of which passes through the tube *t*, sealed by dipping under the water contained in the case.

Fig. 119.



There has been much discussion and dissatisfaction in Liverpool of late, with regard to the water meter, parties asserting that although the company had *lowered* the price of gas, still the bills, when they were sent in, were *higher* than they used to be. So many persons came forward and asserted this, that the Editor was applied to by Mr. WHITTY of the Liverpool Journal, to know in what way the above could be accomplished. The following question had to be solved: Is it possible by manufacturing inferior gas to compel the meter to register against the consumer?

In the Editor's opinion it is no matter what kind of gas, insoluble in water, is made, *the registration would be the same*; but if *atmospheric air* was passed into the mains and entered the meter in company with the *coal gas*, it would tell against the consumer, and the *light emitted* would be deteriorated. Mr. WHITTY remarks in reply to the Editor's statements, that experiments performed at the gas works justified them. It appears by introducing one-tenth of common air into the gas-holder charged with gas, that the meter registers ten per cent. or more against the consumer. Some denied that gas so mixed with air would burn, but the results showed that it does, and had no effect visible to the eye, which is an important fact.

The following table, extracted from a paper containing some experiments by Mr. BARLOW, on the comparative value of coals for the manufacture of gas, may be found useful, especially to persons who are compelled to use canal coal for enriching gas of low illuminating power:—

Name of Coal.	Number of experiments, the average of which is taken.	Produce of one ton of Coal.				Equivalent of one cubic foot of gas in grains sperm.	Consumption of gas per hour to give a light equal to one standard candle.	Value of the gas from one ton of coals in pounds of sperm.
		Cubic feet of gas.	Pounds of coals.	Pounds of tar.	Pounds of ammoniacal liquor.			
Boghead canal,	3	13,334	715	733·3	none.	1109·	1·3	2057
Newcastle canal,	3	9,833	1426	98·3	60·	606·	2·37	851
Wigan canal—Ince Hall,	3	10,850	1332	218·3	161·6	465·8	3·09	718
Lochgelly canal,	2	8,331	1245	225·	340·	439·	3·28	522
Mixture of 7-8ths Lochgelly and 1-8th Boghead,	1	9,055	1200	400·	170·	695·	2·07	899
„ 9-10ths Lochgelly and 1-10th Boghead,	2	9,050	1205	335·	290·	600·	2·4	774
„ 11-12ths Lochgelly and 1-12th Boghead,	1	9,750	1240	227·	270·	443·	3·25	617
Pelton main,	4	9,500	1540	112·5	112·5	311·	4·7	422
Mixture of 3-4ths Pelton and 1-4th Boghead,	3	12,800	1366	206·6	116·6	553·	2·6	1009

Mr. BARLOW is of opinion that coals which contain more than thirty per cent. of volatile matter, require a higher temperature for their distillation.

As all the volatile matter afforded by coal is not combustible, it does not necessarily follow that the

coal which yields the largest amount of gas is the most valuable, although such is generally the case, as will be seen by the following tables, drawn up by Mr. SAMUEL HUGHES:—

Description of Coal.	Cubic feet of gas per ton of coal.	Specific gravity of the gas.	Weight of gas in pounds avoirdupois per ton of coal.	Authority.
NEWCASTLE COALS.				
English caking coal,.....	8,000	·420	257	Dr. Fyfe.
Newcastle coal,.....	11,648	·675	423	Mr. Joseph Hedley.
Pelaw, Newcastle,.....	11,424	·444	389	“ “
Pelton, do.,.....	11,424	·437	382	“ “
Blenkinsopp, Carlisle,.....	11,200	·521	447	“ “
Newcastle,.....	8,500	·412	268	London, 1837.
Wallsend, Newcastle,.....	12,000	·490	550	Quantity made in the revolving web retort —authority, Mr. Clegg.
Pelton,.....	11,000	·430	363	
Leverson,.....	10,800	·425	353	Author of the Chemistry of Gas-lighting in the <i>Journal of Gas-lighting</i> .
Washington,.....	10,000	·430	330	
Pelaw,.....	11,000	·420	355	
New Pelton,.....	10,500	·415	335	
Dean's Primrose,.....	10,500	·430	347	
Garesfield,.....	10,500	·398	321	
Gosforth,.....	10,000	·402	308	
West Hartley,.....	10,500	·420	339	
Hasting's Hartley,.....	10,300	·421	333	
Blenkinsopp,.....	9,700	·450	335	
Berwick and Craister's Wallsend,.....	12,507	·470	449	Mr. Clegg,
Pelaw Main,.....	12,400	·420	399	“
Russell's Wallsend,.....	12,000	·418	384	“
Ellison's Main,.....	11,200	·416	357	“
Felling Main,.....	11,200	·410	351	“
Pearith's Wallsend,.....	11,147	·410	350	“
Dean's Primrose,.....	11,120	·410	349	“
Penton Main,.....	10,987	·420	337	“
Eden Main,.....	10,400	·400	318	“
Heaton Main,.....	10,400	·410	326	“
	9,000	—	—	Average production by the Phoenix Gas Company for the year 1848.
PARROT OR CANNEL COALS.				
Yorkshire parrot,.....	11,000	—	—	Dr. Fyfe.
Wigan cannal,.....	9,500	{ ·460 to ·520 }	357	“
Scotch parrot,.....	9,500	·640	466	“
Ramsay's Newcastle cannal,.....	9,746	{ ·554 to ·580 }	423	“
Lochgelly parrot,.....	9,123	·567	396	“
Lesmahagow cannal—first experiment,.....	11,681	·540	483	Mr. Wright.
“ “ second experiment,....	9,878	·650	492	“
Ramsay's Newcastle cannal,.....	9,016	·604	417	“
“ “ “	9,333	·598	427	John Kay, Manager of Dundee Gas- works.
“ “ “	9,667	·731	541	
Lesmahagow cannal,.....	11,312	·737	638	Dr. Leeson, Dr. Miller, and Mr. G. H. Palmer.
Welsh cannal,.....	11,424	·737	645	
Wigan cannal,.....	11,200	·606	520	“ “
“ “	9,500	·580	422	Liverpool New Gas and Coke Company.
Wemyss cannal,.....	10,976	·670	563	
“ “	10,192	·691	538	

Description of Coal.	Cubic feet of gas per ton of coal.	Specific gravity of the gas.	Weight of gas in pounds avoirdupois per ton of coal.	Authority.
Wigan canal,	9,408	·478	344	Mr. Wright.
Knightswood canal,	9,720	·590	439	"
Boghead canal,	15,000	·752	866	{ Mr. J. Evans, at Westminster Station of Chartered Gas Company; mean of three experiments.
Lesmahagow,	13,500	·642	666	" " "
"	13,200	·618	627	" " "
Capeldrae canal,	14,400	·577	638	" " "
Arniston canal,	12,600	·626	606	" " "
Ramsay canal,	10,300	·548	433	Mr. J. Evans.
Wemyss canal,	14,300	·580	637	"
Kirkness canal,	12,800	·562	552	"
Knightswood canal,	13,200	·550	558	"
Wigan—Ince Hall—canal,	11,400	·528	461	"
Pelton canal,	11,500	·520	459	Mr. Joseph Hedley.
Levenson canal,	11,600	·523	466	" "
Washington canal,	10,500	·500	403	" "
Wigan canal,	14,453	·640	708	Mr. Clegg.
"	14,267	·610	664	"
Scotch canal,	14,000	·580	622	"
"	13,813	·500	529	"
DERBYSHIRE, WELSH, STAFFORDSHIRE, AND OTHER KINDS OF COAL.				
Derbyshire deep main,	9,400	·424	308	Mr. Wright.
Brymbo two-yard coal,	8,880	·463	315	"
Powell coal—two hundredweight charges every five hours,	10,165	·459	357	"
Powell coal—one and a half hundredweight charges every five hours,	8,250	·470	296	"
Bickerstaff—Liverpool,	11,424	·475	415	Mr. Hedley.
Neath—South Wales,	11,200	·468	401	"
Birmingham Gas Company—lamp coal from West Bromwich,	6,500	·453	226	{ Birmingham Gas Company Parliamen- tary Return.
West Bromwich,	6,500	·455	227	{ Birmingham and Staffordshire Parlia- mentary Return.
Macclesfield,	6,720	—	—	—
Stockport,	7,800	·539	322	Parliamentary Return.
Oldham, Watergate, and Wigan canal, mixed,	9,500	·534	388	Manchester Parliamentary Return.
Ormskirk, or Wigan slack,	8,200	·462	290	{ Liverpool Old Company Parliamentary Return.
Low-Moor, mixed with two kinds of slack,	8,000	·420	257	Bradford Parliamentary Return.
Leeds coal,	6,500	·530	263	Leeds Company Parliamentary Return.
Cannel and common coal mixed,	8,000	·466	285	Sheffield Company Parliamentary Return.
Derbyshire soft coal,	7,500	·528	303	Leicester Parliamentary Return.
"	7,000	·448	240	Derby Parliamentary Return.
"	7,000	·424	227	Nottingham Parliamentary Return.
STAFFORDSHIRE.				
South's,	10,933	·398	333	Mr. A. Wright.
Second variety,	10,667	·395	322	"
Third variety,	10,667	·390	318	"
Fourth variety,	9,600	·320	235	"
Forest of Dean,	10,133	·350	271	"
Second variety,	10,133	·360	279	"
WELSH COAL.				
First variety,	10,000	·385	295	"
Second variety,	10,133	·380	295	"

Some practical gas engineers are of opinion that the quantities in the preceding table are larger than are usually obtained in the works. The following table,

by Mr. WRIGHT, in which the results of experiments on the distillation of cannel coals are placed in a very practical commercial form, will be found interesting:—

	Name of Coal.						
	Lesmahagow canal.		Ramsay's Newcastle canal.	Derbyshire deep main	Wemyss' canal.		Wigan canal.
	Exp. 1. Pounds per ton.	Exp. 2. Pounds per ton.	Pounds per ton.	Pounds per ton.	Exp. 1. Pounds per ton.	Exp. 2. Pounds per ton.	Pounds per ton.
Coke,	1091·	1064·	1435·	1335·	1124·5	1188·	1326·0
Gas,	463·	483·5	410·	300·	551·4	528·	338·0
Tar,	594·	603·	295·	219·	224·0	197·	250·0
Ammonia and water,	4·5	4·5	6·72	179·	—	—	—
Loss,	87·5	85·	93·28	207·	340·1	327·	326·0
	2240·	2240·	2240·	2240·	2240·	2240·	2240·
Cubic feet of gas,	11,681	9,878	9,016	9,400	10,976	10,192	9,408
Specific gravity,	0·540	0·650	0·604	0·424	0·670	0·691	0·478
Illuminating power, gas of specific gravity 0·361, being,	—	2·33	2·	0·8	2·47	—	1·5

The annexed tables, by Dr. FYFE, contain, in addition to the quantities of gas afforded by the coals, much valuable information upon the relative illuminating values of the gases, which he arrived at by the chlorine test. When chlorine is added to coal-gas, it forms with the olefiant gas and the vapors of tar oil—with those constituents, therefore, upon which the illuminat-

ing power depends—a fluid compound, which separates, and the original volume is consequently diminished. The diminution which the volume of the gas suffers when mixed with chlorine is, therefore, in direct proportion to its illuminating power, and to the value of the gas—to the amount of olefiant gas and tar oil vapors—which it contains:—

Coals.	Cubic feet of gas per ton.	Comparative value of coals per ton by quantity of gas.	Specific gravity of gas, air = 1000.	Condensation by chlorine per cent.	Duration by jet, five-inch flame.	Comparative value of gas by chlorine.	Comparative value of gas by durability.	Comparative value of gas by chlorine and durability.	Comparative value of coals per ton by quantity of gas condensed by chlorine and durability into account.
ENGLISH CANNEL:—									
Yorkshire,	11,500	1.28	.451	7.66	M. S. 45.	0.85	0.92	0.78	1.00
SCOTCH CANNELS:—									
Knightswood,	8,960	1.00	.557	.9	48.	1.00	1.00	1.00	1.00
Lochgelly,	9,123	1.01	.567	14.5	65.30	1.66	1.36	1.95	1.11
Marq. Lothian,	10,000	1.11	.556	13.	60.	1.44	1.25	1.80	2.00
Torryburn,	11,200	1.24	.624	13.	57.30	1.44	1.19	1.71	2.13
Monkland,	10,190	1.13	.667	16.	67.	1.77	1.4	2.01	2.29
Arniston,	10,640	1.18	.637	17.5	68.30	1.94	1.41	2.03	2.41
Wemyss,	10,080	1.12	.642	19.5	75.	2.16	1.56	2.24	2.54
Kirkness,	9,620	1.07	.711	20.75	80.18	2.30	1.67	2.40	2.58

This table exhibits the quantity of gas afforded from a ton of each of the coals; the specific gravity of the gas; the amount of condensable matter by chlorine; the durability of the gas when burned by a single jet with a five-inch flame; the comparative value of the gas for affording light, as shown by the chlorine test, by the durability, and by these taken together, which,

when test is had recourse to, is the proper method to follow. It shows also the comparative value of the coals for the purpose of illumination by the combustion of their gases, as proved by the quantity of gas afforded by each, and also by the quantity and quality taken together:—

Coals.	Cubic feet of gas per ton.	Specific gravity of gas, air = 1000.	Condensation by chlorine, per cent.	Duration by jet five-inch flame.	Illuminating power, one foot sperm. candles = 1.0 grains per hour.	Value of one foot in grains sperm.	Comparative value of one foot in grains sperm.	Value of one ton of coals in pounds of sperm.	Comparative value of coals.	Pounds of coke per ton of coal.	Fixed carbon per cent. in coal.	Ashes per cent. in coal.	Pounds of sulphur per ton of coal.
ENGLISH CORING:—													
Pelton,	9,746	555	6.5	M. S. 50.40	3.125	382.2	1.	532.	1.	1,563	—	—	—
ENGLISH CANNEL:—													
Ramsay's Newcastle,	9,692	625	13.25	60.40	3.33	399.6	1.04	553.	1.04	1,520	—	—	—
Wigan,	12,010	566	9.9	52.5	3.04	365.4	0.95	627.4	1.17	1,360	55.	7.1	—
SCOTCH CANNEL:—													
Donibristle,	9,923	593	9.	51.5	7.51	901.2	2.35	1277.5	2.4	1,220	49.22	4.28	8.5
Lesmahagow,	10,176	669	17.	60.	8.77	1058.8	2.75	1539.5	2.87	1,360	42.44	4.	—
Capeldrae—one,	11,500	644	18.	65.25	8.312	997.4	2.61	1638.7	3.08	9,999	33.2	7.7	7.7
Capeldrae—two,	9,670	650	17.8	73.37	10.01	1201.2	3.24	1670.3	3.18	1,256	23.9	24.5	7.7
Boghead,	15,426	726	23.37	84.44	10.38	1245.6	3.25	2755.6	4.3	760	9.25	21.7	8.

Having given a full account of the manufacture of coal gas—the Liverpool works, as stated before, being taken as the standard—it will now be desirable to enter upon the fabrication of this compound from other sources, such as oil, resin, *et cetera*; and, in doing so, the Editor will draw largely from the admirable work of Drs. RICHARDSON and RONALDS upon *Fuel*, which has just been published. It contains concise and exact information upon the several heads that will now be discussed.

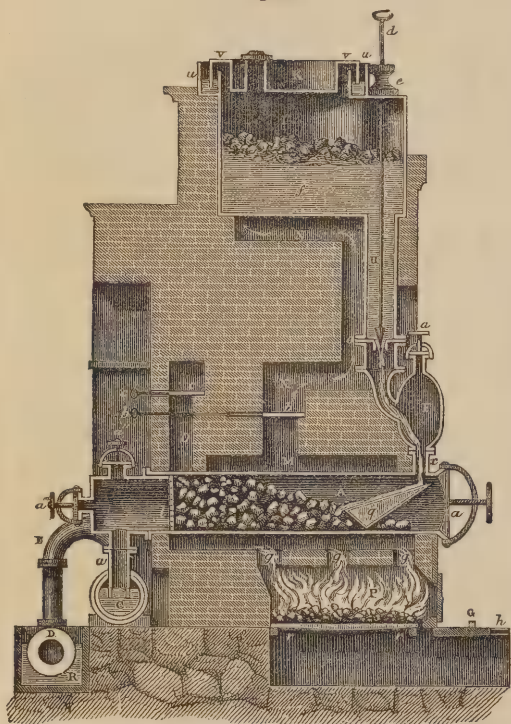
Resin Gas.—Resin could be distilled in the oil-gas apparatus, if it were fluid at common temperatures; but such not being the case, it requires to be liquified

by heat, or some solvent, before it is allowed to pass into the retort. Coal-tar naphtha is often used to dissolve the resin, or the oil which results from its own distillation. When the latter is employed, the flame from the furnace, before escaping into the chimney, is allowed to play upon the reservoir of resin. As the resin melts, it trickles through a sieve into a second division of the vessel, leaving the impurities and the solid portion behind, where it is mixed with an equal part of the resin-oil. Thus a solution which will no longer solidify is obtained, and with it the retort is supplied, as with oil in the former case. When the gas, either from resin or oil, has parted with its condensable

vapors in the coolers, it is in a fit state for consumption, no further purification being required.

According to RONALDS and RICHARDSON, one of the best arrangements of apparatus for making resin gas, and which has stood the test of practice, is that which has been extensively carried out by CHAUSSENOT, and is shown in Fig. 120. The resin is here melted without any additional solvent, and the oil or tar collected and disposed of as a secondary product. The draught to the fire-place, *P*, is regulated through the ash-pit by means of the plate, *G*, which can be moved horizontally backwards and forwards in the groove, *h*. The air traversing from below through the grate and fuel, *rr*, creates a powerful flame, which passing, in the first instance, through the apertures,

Fig. 120.



ggg, in the roof, plays round the retort, *A*, in the space, *M*, and then, before reaching the chimney, heats the vessel, *I*, containing the resin, by means of the flue, *NN*. If this vessel requires filling, the fire is shut off from *N* by the damper, *b*, and is allowed free egress at the aperture, *o*, by drawing back the damper, *c*. Both the dampers are worked by iron rings and rods from without. In this apparatus it is not necessary to dissolve the resin in tar-oil, because the vessel, *I*, in which the resin is melted, and the conducting tube, *H*, being con-

stantly surrounded by hot air, no solidification of the melting resin at the bottom, *f*, can take place. Combustible gases are generated by merely melting the resin, which may possibly endanger the whole apparatus. To avoid such contingencies, the edge of the resin cistern, *I*, is furnished with a groove filled with water, *uu*, into which the lid, *K*, dips at *vv*, and is consequently secured by a water-valve. By means of an aperture in the lid, the vapors can be conducted into the chimney or under the grate. The melted resin flows consecutively through *H*, *F*, and *x*, into the retort, *A*. Between *F* and *H* is a plate, *o*, with a funnel-shaped aperture in the middle, in which the conical end of the rod, *d*, is movable. If this is raised through the stuffing-box, *e*, a more abundant supply of melted resin is furnished to the retort; if it is pushed down, the stream diminishes, or the flow ceases entirely. The resin flowing from *x* is carried to that part of the retort containing the coke, by means of the inclined plate, *q*. The coke is prevented falling back in the retort by the grating, *l*, the gas escapes through a descending pipe, *w*, to the tar-cistern, *C*, and from thence through *E* to the coolers, *D*, which are immersed in water in a long trough, *R*. *C* is nearly always filled with tar, that the mouth of *w* may remain immersed; this, therefore, dips into *C*, whilst the gas-pipe, *E*, behind the sectional level in the drawing, only just passes through the material of the main, *C*. Apertures are constructed in several places, at *a*, *a'*, *a''*, and *a'''*, by which the apparatus may be cleaned at intervals; these are firmly closed during the process of distillation, by flat plates of iron firmly screwed on, by means of iron brackets, similar to that used for closing the mouth of the retort *a*. Distillation goes on continually in this apparatus, until the deposition of carbon renders a renewal of the coke necessary.

Resin contains ten equivalents of carbon, seven of hydrogen, and one equivalent of oxygen. Its atomic weight is, therefore, seventy-five. Supposing the whole of the hydrogen to unite with the quantity of carbon required to form olefiant gas of specific gravity nine hundred and seventy six, the utmost that could be produced from an atom of resin would be forty-nine parts out of seventy-five, or about two-thirds of its weight, accompanied by some carbonic oxide and carbonic acid. If any of the hydrogen is evolved uncombined, or in the form of light carbide of hydrogen, a proportionate quantity of carbon must escape conversion into gas, and hence the loss which must always attend the distillation of resin, even supposing that none of it were distilled unchanged, or converted into resin-oil.

Dr. FYFE obtained the following quantities of gas by distilling resin at different temperatures, of which he also ascertained the relative specific gravities and illuminating power:—

Temperature of distillation.	Quantity of gas per pound of resin.	Specific gravity of gas.	Per centage of carbonic acid.	Durability or quantity consumed per hour in jet 1.39 inch diameter, and five inch flame.	In Argand burner consuming five feet per hour, illuminating power was equal to candles.	Resin not converted into gas; fraction of quantity distilled.
	Cubic feet.			Cubic feet.	Per cubic foot.	
Heat employed for coal-gas, ..	10 [•]	640	10	1.2	2.45	One-half.
Dull red-heat,	6.2	657	6	1.25	2.27	Two-thirds.
Somewhat above dull red-heat, ..	8.42	419	8	1.43	—	One-half.
9 [•]	—	613	—	—	—	One-half.
In White's retort without water-gas,	8.8	57	—	1.12	2 [•]	Three-fifths.

He considers, therefore, that the quantity of gas that can be produced from resin in practice will not exceed eight or nine cubic feet per pound, that is, about one thousand cubic feet per hundredweight; that the gas, after being purified, will be of specific gravity not much beyond six hundred; the condensation by chlorine not much beyond eight or nine per cent.; a cubic foot of gas not giving more than the light of from two and a half to three candles.

Hydrocarbon, or Water-gas.—It is well known that water passed in the form of steam over red-hot iron, is decomposed; its hydrogen being liberated in the form of gas mixed with a little carbide of hydrogen from the carbon of the iron, while the metal becomes converted into oxide. If coke or charcoal be substituted for iron in this operation, hydrogen, carbonic oxide, and carbonic acid gases are produced in variable quantities, according to the temperature employed; carbide of hydrogen, according to Dr. FYFE, being only present in very small quantity.

Gas from Animal Matter.—In the distillation of animal matters, bones, flesh, *et cetera*, which has long been practised for the production of bone-charcoal and bone-black, a tar containing DIPPEL's animal oil, and gases, are generated. The illuminating power of the latter has recently attracted the attention of manufacturers. SEGUIN in particular has carried on the process on a large scale, making use of the gases. When the flesh of dead animals, which contains sixty per cent. of water, is employed, the latter must be removed by exsiccation before the material is placed in the retorts, which are kept at a cherry-red heat. The sulphur—a constituent of albumen, fibrin, *et cetera*—is chiefly found in the gas combined with carbon, and the nitrogen of the flesh as carbonate of ammonia. After being properly cooled, the gas is first passed through a solution of chloride of calcium, where carbonate of lime and chloride of ammonium are formed, and thence through pipes containing lumps of sulphur, which condense the bisulphide of carbon to the liquid state. The latter would be converted in the flame into sulphurous acid and carbonic oxide.

Gas from Wood and Turf.—Wood and turf are not well adapted for yielding gas for the purposes of illumination, but where coal cannot be had, or only at a very high price, they may be advantageously resorted to as a means for illumination, as may be testified by many communities at a distance from bituminous coal, which are in the enjoyment of gas-light obtained from one or other of these sources. The illuminating power of the gas liberated from these by distillation, is, it is true, inferior to coal gas; but it may be rendered even superior to the latter, by transmitting it through vessels containing naphtha or oil of turpentine, or retorts which are charged with charcoal kept incandescent by the application of external heat. These facts are entirely of recent discovery. Dr. PETTENKOFER of Munich claims the honor of being the first to prepare gas suitable for illuminating towns and dwellings, *et cetera*, from wood; and his invention is gaining more attention daily in Germany, where the consumption of wood-gas is already very large. The manufacture of gas from wood is stated to offer many facilities

and advantages which are not experienced in the distillation of coal; among these is that of expedition, the gas being freely evolved from the wood, and allowing the charging of the retorts to take place every hour and a half. The tar from the wood distillations is more abundant, and the charcoal is much more valuable than the coke. Further, in coal gas-works the retorts are rapidly worn out, owing to several causes, such as the superior temperature caused by the sulphur in the coal; but it is not so in the manufacture in question, for the heat of distillation is considerably lower, and sulphur is absent. In Munich, where wood gas is used, the usual U-shaped retorts are employed; they are charged with ninety pounds of wood, from which as much gas is obtained as will suffice for two hundred and eighty burners. Immediately on introducing the dried wood into the red-hot retort, gas is evolved, which passes off through an arrangement of pipes, mains, scrubbers, and dry lime purifiers in the usual way. The charcoal, when drawn out, is cooled with wet sand. LIEBIG and STEINHEIL give the illuminating power of this gas as *six*, coal-gas being estimated at *five*.

Oil-Gas.—It appears, at first sight, both inexpedient and superfluous to distil oil for the production of gas, when it is considered that oil can be burnt in lamps without any further preparation, while it loses carbon by deposition in the retorts. Purified lamp oil is consequently never used; but gas can be prepared from impure oils, train-oil, or refuse fat, with as much ease as from the purer kind. The manufacture of oil-gas is, therefore, under certain circumstances, an admirable means of using up such materials for the production of light as could not otherwise be employed, or could only be applied to the lowest uses.

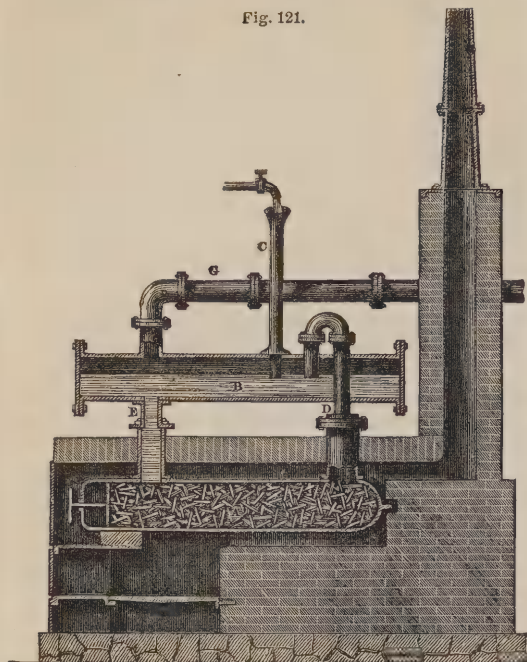
In 1815, Mr. J. TAYLOR obtained a patent in this country for the manufacture of gas from refuse fatty matters, and his plans were carried out at the gas-works at Paris, Liverpool, Bristol, and Hull; but the cost of raw material not being able to compete with that of coal, the oil-gas manufacture has been discontinued in this country.

The experiments of HENRY, which extend also to this part of the subject, show at once the plan that must be adopted upon a large scale. The following account of the results obtained, and the process of the manufacture, is given in KNAPP's *Technology*:—

It appears that the oil-gas is superior to that obtained from coal, as is also shown by its density, and that the produce, dependent chiefly upon the temperature, is of the best quality when obtained at a low red heat. This temperature suffices to convert the oil into gas, but is not sufficiently high to decarbonize the gas to any great extent. The apparatus for obtaining gas by the distillation of oil is represented in Fig. 121. The retort, A, is filled with bricks, or lumps of coke, which very materially increase the red-hot surface, and promote the evolution of gas, shortening the time which the gas already produced has to remain in the red-hot vessel. The second cylinder, B, serves both as reservoir and hydraulic main, A and B being connected in two places, D and E. Oil flows from a large cistern above the apparatus in a constant stream through the

tube C into B, which is thus kept filled up to a certain level. From B, the oil descends through E to A, where it is converted into gas and tar, both of which are volatilized, and return through D to B. The pipe, D, is

Fig. 121.



bent, and its open end delivers just below the fluid level in B, so that the vapors of the decomposed oil must constantly pass through the reservoir of oil, and deposit their tar. The retort, A, is therefore constantly supplied, not only with oil, but with a mixture of oil and tar, in such a manner that all the condensed products return to the retort together with a fresh quantity of oil, until they are completely converted into gas. If the operation be conducted in a long tube, inclined at the hinder part, while the front is kept cool, hardly any tar is produced. The gas which collects above the oil in B passes on through the tube, C. The objections to the use of metallic vessels in distilling coal, are not applicable to the distillation of oils; and cast-iron vessels are, therefore, always employed, and heated over a furnace constructed in the usual manner. According to trustworthy statements, one cubic foot, or about four gallons of oil, produce six hundred to seven hundred cubic feet of gas, which is equivalent to from ninety to ninety-six per cent. of the weight of the oil; the remainder—excepting some unavoidable loss—consists of carbon, which is deposited upon the coke or bricks. According to Dr. FYFE, a gallon of oil seldom yields one hundred cubic feet of gas of good quality, on a large scale. That made at Leith, and in private gas-works at Edinburgh, had a specific gravity of from six hundred and forty to seven hundred and ten, containing matter condensable by chlorine. In this manufacture, about one half only of the oil is converted into gas. The production of oil-gas is a continuous process, and thus differs from the distillation

of coal. The retorts only require opening now and then, for the removal of the deposit of plumbago. Vapors of the same composition and properties are found in oil and coal gas. Thus, according to HESS, all the volatile empyreumatic oils, which occur mixed with each other in the tar from oil, have the same composition per cent. as olefiant gas. In the oil-gas made in England, and submitted to a pressure of twenty or thirty atmospheres, in order to render it portable, FARADAY observed that seven thousand five hundred volumes of gas were converted into one volume of fluid; and among the oily bodies, of which the liquid is composed, and which contain from eighty to ninety per cent. of carbon, this chemist was enabled to study some in an isolated state, as triyl— C_3H_3 , ditriyl— C_2H_4 —and a third hydrocarbon— C_2H_5 .—*Knapp.*

Gas from Soap-Water.—A favorable idea of the practical value of chemical knowledge is afforded by the process carried out at the works of HOUZEAU-MUIRON at Rheims, where very good gas and a handsome profit are obtained from a substance which had previously been a source of expense to the manufacturer to get rid of it. This refuse is the soap-water in which woollen stuffs have been freed from fat. Besides the unchanged fat with which the goods are charged as they come from the loom, the soap-water contains a solution of oleate and stearate of soda, and compounds of the same acids with lime in suspended flakes, and, lastly, animal matter extracted from the wool. From all parts of the town the soap-water is collected, and brought to the reservoirs of the works, where three hundredweight at a time are treated with two per cent. of sulphuric acid, or twice as much hydrochloric acid, mixed with an equal quantity of water. After the lapse of twelve or eighteen hours, the water is found to contain GLAUBER'S salt or sulphate of soda in solution, a little gypsum being formed at the same time, while an impure grey fatty matter rises to the surface. This consists of the fatty acids, oil, and animal matter mixed with water, the greater part of which having already been mechanically separated, the remainder is removed by melting the fat in a copper vessel, and ultimately drawing it off into a second boiler containing some sulphuric acid, for clarification. The filtration which follows affords a clear oil, and this gives with crude soda—containing sulphide of sodium—a very tolerable soap, whilst sulphide of iron separates, leaving a black solid residue containing much fat for distillation in the retorts. The process of distillation is similar to that practised with resin; the tar produced the first day is used on the morrow to dissolve and liquify the solid residue. The soap-water is obtained at the rate of ninepence for every thirty gallons.—*Knapp.*

Hydrocarbon Gas from Boghead Cannel.—The following interesting account of hydrocarbon gas from Boghead cannel, is adapted from an article in the *Journal of Gas-lighting*, from the pen of Dr. FRANKLAND of Manchester:—In the summer of 1851, this excellent chemist made an extensive series of experiments on the manufacture of hydrocarbon gas from cannel coals, in which the results obtained by WHITE'S

process were compared with those yielded by the usual method of gas-making. The experiments were made on a manufacturing scale, the cannels being worked in one hundredweight charges, in diaphragm retorts of the \square shape, six feet long, one foot six inches high, and one foot wide. The condensing and purifying apparatus was of the ordinary description, and the gas was passed through a station-meter immediately previous to its entrance into the holder, and at a temperature rather below than above that of the atmosphere.

Instead of receiving the whole of the gas in a large holder, and then experimenting upon the total quantity, FRANKLAND preferred, for certain reasons connected with the apparatus then at his disposal, to receive a portion only of the gas in a smaller holder, which was placed close to the meter, and received its supply through a very short three-fourths of an inch pipe from the main entering the meter. This small holder was capable of containing eighty cubic feet, and the flow of

gas into it was continuous throughout the whole process, and accurately regulated by a graduated stopcock, so as to allow the admission of a certain per centage throughout the entire working; for instance, if a ten per cent. sample was being taken, ten feet entered this holder during the time that ninety feet passed through the large meter. He had previously satisfied himself that, by attending to certain precautions mentioned below, this method furnished a perfectly fair sample of the total gas produced.

The results proved, in favor of the hydrocarbon process, a gain of from 45.8 to 290.6 per cent. in quantity of gas, and from 11.2 to 108.6 per cent. in total illuminating power, according to the quality of the cannels used. This gain in the total quantity of light yielded by a given weight of cannels, was also very remarkably corroborated by the analytical estimation of the value of the illuminating hydrocarbons in each gas, as is seen from the following summary:—

	Boghead.		Leemahagow.	Methel.	Wigan, Incehall.	Bulcarras.	Ramsey's Cannel.
	1st Exp.	2nd Exp.					
Per centage gain in illuminating power by hydrocarbon process,	88.4	82.4	82.8	108.6	33.9	42.4	11.2
Per centage gain in hydrocarbons expressed in their equivalents of olefiant gas,	83.9	..	85.1	109.2	34.0	..	11.3
Per centage gain in quantity of gas,	188.2	290.6	174.8	176.2	47.9	48.5	45.8

Subsequently, Dr. FYFE also made an extended series of experiments on the same subject; confining his attention, however, to the Boghead cannels, which, he justly remarks, is best fitted for testing the value of the hydrocarbon process. His results differ most widely from FRANKLAND'S, exhibiting invariably a loss of light—sometimes small, at other times enormously great—by the application of the hydrocarbon process.

Dr. FYFE'S experiments were conducted upon a very small scale—small \square -shaped retorts, two feet six inches long, and nine inches wide, being used, whilst the largest charge of cannels was seven pounds, and even still less quantities were frequently employed. They further differed from FRANKLAND'S trials in the whole of the gas being simultaneously received in two holders, so that the subsequent experiments upon it were conducted upon the total quantity of gas produced; whilst, in Dr. FYFE'S trials, a per centage only of the gas was received and submitted to experiment. To this latter circumstance mainly, Dr. FYFE ascribes the discrepancy in the results.

For some months after the publication of Dr. FYFE'S trials, Dr. FRANKLAND was residing on the Continent; and, for a long period after his return, the want of a suitable apparatus, and the little time at his disposal for such matters, prevented a repetition of the experiments upon Boghead cannels, in order to determine the accuracy or fallacy of former conclusions.

The appearance of another article, however, on the same subject, by Dr. FYFE, in the *Journal of Gas-lighting*, for March 1854, confirmatory of his previous results, determined Dr. FRANKLAND at once to institute new experiments, with an apparatus in which the total quantity of gas could be operated upon.

The apparatus employed consisted of a cannels retort

of the same size as that used in former experiments, surrounded by four water retorts, each of the same length as the cannels retorts, and nine inches in diameter, furnished with a diaphragm in the usual manner. The gas passed from the retorts through the hydraulic tubular condenser, and small wet and dry lime purifiers, to a station-meter, and thence to the holder, where the whole quantity produced in each case was received.

Although two hours were considered amply sufficient for complete intermixture and diffusion of the gases in such a holder, yet an interval of twenty-four hours was in each case allowed to elapse before the gas was submitted to the photometrical experiments. In thus using a large holder, it is indispensable that the gas for the illuminating room should be drawn directly from the water itself, and not from the large outlet-pipe, the unknown contents of which would, in many cases, supply a burner for several hours. This was effected by attaching a flexible tube to an aperture in the crown of the holder, and then conducting the gas to the illuminating room by a half-inch iron pipe. In this manner, a fair sample of the gas in the holder was secured. In all the experiments, the modification of BUNSEN'S photometer, by Messrs. CHURCH and MANN, was employed. The gas was consumed in fish-tail and Winfield burners; and, in every instance, the determination was made when the gas appeared to be burning to the best advantage. The numbers obtained were, as usual, corrected to the one hundred and twenty grain candle standard.

Having previously ascertained that Boghead cannels, when distilled alone, yields considerably higher results in small quantities, and being desirous of placing the cannels in the best possible position for a comparison.

only half a hundredweight was used for each experiment, in place of one hundredweight, as employed in previous trials. In making the hydrocarbon Boghead gas, the evolution of water gas was so managed, that the mixture of gases generated throughout the entire working was maintained at a nearly uniform illuminating power. To do this, the generation of water gas must at first be very rapid, and should nearly cease at the end of the second hour. The heat was a good bright red; and, in the trial with Boghead alone, it was slightly higher than in that with Boghead and water.

The following results were obtained:—

I.—BOGHEAD WITHOUT WATER GAS.

Cannel used, Fifty-six pounds.
Gas produced, Three hundred and sixty-four cubic feet.
Time occupied, Two hours and forty-five minutes.
Gas per ton, { Fourteen thousand five hundred and sixty cubic feet.

ILLUMINATING POWER OF GAS.

Two cubic feet per hour, fish-tail No. 1. Candles.	Three cubic feet per hour, fish-tail No. 2. Candles.	Four cubic feet per hour, fish-tail No. 3. Candles.	Five cubic feet per hour, Winfield's burner. Candles.
14.7	25.5	36.4	48.9

ILLUMINATING POWER OF ONE CUBIC FOOT OF GAS.

Candles.	Candles.	Candles.	Candles.
7.35	8.5	9.1	9.78

Illuminating power of total gas, when burnt at the rate of three cubic feet per hour, = 309.4 sperm candles, each sperm candle burning ten hours, at the rate of one hundred and twenty grains per hour.

II.—BOGHEAD WITH WATER GAS.

Cannel used, Fifty-six pounds.
Gas produced, Nine hundred and four cubic feet.
Time occupied, Two hours and forty-five minutes.
Gas per ton, { Thirty-six thousand one hundred and sixty cubic feet.

ILLUMINATING POWER OF GAS.

Two cubic feet per hour, fish-tail No. 1. Candles.	Three cubic feet per hour, fish-tail No. 2. Candles.	Four cubic feet per hour, fish-tail No. 3. Candles.	Six cubic feet per hour, Winfield's burner. Candles.
11.1	1.90	26.9	48.1

ILLUMINATING POWER OF ONE CUBIC FOOT OF GAS.

Candles.	Candles.	Candles.	Candles.
5.35	6.33	6.72	8.0

Illuminating power of total gas, when burnt at the rate of three feet per hour, = 572.5 candles. Hence, gain in illuminating power by employment of water gas, per ton, = 10,524 candles; 85.0 per cent. Gain in quantity of gas, = 21,600 cubic feet; 175.9 per cent.

These results, therefore, most satisfactorily confirm those obtained in former experiments, *vide* *supra*:—

	Per Ton.		Per Cent.	
	1st Experiment.	2d Experiment.	1st Experiment.	2d Experiment.
Gain in illuminating power by employment of water gas,	10,028 candles.	9,348 candles.	88.4	82.4
Gain in quantity of gas,	24,920 cubic feet.	38,480 cubic feet.	188.2	290.6

Thus showing that experiments, in which a certain per centage only of the total gas generated is operated upon, are worthy of full reliance if conducted with the necessary precautions; but, in order that the results may be received with the same confidence, FRANKLAND admits that this method requires more faith in the manipulatory skill of the operator than the other; for, as Dr. FYFE has shown, it is easy to commit very serious errors if the necessary precautions be not attended to. The essentials to accuracy are—first, that the tube supplying the small holder from the main should be as short and narrow as practicable; secondly, the gas should be admitted into the small holder *continuously* throughout the entire working, and not in isolated portions at stated periods; and, thirdly, the sample thus taken should not bear too small a proportion to the total quantity of gas generated. In FRANKLAND's former experiments all these conditions were secured; but in the trial quoted by Dr. FYFE, in which the sample collected in the small holder was thirty-three per cent. worse than it ought to have been, they were disregarded. In Dr. FYFE's experiments, the capacity of the inlet-pipe was one hundred and thirty-two cubic inches, the gas was received in isolated portions at stated periods, and the sample thus collected bore a relation to the total gas of only 1 : 500. In FRANKLAND's experiments, the contents of the inlet-pipe were only eighty-three cubic inches; the sample was collected continuously, and in the three experiments on Boghead cannel, it bore relation to the total gas:—

First Experiment,	1 : 8.3
Second Experiment,	1 : 23.8
Third Experiment,	1 : 32.3

These considerations clearly point to the causes of

the discrepancy observed by Dr. FYFE in his small per centage sample; and as the results of FRANKLAND's second series of experiments, made with all the precaution which Dr. FYFE considers necessary to accuracy, coincide closely, as seen above, with those he already published,—the actual gain of light per ton, ten thousand five hundred and twenty-four sperm candles, being somewhat greater than the mean of the first series, nine thousand six hundred and eighty-eight, and the per centage gain eighty-five,—it now only remains to show the cause of the discordance between Dr. FYFE's experiments and his—the one assigned by Dr. FYFE, viz., the use of a per centage sample, being completely disproved.

In pointing out what FRANKLAND conceives to be the true cause of the discordance, attention will principally be confined to Dr. FYFE's last experiments, in which he used retorts of the customary size; because FRANKLAND is convinced that no results obtained with such a small apparatus, and such minute charges of cannel as those used in his first experiments, can be relied upon for comparison with experiments on a manufacturing scale. He feels also less reluctance in leaving these experiments out of consideration, since Dr. FYFE himself admits, to a certain extent, that they were made upon too small a scale to be depended upon. For the hydrocarbon process especially, retorts of such small *longitudinal* dimensions are peculiarly unfitted; because the amount of carbonic acid generated in the water retort is greatly augmented by diminishing the length of charcoal surface over which the water gas has to travel, and, for the same reason, a great excess of steam is also very liable to pass into the coal retorts, thus damaging the luminiferous constituents there gene-

rated. In addition to this cause of error, the experiments in question must have been much vitiated by the rapid carbonization of the very small quantity of cannel used, nearly the whole of the gas from which would certainly be expelled in thirty minutes—a length of time far too short for the generation of the requisite quantity of water gas from one small retort.

In Dr. FYFE's last experiments, he used two retorts of a large size, one containing the charcoal or coke by which the water was decomposed, the other the coal, of which two hundredweight were used in each charge. Two charges were worked off, both with water gas, and the gaseous products received in a large holder. The average of these trials was twenty-seven thousand cubic feet per ton, yielding light equal to 2830·15 pounds of sperm. Dr. FYFE then compares this result with that which he obtained by working the seven pound charges above alluded to, and thus shows a loss of thirteen per cent. by the hydrocarbon process.

The two principal points, in which the conclusions drawn by Dr. FYFE from these results differ from FRANKLAND's, are—first, his high estimate of the powers of the Boghead cannel distilled alone; and, secondly, the comparatively low results which he obtained by the collateral use of water gas. The first of these points arises, as just mentioned, from reliance being placed upon certain results obtained in small retorts with seven pound charges of cannel, which results differ most widely from those of all other experiments, as also from the previously published report of Dr. FYFE himself.

To determine the influence of small charges in increasing the yield and the illuminating power of the gas from Boghead cannel, FRANKLAND put 2·5 ounces of the same sample as that used in his last experiments in a hand glass tube; it gave 1·88 cubic feet of gas, five feet per hour of which yielded a light equal to 64·5 candles. These numbers are equivalent to fifteen thousand four hundred and eighty-two cubic feet per ton, or 3423·7 pounds of sperm per ton—a result which even exceeds that of Dr. FYFE, and shows how little dependence can be placed in experiments upon small quantities of this cannel.

It is, therefore, greatly to be regretted, that Dr. FYFE did not, at the time of making his last experiment at Leith, try a corresponding one with Boghead cannel alone in the same apparatus, instead of continuing to quote the results of his former trials on the small scale, which he admits to be unworthy of full confidence. Had he done so, FRANKLAND feels assured that he would have removed one cause of discrepancy—*videlicet*, his estimate of the value of Boghead cannel when distilled alone, which, as proved, is far too high.

Dr. FRANKLAND acknowledges himself indebted to Mr. A. WRIGHT and Mr. T. G. BARLOW of London, and to Mr. A. KING of Liverpool, for some very important information on this subject—the first gentleman having tested the value of the Boghead cannel during several weeks' working on a very large scale, and the latter two having made a very extensive series of most careful experiments upon a small scale. In Mr. WRIGHT's experiment, three parts of Newcastle coal—Dean's Primrose—and one part of Boghead can-

nel, were distilled in separate retorts, yielding nine thousand five hundred cubic feet per ton; the mixed gases were burnt in a Number 2 fish-tail burner, 2·5 feet per hour giving light equal to thirteen candles. From this result of the mixed gases, the value of the Boghead was calculated to be 5·44 times that of an equal weight of the Newcastle coal; and therefore, taking the well-known value of Newcastle coal at nine thousand feet per ton—five feet per hour = thirteen candles—it follows that a flame of Boghead gas burning five feet per hour would give a light equal to 57·9 candles, at which rate of consumption the total gas from one ton of Boghead would be equal to 2182·1 pounds of sperm. Mr. KING's result is the average of eleven experiments, each made upon the one-thousandth of a ton; the gas was burnt by a Number 1 fish-tail burner, at rates of consumption varying from 1·38 to 2·04 feet per hour. The value assigned by Mr. BARLOW to Boghead is the average of three experiments, which were also made upon the one-thousandth of a ton of cannel, the gas having been burnt at the rate of from 1·44 to 1·92 feet per hour. If, in the experiments of Mr. KING and Mr. BARLOW, the gases had been burnt at higher rates of consumption, there is no doubt that the equivalent of sperm per ton would have been somewhat higher. In addition to this valuable evidence from gentlemen so intimately acquainted with the subject, there is also the statement of the owners of the cannel, contained in their advertisement, which appears monthly. FRANKLAND considers this statement as good evidence on one side of the question, inasmuch as it is not usual for merchants to underrate the value of the commodities they have to sell. These estimates, along with that contained in Dr. FYFE's printed report to the owners of the coal, are now appended with FRANKLAND's results:—

ESTIMATES OF THE VALUE OF BOGHEAD CANNEL.

Authority.	Cubic feet of gas per ton.	Gas from one ton, = 16 sperm.
Mr. Wright,.....	11,000	2182·1 pounds.
Mr. Barlow,.....	13,344	2057·0 “
Mr. King,.....	13,549	1993·6 “
Dr. Fyfe,.....	14,800	2283·2 “
Advertisement of proprietors of Boghead cannel,.....	13,500	1967·1 “
Dr. Frankland's 1st experiment,.	13,240	2387·7 “
Dr. Frankland's 2nd experiment,	14,560	2441·1 “

The above are by no means selected; they include all the experiments upon this cannel, with the exception of the subsequent ones by Dr. FYFE, to which allusion has already been made. It will be seen from this statement, that FRANKLAND's results are considerably higher than those of any other experimenter. This is ascribed to the use of a diaphragm retort, and he believes that it is impossible to obtain numbers so high as his in retorts of the ordinary construction. The relation of these numbers to those employed by Dr. FYFE for comparison with his experiments on the hydrocarbon process—namely, Dr. FYFE's results with seven pound charges, 16,093 cubic feet of gas per ton; gas from one ton = 3253·5 pounds sperm—must convince every candid mind that his results are far too high, and cannot fairly be quoted for comparison with any experiments on the hydrocarbon process.

Having thus obtained a basis of experimental results for comparison with those yielded by the same cannell when treated according to the hydrocarbon process, FRANKLAND proceeds to show the gain in illuminating power which that method exhibits, when the experiments upon it by Dr. FYFE and himself are compared with these several results; for Dr. FYFE rightly contends that it is to this test, and not to that of gain in quantity of gas only, that the hydrocarbon process must be submitted.

The comparison which FRANKLAND formerly published, as well as the one previously cited, were founded upon equal consumptions of the respective gases; but Dr. FYFE prefers to burn each gas to the best advantage, with a given burner—generally a Winfield—at high rates of consumption, and then to calculate the value of each cubic foot. By this

method, the comparison may be said to be nearly that of equal light, instead of equal consumpts. FRANKLAND and FYFE agree on this point, and think that the basis of comparison, especially in gases differing much in richness, ought to be that of equal lights and not of equal consumpts. By adopting this plan in the following comparisons, the former has been compelled, in the case of his second experiment, to calculate the hourly consumption of a flame giving a light equal to about fifty candles, as he made no experiment beyond twenty candles. A consumption of ten feet per hour in a Winfield's burner is estimated as being equal to the light of 50·6 candles of one hundred and twenty grains per hour. He does not insist upon the absolute correctness of the gain exhibited by his second experiment, although he believes it to be very near the truth:—

PER CENTAGE GAIN IN ILLUMINATING POWER BY THE HYDROCARBON PROCESS AS APPLIED TO BOGHEAD CANNEL.

Name of Experimenter on Hydrocarbon Process.	Comparison with results obtained with Boghead Cannel alone, by				Proprietor of Boghead Cannel.	Dr. Frankland's First Experiment.	Dr. Frankland's Second Experiment.
	Mr. Wright.	Mr. King.	Dr. Fyfe.	Mr. Barlow.			
Dr. Fyfe—experiment at Leith gas-works,	Per cent. 29·7	Per cent. 42·0	Per cent. 24·0	Per cent. 37·6	Per cent. 43·9	Per cent. 18·5	Per cent. 15·9
Dr. Frankland's first experiment,	89·6	107·5	81·2	101·1	110·3	73·3	69·5
Dr. Frankland's second experiment,	105·6	125·0	96·5	118·1	128·1	87·9	83·8
Dr. Frankland's third experiment,	127·7	149·2	117·6	141·5	152·6	108·1	103·6

These numbers prove, in the most incontestable manner, that there is invariably a very large gain by the employment of the hydrocarbon process, varying with the amount of water-gas used, and with the value at which the gas from Boghead alone is estimated. This gain is even apparent from Dr. FYFE's own experiments, although its smallness, in comparison with that exhibited by FRANKLAND's own trials, must strike every observer of the above table. The cause of this is, however, made clearly apparent when the mode in which Dr. FYFE conducted his is taken into account.

Dr. FRANKLAND has found that one water retort is incapable of generating more than one-half the amount of water-gas requisite for one hundredweight of Boghead cannell; and yet, notwithstanding this caution, Dr. FYFE carbonized two hundredweight of cannell with only one water retort; the water-gas power was, therefore, only one-fourth of what it ought to have been, and, as might naturally be expected, the gain was only one-fourth of that which a properly-conducted experiment would yield. The Editor considers that Dr. FRANKLAND has clearly demonstrated that there is a high gain in the total illuminating power obtainable from a given weight of Boghead cannell by the employment of the hydrocarbon process, and that his former estimate of that gain—at from eighty to ninety per cent.—was by no means too high. Since the publication of his first report on hydrocarbon cannell gas, he has had abundant opportunities of witnessing the working of the process; and although he admits that it is more liable to suffer from the carelessness of workmen than the old process, yet his confidence in its merits, and in its ultimate extensive adoption by gas engineers, continues in every respect unshaken.

Illuminating Power of Gases.—The illuminating power of gas, say RICHARDSON and RONALDS, has generally been estimated by the shadow-test, or by BUNSEN's photometer, in conjunction with an experimental meter for accurately measuring the consumption. The standard of comparison used by different experimenters has not always been the same; but a spermaceti candle, consuming one hundred and twenty grains per hour, is now generally adopted.

Illuminating gas must vary in its power of giving light according to the proportion of carbon it contains; but much depends upon the mode of combination in which this element is present, and also upon the manner in which the gas is burned. Thus, carbon, in the form of carbonic acid, is not only useless as a source of light, but actually prejudicial, a very small proportion of carbonic acid in coal-gas reducing the illuminating power to a great extent. Carbon, in the form of carbonic oxide, and as light carbide of hydrogen, is of little or no value as a source of light, these gases burning with a very faint flame. The heavy carbide of hydrogen, as olefant gas, oil-gas— C_8H_8 —and the vapors of naphtha, many and indeed most of which are condensed by chlorine, bromine, and anhydrous sulphuric acid, are the ingredients of coal-gas to which it owes its illuminating power. Hence the value of gas as an illuminating agent has been frequently estimated since the time of HENRY, by the amount of condensation which it undergoes when mixed with a sufficient quantity of chlorine to absorb these higher compounds of carbon with hydrogen. Dr. FYFE relies most implicitly upon the condensation test by chlorine, in connection with what he terms durability, for an accurate indication of the value of any gas; and he has shown, in a great many

instances, that these two points give a value which agrees very well with carefully-conducted photometrical experiments. By durability, is to be understood the time during which a certain volume of gas will continue to afford a standard amount of light. Bromine is employed by many to replace the chlorine in condensing the heavy carbo-hydrogens, and is, in many respects, more convenient for manipulation. In both cases, the vapors of these substances left after condensation require to be removed from the gaseous mixture by a solution of potassa before the amount of condensation is estimated. Anhydrous sulphuric acid, obtained by warming the Nordhausen acid, is preferred by others for effecting this condensation, a ball of porous coke attached to a platinum wire being saturated with the acid and thrust up into the mixture of gases. The substances condensed from the gas by all these agents appear to be the same; but from what has been stated with reference to the nature of these condensed hydrocarbons from different specimens of coal-gas, the illuminating power of the gas must depend far more upon the chemical constitution, and upon the amount of carbon which they respectively contain, than upon the volumes which they occupy before condensation; and hence, although the test may be a good one, obtained from the same species of coal under like conditions, and containing the same kinds of hydrocarbons, it is not applicable as a means of setting a value upon gases obtained under different circumstances from different species of coal.

The substances condensed by these re-agents are probably similar, if not identical, in composition with those condensed from oil-gas and resin-gas. It has been ascertained, by comparing the density of ordinary Newcastle coal-gas before and after condensation by bromine, that the vapors of the light-giving portions give a specific gravity ranging from 2·8 to 3·3.

The liquid condensed from resin-gas by Mr. COUERBE yielded six fluids, the nature of which, with the calculated and experimental density of their vapors, are given in the following table:—

No.		Density of Vapor.	
		Calculated.	Found.
1.	C ₄ H ₄	1·763	2·000
2.	C ₅ H ₄	2·385	2·254
3.	C ₆ H ₄	2·806	2·802
4.	C ₇ H ₄	3·230	3·340
5.	C ₈ H ₄	3·660	3·765
6.	C ₂₅ H ₂₂	2·665	2·637

The first of these has a specific gravity about equal to the condensable matter in Wigan cannel and Ramsey's cannel, while the third and fourth resemble that from Pelaw, Pelton, and other Newcastle coals. A more elastic vapor probably remained in the gas from which these substances were condensed, which would have a lower specific gravity, and come to resemble the condensable matters and Lesmahagow cannel-gas. The specific gravity of the condensable matter from these gases may be seen from the annexed table by Mr. EVANS of the Westminster Gas Works, taken from the *Journal of Gas-lighting*:—

Name of Coal.	Gas per ton.	Condensed per cent. by bromine.	Specific gravity of gas.	Specific gravity of condensed matter.	Photogenic Power.	
					Actual.	By analysis.
Boghead,.....	15,000	30·	·752	1·21	37·75	36·3
Lesmahagow, No. 1,.....	13,500	16·	·642	1·64	27·1	26·24
Do., No. 2,.....	13,200	17·	·618	1·43	24·8	24·31
Capeldrae,.....	14,400	16·5	·577	1·29	19·75	21·23
Arniston,.....	13,600	17·	·626	1·40	22·50	23·80
Ramsey,.....	10,300	12·5	·548	1·82	21·40	22·95
Wemyss,.....	14,300	14·5	·580	1·87	24·50	27·11
Kirkness,.....	12,800	10·2	·562	1·95	21·20	19·88
Knightwood,.....	13,200	9·5	·550	2·28	19·00	21·66
Wigan—Ince Hall,.....	11,400	11·5	·528	1·77	20·00	20·35

The following table shows the illuminating value of the gas obtained from Newcastle coal, and may serve as a fair indication of the character of the gas supplied in the metropolis:—

Name of Coal.	Gas per ton.	Illuminating power.	Specific gravity of gas.	Condensation per cent.
Pelton,.....	11,000	14·0	·430	4·5
Pelton Cannel,.....	11,500	18·5	·521	10·5
Levenson,.....	10,800	12·5	·425	4·
Levenson Cannel,.....	11,600	18·	·523	10·
Washington,.....	10,000	14·	·430	5·
Washington Cannel,.....	10,500	18·	·500	10·5
Pelaw,.....	11,000	12·75	·420	4·5
New Pelton,.....	10,500	12·	·415	4·75
Dean's Primrose,.....	10,500	13·5	·430	5·
Ponesfield,.....	10,500	11·5	·398	3·75
Gosforth,.....	10,000	12·	·402	4·
West Hartley,.....	10,500	12·5	·420	4·2
Hastings Hartley,.....	10,300	12·5	·421	4·3
Blenkinsop,.....	9,700	14·	·450	6·

The only sure method of arriving at the actual

amount of carbon in a gaseous mixture, and at the same time showing the character of the carbonaceous compounds contained in it, is to combine the condensation method with an organic analysis, or by the old plan of combustion with oxygen, as proposed by HENRY, noting the quantity of oxygen consumed, and the amount of carbonic acid produced. Thus, a known volume of coal-gas is mixed with an excess of oxygen and exploded, the amount of carbonic acid produced and of oxygen consumed being ascertained. Another equal volume is then treated with an absorbent, as anhydrous sulphuric acid, and after all the residue is again mixed with oxygen, and exploded; the amount of carbonic acid being again ascertained, and deducted from the quantity obtained by exploding the original gas. The quantity of carbon contained in the condensed portion of the gas being thus ascertained, its value as an illuminating agent may be calculated accordingly. There appear to be some compounds of

carbon and hydrogen in certain coal gases different from light carbide of hydrogen, and which are not condensed by any of the absorbents named, and which, nevertheless, add much to the illuminating power; so that calculations based upon the above method of analysis will prove rather below than above the true value of the gas.

In estimating the value of gases by the photometer, it is absolutely necessary to burn the gas in a great variety of ways—with differently constructed burners, in different quantities, and under varying amounts of pressure—in order to ascertain under what conditions it affords its full value as an illuminating agent. A gas which is very rich in heavy hydrocarbons cannot be burned to advantage with a burner adapted for less rich gas—the apertures require to be smaller, in order to bring more oxygen into contact with each flame; and a poor gas, on the contrary, burned in a manner suitable for rich gas, will not afford its maximum effect, in consequence of too much air being brought into contact with the flame.

If the central ring of an argand burner, consuming oil without smoke at its maximum degree of brightness, be closed so as to exclude the inner current of air from the flame, the brightness is visibly diminished, but, strange as it may appear, the amount of light, as indicated by the photometer, is increased. A greater number of the particles of carbon are rendered luminous before being consumed, by diminishing the supply of air in this manner, and a greater quantity of light diffused, although the light is not so brilliant. By increasing the supply of air, much of the carbon is consumed at once, without taking a solid form in the flame; more heat is then produced, and those particles which are solid in the flame are more intensely heated: quantity of light is then sacrificed to intensity. Gas has little tendency to smoke. It is generally better suited to the production of intensity than quantity of light; and for this reason, in comparing the illuminating power of different gases with each other, it would be better to adopt as a standard the flame of some gaseous mixture of known composition, instead of the spermaceti candle, which is calculated for affording quantity rather than intensity of light.

The more carbon there is contained in gas the heavier it is, and specific gravity has, therefore, been often resorted to, as an indication of the relative value of different gases. If carbonic acid has been completely separated, and no excess of carbonic oxide is present, the specific gravity may furnish an important indication to the manufacturer of the value of gas made under similar circumstances; but it can never replace an analysis in judging of the value of different gases, as the amount of carbonic oxide will vary with the kind of coal used, and the method of conducting the distillation, the specific gravity of which is very nearly equal to that of olefant gas.

Mr. WRIGHT employs a small balloon, capable, when filled, of holding one thousand cubic inches of gas, which is gauged by a ring fitting its largest diameter when full. The weight of the balloon and car being known, and the air expelled, it is filled with gas; weights are then placed in the car until it remains

in equilibrium in the air. The data thus obtained, with corrections for temperature and pressure, afford an approximate means of ascertaining the specific gravity of the gas. Mr. WRIGHT has constructed a table, by simple reference to which, and a knowledge of the weights required to balance the balloon, the specific gravity may be read off for any variations of temperature and pressure. Little reliance is, however, placed by gas engineers upon any test of illuminating power based upon specific gravity, as this is often considerably increased by the presence of carbonic acid and carbonic oxide, which add to the weight without increasing the illuminating power of gas.

CHRISTISON and TURNER observed the following relations between the specific gravity and illuminating power of coal and oil gas:—

Specific gravity.		Relation of Illuminating power.	
Of Coal-gas.	Of Oil-gas.	Of Coal-gas.	Of Oil-gas.
0.659	0.118	100	140
0.578	0.910	100	225
0.605	1.110	100	250
0.407	0.940	100	354
0.429	0.965	100	356
0.508	1.175	100	310
0.529	0.986	100	272 average.

According to a report made by HEDLEY to Parliament, the illuminating power of coal-gas, in twelve principal districts of England, amounts to between 4.408 and 1.645 times that of a tallow candle—six to the pound; but ordinarily about two or three times, when the consumption varies from 2.3 to 1.5 cubic feet per hour, and the specific gravity from 0.58 to 0.412.

With the same burner and gas, the amount of light depends upon the height of the flame, which practically, the pressure being nearly constant, is regulated by the position of the cock, or by varying the size of aperture in the burner. According to CHRISTISON and TURNER, the advantage increases with the height of the flame, but to a limited extent only, and for a simple jet in the following proportion:—

Length of the flame in inches.	Intensity of the light from equal quantities of		Coal-gas.		Oil-gas	
	Coal-gas.	Oil-gas.	Intensity of the light.	Gas consumed.	Intensity of the light.	Gas consumed.
1	—	100	—	—	22.0	33.1
2	100	122	55.6	60.5	63.7	78.5
3	109	159	100.0	101.4	96.5	90.0
4	131	181	150.0	126.3	141.0	118.0
5	150	174	197.8	143.7	178.0	153.0
6	150	—	247.4	182.2	—	—

Thus the point at which further advantage ceases to result on raising the flame of oil-gas is four inches, whilst for coal-gas it is five inches, which in general requires the flames to be higher. The consumption of gas and the intensity of the light increase together, but the latter in a more rapid ratio up to a certain point. This occurs to a still greater extent with argand burners, for which, with the same consumption of gas, these observers found the intensity of the light to be,—

100 282 560 582 582 504
At a height of 0.50 1 2 3 4 5 inches.

According to FYFE's experiments upon different burners, in which he probably used a better kind of coal-gas, the increase is as follows:—

With twenty-four apertures of one-fortieth of an inch, the diameter of the perforated ring being seven-eighths of an inch,..... 100 121·8 — 188·5 — 236·6 — 235·4
 With forty-two apertures of one-fiftieth of an inch, the ring being twenty-one twentieths of an inch in diameter, 100 136·6 — 176·2 — 194·8 — 242·3
 Height in inches,... 1 1·5 1·75 2 2·5 2·75 3 3·5

Lastly, his experiments gave a view of the intensity of the light produced by the same quantity of gas in different burners, when separately compared at the most advantageous height of the flame:—

Burners.	Bat's-wing.			Argand burners.		
	Simple Jet.	Small.	Large.	Fish-tail burner.	With 24 holes.	With 42 holes.
Quantity of light from the same amount of gas, }	100	135	164	138	183·5	182·3

According to the observations of HEDLEY, already quoted, which were made in the gas-works at Sheffield, the intensity of the light of a simple four-inch jet is to that of a 3·5 inch argand flame—from fourteen apertures—as 1 : 4·4 to 4·8, the amounts consumed being as 1 : 3 cubic feet, which corresponds to a greater amount of light from the argand burner by from 1·47 to 1·6 for the same quantity of gas. From the general report of the same engineer upon the principal gas-works in England, it is found—in the case of coal-gas—the average specific gravity being 0·476, that a simple jet, four inches in height, consumes on the average one cubic foot per hour.

The superiority of the flat flames over the simple round ones, explains an observation which has been made with regard to the argand burners. When the apertures in it are placed so far apart as to form a circle of distinct jets, the effect is one-third weaker, with the same current of gas, than when the jets—of one-sixth, to one-eighth of an inch—unite into a single flat ring.

The subjoined experiments on the illuminating power of Wigan canal-gas with different burners have been recorded by Mr. ALFRED KING:—

	One-half foot.	One foot.	One and a half feet.	Two feet.	Two and a half feet.	Three feet.	Three and a half feet.	Four feet.	Four and a half feet.	Five feet.	Five and a half feet.
<i>Single Jet:</i>											
Consumption per hour,.....	·5	1·	—	—	—	—	—	—	—	—	—
One foot = candles,.....	2·15	2·6	—	—	—	—	—	—	—	—	—
One foot = grains of sperm,...	258·3	311·8	—	—	—	—	—	—	—	—	—
<i>Lancashire Fish-tail, No. 0:</i>											
Consumption per hour,.....	·5	1·	1·5	—	—	—	—	—	—	—	—
One foot = candles,.....	1·78	2·18	1·76	—	—	—	—	—	—	—	—
One foot = grains of sperm,...	214·1	262·5	211·9	—	—	—	—	—	—	—	—
<i>Lancashire Fish-tail, No. 1:</i>											
Consumption per hour,.....	·5	1·	1·5	2·	—	—	—	—	—	—	—
One foot = candles,.....	1·76	2·65	2·55	2·53	—	—	—	—	—	—	—
One foot = grains of sperm,...	211·3	317·9	306·5	303·7	—	—	—	—	—	—	—
<i>Lancashire Fish-tail, No. 2:</i>											
Consumption per hour,.....	·5	1·	1·5	2·	2·5	3·	—	—	—	—	—
One foot = candles,.....	2·26	3·11	3·5	3·76	3·79	3·66	—	—	—	—	—
One foot = grains of sperm,...	271·2	373·3	420·6	455·7	455·7	439·4	—	—	—	—	—
<i>Lancashire Fish-tail, No. 3:</i>											
Consumption per hour,.....	·5	1·	1·5	2·	2·5	3·	3·5	—	—	—	—
One foot = candles,.....	2·26	3·48	3·86	4·07	4·07	4·18	4·1	—	—	—	—
One foot = grains of sperm,...	271·2	417·4	463·6	488·3	488·3	501·9	492·8	—	—	—	—
<i>Lancashire Fish-tail, No. 4:</i>											
Consumption per hour,.....	·5	1·	1·5	2·	2·5	3·	3·5	4·	—	—	—
One foot = candles,.....	2·38	3·49	4·00	4·17	4·74	4·5	4·41	4·3	—	—	—
One foot = grains of sperm,...	285·5	419·5	484·4	500·5	566·7	539·9	530·1	516·6	—	—	—
<i>Bat's Wing:</i>											
Consumption per hour,.....	·5	1·	1·5	2·	2·5	3·	3·5	4·	4·5	5·	—
One foot = candles,.....	1·83	3·01	3·73	4·1	4·12	4·31	4·3	4·46	4·32	4·4	—
One foot = grains of sperm,...	220·	361·6	448·3	492·3	494·8	578·1	516·2	535·1	519·	528·9	—
<i>Sixteen-hole Argand, small holes in ring 0·82 in diameter:</i>											
Consumption per hour,.....	—	1·	1·5	2·	2·5	3·	3·5	4·	4·5	—	—
One foot = candles,.....	—	0·323	1·02	1·9	2·6	3·27	3·72	3·84	3·96	—	—
One foot = grains of sperm,...	—	38·76	123·3	228·7	313·	393·3	446·4	461·7	479·2	—	—
<i>Winfield's twenty-eight hole Argand, registered July 25, 1848, with slightly conical chimney:</i>											
Consumption per hour,.....	—	1·	1·5	2·	2·5	3·	3·5	4·	4·5	—	—
One foot = candles,.....	—	0·344	1·16	2·26	2·71	3·5	3·72	3·84	4·	—	—
One foot = grains of sperm,...	—	41·2	139·1	271·3	325·6	420·5	446·4	461·7	481·	—	—
<i>Winfield's fifty-eight hole Luculent Argand, registered March 20, 1845:</i>											
Consumption per hour,.....	—	—	1·5	2·	2·5	3·	3·5	4·	4·5	5·	5·5
One foot = candles,.....	—	—	0·318	0·75	1·09	1·57	2·09	2·59	3·07	3·82	4·5
One foot = grains of sperm,...	—	—	38·2	87·5	131·8	188·4	251·1	311·3	368·9	458·8	540·

The following experiments upon the illuminating power of Newcastle cannel-gas, were made by Mr. WRIGHT with the burners used in London for consuming that kind of gas:—

The No. 1 Scotch fish-tail gives a flame fully spread with .85 inch pressure, and when burning at the rate of 1.4 feet per hour, beyond which point it begins to show streaks of blue.

The No. 2 Scotch fish-tail is fully spread with .9 inch pressure, and when burning at the rate of 2.4 feet per hour.

GUISE's burner is an argand with twenty-six holes, the inner diameter of the ring being six-tenths of an inch, and the outer nine-tenths of an inch. It has a metal button, five-tenths of an inch diameter, one inch above the face of the burner. The glass chimney is a

straight cylinder, two inches diameter and six inches long.

With a three-tenth inch pressure, and a consumption of 4.5 feet per hour, the flame becomes irregular, and has a tendency to deliver smoke.

The standard candle used by Mr. WRIGHT consumed one hundred and thirty grains per hour, and for this, to insure a greater regularity of flame, a No. 2 fish-tail, burning .4 feet per hour, was substituted, and found exactly equal to the candle.

In the first of the following tables, the results are multiplied by one hundred and thirty, and divided by one hundred and twenty, so as to reduce them to a standard candle of one hundred and twenty grains per hour, as done by Mr. KING:—

Consumption per hour.	One foot.	One and a half feet.	Two feet.	Two and a half feet.	Three feet.	Three and a half feet.	Four feet.	Four and a half feet.
<i>Scotch Fish-tail, No. 1:</i>								
One foot = candles,.....	4.875	5.02	—	—	—	—	—	—
One foot = grains of sperm,.....	585.	602.	—	—	—	—	—	—
<i>Scotch Fish-tail, No. 2:</i>								
One foot = candles,.....	5.05	5.77	5.95	5.84	5.53	—	—	—
One foot = grains of sperm,.....	606.	690.	714.	700.	563.	—	—	—
<i>Guise's Argand:</i>								
One foot = candles,.....	—	1.08	1.85	3.12	4.85	4.95	5.77	6.74
One foot = grains of sperm,.....	—	129.	222.	374.	582.	594.	692.	808.

Mr. WRIGHT, however, prefers the subjoined form of quoting the above results:—

SPERMACEI CANDLES OF ONE HUNDRED AND THIRTY GRAINS PER HOUR.

<i>No. 1, Scotch Fish-tail:</i>																		
Gives light =	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{2}{3}$	1	2	4	6	8	....	....	....	....	....	....	....	....	....	candles.
When burning.....	.15	.2	.3	.4	.6	.9	1.3	1.8	....	....	....	....	....	....	....	....	....	feet per hour.
Feet of gas required to produce a light = one candle,....	1.2	.8	.6	.4	.3	.225	.217	.225										
<i>No. 2, Scotch Fish-tail:</i>																		
Gives light =	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{2}{3}$	1	2	4	6	8	10	12	14	16						candles.
When burning.....	.15	.2	.3	.4	.6	.9	1.2	1.5	1.8	2.2	2.6	3.2						feet per hour.
Feet of gas required to produce a light = one candle,....	1.2	.8	.6	.4	.3	.225	.2	.1875	.18	.183	.185	.2						
<i>Guise's Argand:</i>																		
Gives light =	2	4	8	12	16	20	24	28	....	....	....	....						candles.
When burning.....	1.7	2.1	2.6	3.1	3.5	3.19	4.2	4.5	....	....	....	....						feet per hour.
Feet of gas required to produce a light = one candle,....	.85	.525	.325	.258	.219	.195	.175	.160										

Mr. BARLOW has recorded some experiments made by him with different burners on gas manufactured from a mixture of Pelton, Felling, and Dean's Primrose, all first-class Newcastle gas coals, the average produce being eight thousand five hundred feet per ton of coal. The burners he used were:—

1st. A Number 3 fish-tail, or union jet.

2nd. A Number 5 bat's-wing.

3rd. A common argand, with fifteen large holes in a ring .85 inch diameter, and a cylindrical chimney-glass 7 inches high.

4th. A Platow's registered argand, with large holes

in a ring .9 inch diameter, with inside and outside cone, and cylindrical chimney-glass 8.5 inches high.

5th. A Bizner's patent Number 3 argand, with twenty-eight medium-sized holes in a ring .75 inch diameter, and cylindrical chimney-glass 8.65 inches high.

6th. A Winfield's registered argand, with fifty-eight medium-sized holes in two rings of twenty-nine holes in each, the mean diameter being one inch, with deflecting button inside and gauze below; bellied chimney-glass eight inches high.

7th. A Leslie's patent argand, with twenty-eight jets

in a ring .95 inch diameter, and chimney-glass 3.5 inches high.

8th. A Guise's registered shadowless argand, with twenty-six large holes in a ring .85 inch diameter, and deflecting button; cylindrical chimney-glass 6.1 inch high, and glass reflecting cone to outside gallery.

On an average of numerous trials the annexed results were obtained:—

SERIES NO. I.				
Burner.	Consumption per hour.	Value of one cubic foot in grains of spern.	Standard candles per cubic foot.	Value of eight thousand five hundred feet of gas in pounds of spern.
No. 2,....	4.9	289.	2.4	351.
No. 3,....	5.5	343.	2.85	416.
No. 5,....	5.5	374.	3.11	447.
No. 6,....	5.5	337.	2.8	409.
No. 8,....	5.5	350.	2.91	425.

SERIES NO. II.				
No. 1,....	5.5	276.	2.3	335.
No. 2,....	5.0	290.	2.41	352.
No. 3,....	5.5	341.	2.84	414.
No. 4,....	5.5	348.	2.9	422.
No. 5,....	5.5	380.	3.16	461.
No. 6,....	5.5	335.	2.79	406.
No. 7,....	4.1	369.	3.07	448.
No. 8,....	5.5	364.	3.03	442.

It is quite evident from these experiments that the No. 6, or Dr. Fyfe's Aberdeen argand, required a longer consumpt than 5.5 feet per hour to bring out the full effect of Newcastle coal-gas of the quality used in this case, for, when the consumpt was increased to 6.5 feet per hour, it gave results equal to any of its compeers at 5.5 feet. No. 2 and No. 7 burners were tried with the utmost quantity which could be consumed in them without smoking or burning advantageously.

Though these experiments indicate the relative adaptation of the several burners for the combustion of Newcastle coal-gas, they must not be taken as settling the question of the practical value of each. Some of them cast shadows, which detract considerably from the light they yield when placed above the level of the eye; this is particularly the case with No. 5, which otherwise gives the best results. Others, like No. 7, require a perfect uniformity of pressure, and an absence of all currents of air. Taking all things into consideration, No. 8 is, perhaps, the one to which these objections least apply, and it gives the next largest amount of light for the gas consumed, though the slight advance upon the old argand, as constructed twenty-five years since, cannot fail to be remarked.

Glass chimneys are not so requisite for gas as for lamp flames, and their effect is quite different from that exerted upon the wick flame of a lamp. The jet of gas, as it leaves the burner, is in far more correct relation to the air, than is the case with the gas produced at the burning margin of the wick.

Argand wick flames require a strong draught, and never burn without smoke, unless a chimney is used; with gas flames, the glasses are used rather to steady the flame than to insure its perfect combustion: they are always made shorter than the glasses of oil-lamps. If too high chimneys are used, the draught of air soon cools the base of the flame, and the air becoming mixed with the gas, a diminution of the light results,

which is caused by the combustion of too much carbon simultaneously with the hydrogen; hence but little is momentarily separated in the flame. A striking proof of this is afforded by the well-known experiment, in which a closed cylinder of wire-gauze, through which flame cannot be communicated to a combustible mixture, is adapted to a gas-burner. The jet of gas which, without the case of wire-gauze, yields a perfect flame, becomes intimately mixed with air in the interior of the case, and on its exit burns with a pale blue light, because the separation of carbon in the flame no longer occurs, both carbon and hydrogen being burnt simultaneously. This experiment gives an important hint on the general management of the draught in illumination. The same result may be observed when the gas is allowed to escape with too great velocity; and, if the proper limit is exceeded, the flame may be extinguished by being too much cooled: with a certain velocity, the current will not ignite for a distance of several lines from the aperture, and then burns with a faint blue flame, the gas having become mixed with air.

It is by taking advantage of this effect of a strong current of air, that the highly carbonaceous vapors of oil of turpentine, coal-tar naphtha, and similar substances, may be burned without smoke, as in BUSSON and ROUEN'S apparatus, or in HOLLIDAY'S lamps. The oils being allowed to escape in the form of a jet of vapor, under a pressure varying, according to circumstances, from four to twenty-four lines of mercury, the excess of carbon is brought to a proper proportion by the admixture of air, without interference with the order of combustion. In this manner brilliant flames, free from soot, are produced.

Among the arrangements which increase the light by raising the temperature of the air, the burner invented by M. PARISOT of Paris is distinguished by its simplicity and great facility of construction. It admits the air by narrow passages between two thick concentric cylinders or cones, about four inches in height. The gas escapes by a circular slit, easy to clean. This burner gives a full light and a very steady flame.

Application of Gas as a source of Heat.—Gas has long been employed as a source of heat in chemical and pharmaceutical laboratories, but it is only during the last few years that it has been more extensively used for cooking, warming apartments, *et cetera*.

Comparison of the various methods of Illumination with each other.—In the foregoing remarks, the relative illuminating values of the various methods of producing artificial light have generally been shown, without reference to the cost of the light. This still remains to be considered, in order to estimate their relative economy. PECKET, in the following sketch, has in each case taken the cost into account; but this will vary with the rise and fall of markets, and with the locality. The price of a pint of oil—0.9 lb.—is here fixed at about fivepence; of one pound of tallow candles at sevenpence, wax candles at two shillings and twopence, stearin candles at one shilling and fourpence; a pint of illuminating spirit—0.8 lb.—at eightpence; of one hundred cubic feet of coal-gas at sevenpence; and lastly, of one hundred cubic feet of oil-gas at two shillings and threepence.

Means of Illumination.	Intensity of the light.	Consumption of illuminating material per hour.	Illuminating power, Carcel's lamp = 100.	Price of 100 grammes of illuminating matter.	Cost of the light per hour in pence.	Cost of a light of the same intensity per hour in pence.
Tallow candles, six to lb.,	10·66	8·5	54·04	1·5	0·125	1·169
Wax " six "	14·60	9·6	61·57	5·	0·461	3·155
Stearin " five "	14·40	9·3	66·58	3·2	0·298	2·066
Kitchen lamp,	6·65	8·0	33·60	1·4	0·083	1·246
Lamp with flat wick,	12·50	11·0	47·50		0·114	0·912
Astral lamp,	31·00	26·7	48·70		0·280	0·893
Sinumbra lamp,	56·00	37·1	63·0		0·385	0·687
Lamp with inverted reservoir,	90·00	43·0	87·8		0·446	0·495
Hydrostatic lamp,	45·00	17·26	109·2	1·3	0·179	0·398
Carcel's lamp,	100·00	42·0	100·0		0·435	0·435
Vapor lamp,	130·70	151·0	36·2		2·013	1·207
				Per 100		
		C. F.		C. F.		
Coal-gas,	127·00	8·70		7·0	0·580	0·456
Oil-gas,	127·00	2·43		19·2	0·630	0·367

The light of wax candles is the most expensive, then that of stearin candles and the vapor lamp, which are also costly. There are, however, few instances in which public opinion and scientific estimation of the value of an article are so much at variance as with reference to the means of illumination in general; occasional deceptions, such as occur in the lamp of BENKLER, not being taken into consideration. A glance at the last column in the above table shows that the modes of illumination which, on account of their supposed cheapness, are partly used by the wealthy and exclusively by the poor, are those which—excluding

articles of luxury, such as wax, *et cetera*—cost most in producing a certain degree of brilliancy. A given amount of light yielded by tallow candles costs from three-fifths to twice as much as when it is obtained from the lamp of CARCEL; with the kitchen lamp it costs nearly three times, and by the lamp with the flat wick more than twice as much.

The more ordinary light-giving materials have recently been examined, and compared with the light obtained from what is called common or thirteen-candle coal-gas. Tried by the photometer:—

One thousand cubic feet of gas were found equal to the light of 312,000 grains, or 44½ pounds of sperm candles.	
" " " " 341,750 " 48½ pounds of carefully-snuffed wax candles.	
" " " " 358,000 " 51½ pounds of stearic acid candles.	
" " " " 370,540 " 52½ pounds of best mould candle.	
" " " " 381,000 " 54½ pounds of best dip candles.	
" " " " 417,220 " { 6½ gallons of purified colza oil, specific gravity 915.	
" " " " 366,310 " 5½ gallons of sperm oil, specific gravity 888.	

As the price of gas varies in different parts of the United Kingdom from four shillings and sixpence to ten shillings per thousand cubic feet, to obtain the relative cost it is necessary to multiply the prices of the other materials per pound with the numbers in the above table.

Thus, with gas at four shillings and sixpence per thousand cubic feet, and dip candles at sevenpence per pound, the cost of an equal amount of light from the two sources will be as four shillings and sixpence to one pound ten shillings and tenpence.

The great obstacles to the more general introduction of gas-light into private houses, are the difficulty of placing the light in such a position as to be available for all purposes, and that of reducing the consumption to the requirements of the consumer. A candle or a lamp can be placed wherever it is wanted, while a gas-light, even when flexible india-rubber tubes are used, is always more or less a fixture. The burners in common use are also calculated for giving more light than is required for one or two persons; and hence, though the light from gas is so very much cheaper, yet a larger quantity of light than is absolutely necessary being generally employed wherever gas is introduced, the

actual saving by its introduction is not so great as the difference of price in the light would make it appear.

The foregoing tables also show that the most economical light is obtained from the best constructed lamps, which, in addition to being costly themselves, also consume large quantities of oil, and are therefore not economical when used by a single person. There still appears much room for improvement in the adaptation of good lamps to the requirements of small consumers. A lamp which would give the light of one or two spermaceti candles, and yet be relatively as economical in the consumption of oil as CARCEL'S or the French moderator lamp, would probably command an extensive sale.—*Richardson and Ronalds.*

Detection of Sulphide of Hydrogen, Bisulphide of Carbon, and Atmospheric Air in Coal-Gas.—A quick approximative method of estimating the above in coal-gas, which has long been considered a great desideratum by chemists, has been given by THORNTON J. HERAPATH. The reagents and apparatus required are:—

1. A weak aqueous solution of caustic potassa.
2. A strong alcoholic solution of caustic potassa.

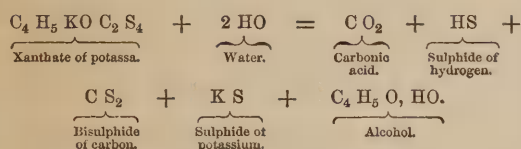
3. A solution of the nitrate or acetate of lead.

4. A standard solution of lead, containing one, two, or three one-hundredths of a grain of metallic lead, as nitrate or acetate, to one hundred or one thousand water-grain measures of solution.

5. A standard meter, such as is generally used for testing the illuminating quality of coal-gas.

6. Two Liebig's triangles, and

7. Three graduated tubes or colorimeters of uniform bore. The aqueous solution of potassa is used to absorb the sulphide of hydrogen, whilst the alcoholic is afterwards employed to dissolve the bisulphide of carbon vapor, which it converts into xanthate of potassa, a salt decomposable by heat into sulphide of potassium, sulphide of hydrogen, *et cetera*, as exhibited by the equation:—



In testing a gas by this method, one proceeds as follows:—The two triangles having been properly filled, the one with the aqueous, and the other with the alcoholic solution of caustic potassa, they are connected together by a piece of sheet caoutchouc in the usual way, and attached to the exit pipe of the standard meter, care being taken to place the one containing the aqueous solution next to the exit pipe. A known quantity, say ten, twenty, or thirty cubic feet of the gas to be examined, is then tardily transmitted through the triangles; the apparatus is slowly disconnected, and the contents of the triangles are separately poured into two different colorimeters. The solutions are next diluted with a little distilled water, mixed with a few drops of a solution of lead, and the alcoholic solution is heated to the boiling point, or until no further darkening in color ensues. The caustic alkali of both solutions is then supersaturated either with acetic or with very dilute nitric acid, and water is added to dilute to the required degree. As the sulphide of lead produced by the decomposition of the xanthate of potassa that was contained in the alcoholic solution is generally, if not always, much less in quantity than that produced by the sulphide of hydrogen absorbed by the aqueous solution of the alkali, it is advisable to dilute the former with less water. The depth of tint communicated to the fluid by the sulphide of lead in the alcoholic solution, is then compared with that produced, by adding the standard solution of lead, drop by drop, from a graduated tube, into a third colorimeter, which is filled nearly up to the same mark with distilled water, mixed with a few drops of pure citric acid, and of a solution of sulphide of hydrogen. So soon as the tints correspond, the measure of the solution in the two colorimeters is accurately adjusted by adding a little more water either to the one or the other; a little more of the standard solution of lead is then poured in, if requisite, to the trial colorimeter, and the number of measures of the standard solution that has been taken is carefully noted. The operation is then repeated with

the contents of the other colorimeter, containing sulphide of lead from the aqueous solution of potassa; and the number of measures of the standard solution of lead taken, is again read off. By a simple calculation are estimated the relative proportions of bisulphide of carbon and sulphide of hydrogen, by weight, contained in the gas examined.

For example, let *a* represent the quantity by weight of bisulphide of carbon which is equivalent to the lead contained in one thousand grain measures of the standard plumbous liquid; *b* the quantity of sulphide of hydrogen equivalent to the lead contained in the same bulk of the standard solution taken, as before explained, to produce a tint equal in intensity to that of the sulphide of lead in the alcoholic solution; and *d* the number of measures of the same solution by the aqueous solution:—then the proportion by weight of sulphide of carbon and sulphide of hydrogen contained in the number of cubic feet of gas operated upon, is obtained in the following equations:—

$$\text{Bisulphide of carbon,} \dots\dots\dots = \frac{c+a}{1000} + 2 \text{—nearly.}$$

$$\text{Sulphide of hydrogen,} \dots\dots\dots = \frac{d+a}{1000}$$

And as one hundred cubic inches of bisulphide of carbon vapor, and sulphide of hydrogen, weigh respectively at 600°, and 30 inches of Bar. 81·8167 and 36·331 grains, the result of the above calculation affords the means of ascertaining the proportion of these two substances by volume.

The presence of atmospheric air in coal-gas can be readily detected, by collecting a portion of the gas over mercury, and then passing up, first a few drops of caustic potassa, and afterwards a drop or two of a solution of pyrogallie acid. If the liquid assume a blood-red hue, oxygen, indicating the presence of atmospheric air, is mixed with the gas.

It would be quite out of place in a work like this to enlarge upon the different varieties of gas-burners, as that subject relates more particularly to mechanics. Still the Editor will cursorily glance at them, and for this purpose he cannot do better than append the following remarks from the able work of Drs. RICHARDSON and RONALDS:—

The Burners.—From the leaden pipes—in the circuit of which the meter is placed, if used at all—the gas passes to the *burners*, each of which is furnished with a separate brass tap. Good tight stopcocks are much more difficult to make for so light a substance as gas, than for liquids. The burners are very similar to those used for lamps, but as neither wick nor oil level requires special consideration, the management of the gas-burners is comparatively simple. The amount of gas consumed in a given time, however, must bear a proper relation to the supply of air, that the flame may not smoke or burn with a blue flame. This is regulated partly by the tap attached to the burner, and an excess of gas is avoided by making the aperture of the burners very small, which increases the velocity of the current. The same quantity of gas issuing from a wide orifice would produce a thick, short, and dull flame, because the surface in contact with the air would be increased. No gas flame should be allowed to issue from a wide open-

ing, for the same reason that thick massive lamp-wicks are not desirable.

When the burner has a single aperture of the diameter of a bristle, a *simple jet* is produced in the form of a long, thin, conical flame. The *bat's-wing*, or flattened flame, which the gas forms when it issues from a narrow slit, instead of a round aperture, is much more appropriate. A similar and equally good flame is produced by a burner with two apertures close to each other, the channels of which are inclined inwards, so that both the currents of gas cross each other at the base. They then form a flat flame spreading out in the form of an inverted triangle, and the burner is called a *fish* or *swallow-tail*.

Simple flames of this kind are generally burnt without any chimney. When a greater quantity of light is required, a greater intensity of flame, the argand burner, Fig. 122, is generally chosen. The gas from the pipe enters the annular space, *a a*, which is closed above by the flat plate, *b*, Fig. 123. In this plate are a number of fine apertures, arranged in a circle, and so near to each other that the separate flames unite to form a hollow cone. The gallery, *c*, supports the chimney, *d*; and to produce an internal current of air, *e*, is open at the sides. The distance between the apertures in these burners varies with the quality of the gas, as does the size of the aperture itself. An aperture $\frac{1}{32}$ of an inch is often used for coal-gas, and one of $\frac{1}{60}$ of an inch for oil-gas; for the former they should be $\frac{1}{8}$ th of an inch, for the latter $\frac{1}{4}$ th of an inch apart. These dimensions are, therefore, larger for coal-gas than for oil-gas, the latter possessing double the illuminating power of the former. The holes should be as uniformly and accurately bored as possible; if this is not done, there will be parts of the flame which will smoke. Sometimes the heat of the flame is applied to warm the current of gas before it issues from the burner, by which means the flame is less cooled, and whiter light is produced. For this purpose, the gas-pipe is formed into several revolutions at a certain height above the flame.

An important improvement upon ARGAND's burner for illuminating public places, bridges, *et cetera*, where one large lamp, and a very intense light, is preferred to a number of small ones, is the *bude burner*, proposed by GURNEY, upon the principle of FRESNEL's lamp. Two, three, or more hollow ring tubes, each furnished at the top with a circle of holes, form the principal part of the burner, and are connected at bottom with parts of the gas-pipe bent horizontally, from which they receive the gas. Each inner ring is placed somewhat higher than the one before it, so that a number of concentric flames are produced, the light of which is thrown by reflectors in the proper direction. The bude burner must not be confounded with the *bude light* of the same inventor, which is produced by conveying oxygen into the inner space of an argand oil-lamp. A similar effect

to that of the bude burner, is produced by a number of single flat flames arranged in a ring. The Victoria Bridge at Manchester, for instance, is lighted by such a burner, consisting of two concentric rings, each containing twelve, therefore altogether containing twenty-four flat flames; the inner ring, four inches in diameter, stands one inch higher than the outer, which is six and a half inches in diameter, the whole thus being rounded off in the shape of a rose. A great variety of gas-burners have been successively brought into public notice, all of which lay claim to the production of an increase of light, with a smaller consumption of gas. It is impossible, however, from a mere inspection of the flame produced by these burners, without accurately measuring the amount of gas consumed by each, to arrive at any conclusion as to which form is the most economical or generally desirable. Until, as RICHARDSON and RONALDS justly remark, impartial comparative experiments have been instituted with them all, decided preference cannot be awarded to any one in particular.

Fig. 124 is a representation of WINFIELD's lucent burner, in which the Liverpool button is applied to an argand gas-burner, and the peculiar form of chimney causes an external current of air to impinge at a certain angle upon the flame, producing the same effect as the metallic cone in the solar lamp; a basket of wire-gauze is fitted into the crutch of the burner, which moderates the supply of air from below, and prevents the flickering caused by sudden draughts. By fixing the chimney to a circular collar, which screws up or down upon the triangular support, Mr. LOWE is enabled, in his improvement upon this form of burner, to alter the direction of the external current caused by the contraction of the chimney; and by converting the button into a screw, its height can also be altered, and the internal current regulated.

Fig. 125 shows a form of burner, patented by Mr. LESLIE, in which the gas is caused to flow through a

Fig. 122.



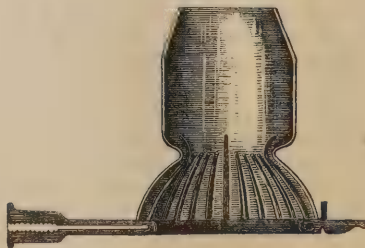
Fig. 123.



Fig. 124.



Fig. 125.



number of small copper tubes, instead of from the apertures of an argand burner. The object of this is to effect a more complete combustion of the gas, by surrounding each single jet with abundance of air as it issues from the orifice. A low form of chimney or combustion-chamber is adapted to this burner, which

diminishes the velocity of the draught. If the gas be impure, the orifices of the copper tubes become stopped up either with sulphide of copper or ammoniacal compounds, and require to be cleansed with a stiff brush. The only effectual remedy for this objection to the burner, is the use of purer gas; and this must be obtained, when not supplied in a pure state from the gas-works, by the use of a separate purifier in each house.—*Richardson and Ronalds.*

Ventilation of Gas-burners.—Serious objections stood in the way of using gas-light in private dwellings at first, in consequence of the impurities contained in the gas, the great heat produced, and the large quantity of carbonic acid evolved; and to avoid inconvenience, some system of ventilation had to be adopted; but now, owing to the general purity of the gas, and the loftiness of rooms, this is not necessary.

HOFMANN'S BURNER.—It will not be out of place here to remark, that the very extensive and daily increasing application of gas as a source of heat, suggested to HOFMANN a small contrivance which is intended to facilitate the operations of the analyst.

The ordinary argand gas-burner, which is almost universally employed for heating small vessels, such as flasks, retorts, and test-tubes, is not adapted to the purposes of the blowpipe. In operations with the latter instrument, a simple jet of gas is required, issuing from a cylindrical orifice of rather considerable dimensions, the necessary amount of gas being adjusted by the stopcock. This simplest of all gas flames serves equally well for oxidation and reduction, and exhibits the phenomena of color in the most conspicuous manner.

The ordinary method of analysis being a combination of testing in the moist way and by the blowpipe, it is necessary either to use the two gas lamps—the one

with the argand burner, the other with the single jet—or to have a gas-stand so arranged as to admit of screwing on either the one or the other. But as it is inconvenient to multiply the number of gas lamps, especially in a laboratory in which several analytical students are working, and as unscrewing hot gas-jets is a most unpleasant operation, the above chemist endeavored to unite the two jets in one stand, dispensing, at the same time, with the necessity of taking the apparatus to pieces.

The object in view is accomplished simply by

substituting for the ordinary stopcock a three-way tap. The whole arrangement becomes at once intelligible by a glance at the woodcut, which represents the burner half size.

A is the loaded foot, into which the elbow union-

piece, B, is screwed. One end of this union is connected with a flexible pipe, not shown in the drawing; to the other screws the three-way stopcock, C. The plug, D, has only one orifice, and, when turned in a vertical direction, supplies the argand burner through the perforation, E. Into the side of the stopcock is soldered a small pipe, F, having a bore of about one-eighth of an inch. This is prolonged to the distance of one-tenth of an inch above the top of the argand burner, where it is brazed to a small support for the blowpipe, not represented in the drawing.

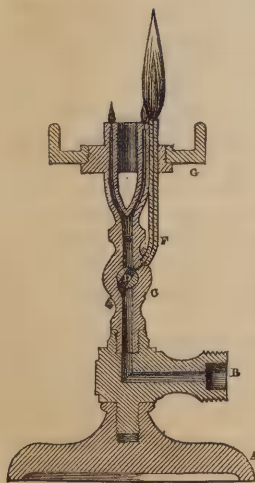
When the plug, D, is turned in a horizontal direction, the gas is shut off from both jets, but when turned in an inclined position, may be made to supply both jets at once, or either alternately. By this contrivance, either of the jets will be lighted before the other is extinguished.

In order that the jet may be likewise used for heating larger apparatus, there is a support, G, on which may be fixed a copper chimney, either plain or provided with the wire-gauze for producing the air flame.

ANALYSIS OF COAL-GAS.—The accurate analysis of gaseous mixtures—says Dr. FRANKLAND, in an able paper published in *Clegg's Treatise on Coal-Gas*, from which the following method is extracted—is one of the most delicate operations of modern chemistry. This arises not only from the difficulty of preserving gases, during the requisite manipulation, free from admixture with atmospheric air; but also from the circumstance, that their volume, the measurement of which is, in most cases, the only means of estimating their quantity, is liable to constant and considerable change, by fluctuations of temperature and of the pressure of the atmosphere, as well as by the dryness or humidity of the gas itself. This branch of chemical analysis owes much of its present accuracy and perfection to the admirable researches of Professor BUNSEN of Heidelberg.

All analytical operations upon gases must be conducted over mercury, which metal should be placed in a small wooden pneumatic trough, with plate-glass sides. The eudiometers, or measuring tubes, should be accurately calibrated and graduated into cubic inches and their tenths, the latter being subdivided by the eye into hundredths, when the volume of a gas is read off: such a division is readily attained by a little practice. At each determination of volume, it is necessary that the gas should either be perfectly dry, or quite saturated with moisture. The first condition is attained by placing in the gas for half an hour, a small ball of fixed chloride of calcium, attached to a platinum wire; the second, by introducing a minute drop of water into the head of the eudiometer before filling it with quicksilver. The determinations of volume must either be made when the quicksilver is at the same level inside and outside the eudiometer; or, as is more frequently done, the difference of level must be accurately measured in the subsequent reduction to a standard pressure. The height of the barometer, and the temperature of the surrounding atmosphere, must also be observed each time the volume of gas is measured, and proper corrections made for pressure, temperature, and also the tension of aqueous vapor, if the gas be moist.

Fig. 126.



The process of analysis described below has reference to purified coal-gas; the method of detecting the principal impurities being given in a former page.

1. *Estimation of Carbonic Acid.*—A few cubic inches of the gas are passed into a short eudiometer, moistened as above described; the volume is accurately noted with the proper corrections, and a bullet of caustic potassa is then passed up through the mercury into the gas, and allowed to remain for at least an hour; the volume of the gas being ascertained and deducted from the first volume, gives the amount of carbonic acid which has been absorbed by the potassa. Bullets of caustic potassa, or of any other fusible substance, should be of the size of a large pea, and may be prepared by melting the materials in a crucible, and then pouring them into a small bullet-mould, in which the curved end of a fine platinum wire has been placed. The ball attached to the wire is easily removed when cold.

2. *Estimation of Oxygen.*—LIEBIG has devised very accurate means for the estimation of this element, depending upon its rapid absorption by an alkaline solution of pyrogallic acid. To apply this menstruum, a small test-tube is filled with mercury and inverted in the trough: first, a few drops of pyrogallic acid, and then a similar quantity of *aqua potassæ*, are introduced into this tube by means of a pipette; a coke bullet—made by filling a bullet-mould containing a platinum wire with a mixture of two parts of coke and one of coal, both finely powdered, and then exposing the mould and its contents to a heat gradually increased to redness for fifteen minutes—attached to a platinum wire, is introduced into this liquid, and allowed to become saturated; it is then withdrawn, and conveyed carefully below the surface of the mercury into the eudiometer containing the residual gas of the first determination. Every trace of oxygen will be absorbed in a few minutes, and the volume being again measured, the diminution from the last reading will represent the amount of oxygen originally present in the gas. It is essential that the coke-bullet, after saturation with the alkaline solution of pyrogallic acid, should not come into contact with the air before its introduction into the gas.

3. *Estimation of the Luminiferous Constituents.*—Various methods have been employed for the estimation of the so-called olefiant gas—luminiferous constituents—in coal-gas. That which has been most generally employed depends upon the property which is possessed by olefiant gas and most hydrocarbons, of combining with chlorine, which causes their condensation to the state of an oily liquid. Hydrogen and light carbide of hydrogen are both acted upon in a similar manner, when a ray, even of diffused light, is allowed to have access to the mixture; but the condensation of olefiant gas and hydrocarbons takes place in perfect darkness, and advantage is, therefore, taken of this reaction to observe the amount of condensation which takes place when the mixture is excluded from light; the volume which disappears during this action of the chlorine being regarded as indicative of the quantity of olefiant gas present in the mixture. There are many sources of error inseparably connected with this

method of operating, which render the results unworthy of the slightest confidence. The same remark will equally apply to the employment of bromine in the place of chlorine. In addition to the circumstance that these determinations must be made over water, which allows a constant diffusion of atmospheric air into the gas, and *vice versâ*, there is also formed in each case a volatile liquid, the tension of the vapor of which augments the volume of the residual gas, and this increase admits of neither calculation nor determination.

The only material by which the estimation of the luminiferous constituents can be accurately effected, is anhydrous sulphuric acid, which immediately condenses the hydrocarbons, but has no action upon the other ingredients, even when exposed to sunlight. The estimation is conducted as follows:—A coke bullet, prepared as described above, and attached to a platinum wire, being rendered thoroughly dry by gently heating it for a few minutes, is quickly immersed in a *saturated solution of anhydrous sulphuric acid*, and allowed to remain for one minute; it is then withdrawn, leaving as little acid adhering to it as possible, quickly plunged beneath the mercury in the trough, and introduced into the same portion of dry gas from which the carbonic acid and oxygen have been withdrawn. Here it is allowed to rest for about two hours, in order to insure the complete absorption of every trace of carbide of hydrogen. The residual volume of the gas cannot, however, yet be determined, owing to the presence of some sulphurous acid derived from the decomposition of a portion of the sulphuric acid. This is absorbed in a few minutes by the introduction of a moist ball of binoxide of manganese, which may be readily made by converting the finely-powdered binoxide into a stiff paste with water, rolling it into a globular shape, and then inserting a bent platinum wire in such a manner as to prevent its being readily withdrawn; the ball being gradually dried, it will become hard, and possess considerable cohesion, even after being moistened with water, previous to its introduction into the gas. After half an hour the manganese bullet may be withdrawn, and replaced by one of caustic potassa, to remove the aqueous vapor introduced with the previous one; in half an hour this bullet can be removed, and the volume of the gas at once noted. The difference between this and the previous reading gives the volume of the luminiferous constituents of the gas. This method is very accurate; according to its author, Dr. FRANKLAND, the per centage of luminiferous constituents seldom varies, in two analyses of the same gas, more than .01 or .02.

4. *Estimation of the Non-luminous Constituents.*—These are, light carbide of hydrogen, hydrogen, carbonic oxide, and nitrogen. Their per centages are ascertained in a graduated eudiometer, about two feet in length, and three-fourths of an inch internal diameter, the thickness of the glass being not more than one-tenth of an inch. This eudiometer is furnished, at its closed end, with two platinum wires fused into the glass, for the transmission of the electric spark. A drop of water, about the size of a pin's head, is introduced into the upper part of the eudiometer before it is filled with quicksilver, and inverted in the mercurial trough; this

small quantity of water serves to saturate with aqueous vapor the gases subsequently introduced. About a cubic inch of the residual gas from the last determination is passed into the eudiometer, and its volume accurately read off; about four cubic inches of pure oxygen are now introduced, and the volume—moist—again noted. The oxygen is best prepared at the moment when it is wanted, by heating, over a spirit or gas flame, a little chlorate of potassa in a very small glass retort, allowing sufficient time for every trace of atmospheric air to be expelled from the retort before passing the gas into the eudiometer. The open end of the latter must now be pressed firmly upon a thick piece of caoutchouc placed at the bottom of the trough, and an electric spark passed through the mixture. If the above proportions have been observed, the explosion will be but slight, which is essential if nitrogen be in the mixture, as this element will otherwise be partially converted into nitric acid, the results being thus vitiated. By using a large excess of oxygen, all danger of the bursting of the eudiometer by the force of the explosion is also avoided. The volume after explosion being again determined, a bullet of caustic potassa is introduced into the gas, and allowed to remain so long as any diminution of volume takes place. This bullet absorbs the carbonic acid produced by the combustion of the light carbide of hydrogen and carbonic oxide, and also renders the residual gas perfectly dry; the volume noted after this absorption, when deducted from the previous one, gives the volume of carbonic acid generated by the combustion of the gas.

The residual gas now contains only nitrogen, and the excess of oxygen employed.

The former is determined by first ascertaining the amount of oxygen present, and then deducting that number from the volume of both gases; for this purpose, a quantity of dry hydrogen, at least three times as great as the residual gas, is introduced, and the bulk of the mixture determined; the explosion is then made as before, and the volume—moist—again recorded. One-third of the contraction caused by this combination represents the amount of oxygen, and the remainder, when this is deducted from the volume of residual gas, after absorption of carbonic acid, shows the quantity of nitrogen.

The behavior of the other three non-luminous gases on explosion with oxygen, enables the operator readily to find their respective amounts by three simple equations, founded upon the quantity of oxygen consumed, and the amount of carbonic acid generated by the three gases in question. Hydrogen consumes half its volume of oxygen, and generates *no* carbonic acid; light carbide of hydrogen unites with twice its volume of oxygen, and generates *its own volume* of carbonic acid; whilst carbonic oxide combines with half its volume of oxygen, causing the formation of *its own volume* of carbonic acid.

If, therefore, the volume of the mixed gases be represented by A; the amount of oxygen taken up, by B; and the quantity of the mixed gases generated, by C; and further, the volumes of hydrogen, light carbide of hydrogen, and carbonic oxide respectively, by x , y , and z , the following equations arise:—

$$\begin{array}{rcl} x + y + z & = & A \\ \frac{1}{2}x + 2y + \frac{1}{2}z & = & B \\ y + z & = & C \end{array}$$

From which the annexed values for x , y , and z are derived:—

$$\begin{aligned} x &= A - C \\ y &= \frac{2B - A}{3} \\ z &= C - \left(\frac{2B - A}{3} \right) \end{aligned}$$

5. *Estimation of the Value of the Luminous Constituents.*—The methods above given will show the respective quantities of all the constituents in any specimen of coal-gas; but analytical results afford no clue to its illuminating power; they give, it is true, the amount of illuminating hydrocarbons contained in a given volume of the gas, but it is evident, from what has already been said respecting the luminiferous powers of these hydrocarbons, that the greater the amount of carbon contained in a given volume, the greater will be the quantity of light produced on their combustion; and, therefore, as the number of volumes of carbon vapor contained in one volume of the mixed constituents, condensable by anhydrous sulphuric acid, has been found to vary from 2.54 to 4.36 volumes, it is clear that this amount of carbon vapor must be accurately determined for each specimen of gas, if it be desirable to ascertain the value of that gas as an illuminating agent. Fortunately, this is easily effected, for if the amount of carbonic acid generated by one hundred volumes of the gas in its original condition be ascertained, knowing from the preceding analytical processes the percentage of illuminating hydrocarbons, and also the amount of carbonic acid generated by the non-luminous gases, the operator has all the data for calculating the illuminating value of the gas. For this purpose a known volume—about a cubic inch—of the original gas is introduced into the explosion eudiometer, mixed with about five times its bulk of oxygen, the electric spark passed, and the amount of carbonic acid generated by the explosion ascertained, as before directed. If the percentage of hydrocarbons absorbed by anhydrous sulphuric acid be denoted by A; the volume of carbonic acid generated by one hundred volumes of the original gas, by B; the carbonic acid formed by the combustion of the non-luminous constituents remaining after the absorption of hydrocarbons from the above quantity of original gas, by C; and the volume of carbonic acid generated by the combustion of the luminiferous compounds—hydrocarbons—by x , one has the following equation:—

$$x = C - B;$$

and, therefore, the amount of carbonic acid generated by one volume of the hydrocarbons is represented by

$$\frac{C - B}{A}.$$

But, as one volume of carbon vapor gives rise to a similar quantity of carbonic acid, this formula also expresses the amount of the former in one volume of the illuminating constituents. For the purpose of comparison, however, it is more convenient to represent

the value of these hydrocarbons in their equivalent volume of olefant gas, one volume of which contains two volumes of carbon vapor; for this purpose the last expression need only be changed to

$$\frac{C - B}{2 A}$$

Thus, if a sample of gas contain ten per cent. of hydrocarbons, of which one volume contains three of carbon vapor, the quantity of olefant gas to which this ten per cent. is equivalent will be fifteen.

The application of this method furnishes an exact chemical standard of comparison for the illuminating value of all descriptions of gas; and by a comparison of the arbitrary numbers thus obtained, with the practical results yielded by the same gases when tested by the photometer, much valuable and useful information is gained.

Estimation of the Specific Gravity of Gas.—Although the mere determination of the specific gravity of gases is of very little use as a test of their commercial value—unless the gas is to be used for aeronautic purposes—yet, as it is still much employed by gas engineers, and as such an estimation is occasionally useful for controlling the results of chemical analysis, a method by which such a determination may be made is here subjoined.

The specific gravity of gases should be taken in a room where there is no fire, and where the temperature is liable to little variation during the time occupied in the operations. The following apparatus is necessary: First, a thin glass globe, capable of holding at least two hundred cubic inches, and furnished with a brass cap and stopcock, so accurately fitted as to prevent all ingress of air when the globe is exhausted; secondly, a small exhausting syringe or air-pump, to which the globe can be screwed air-tight; thirdly, a balance capable of weighing to one-fiftieth of a grain, when loaded with a quarter of a pound in each pan; fourthly, a glass tube, eighteen inches long, and half an inch in diameter, filled with fragments of fused chloride of calcium, and closed at each end with a perforated cork, through which passes a glass tube, of such dimensions as to admit of adaptation by means of caoutchouc tubing at one end, to the exit pipe of a small gas-holder, and at the other, to the stopcock of the glass globe.

The process consists in ascertaining the weight of equal volumes of atmospheric air, and of the gas under examination, at the same temperature and pressure. This is accomplished by first exhausting the globe by means of the syringe or air-pump, and then accurately ascertaining its weight, care being taken to allow time for the globe to assume the same temperature as that of the air surrounding the balance. The globe should then be connected with one extremity of the chloride of calcium tube, by means of a piece of vulcanized caoutchouc tube, and the stopcock being then very slightly opened, the air passing through the chloride of calcium, and thus being thoroughly deprived of moisture, should be allowed slowly to fill the globe. The latter being detached from the desiccating tube, is replaced in the balance, where it should remain undisturbed for at least

five minutes, when the stopcock is opened for a moment to equalize the pressure within and without, and the weight then accurately determined. The difference between the two determinations gives the weight of the air enclosed in the globe. The exsiccating tube should now be attached to the exit pipe of the gas-holder, and a stream of gas allowed to rush through it, until every trace of air has been expelled from the interstices of the chloride of calcium; the globe, again exhausted, is then to be attached to the other extremity of this tube, and the stopcock being slightly opened, as before, the gas, perfectly dried in traversing the fragments of chloride of calcium, is permitted slowly to fill the globe, which should, whilst still attached to the drying tube, be allowed to stand undisturbed for a few minutes near the balance, before the stopcock is finally closed and detached from the drying tube. The weight of the globe thus filled with gas is ascertained, and that of the exhausted globe being subtracted from it, the difference indicates the weight of the gas. The weight of equal volumes of gas and atmospheric air at the same temperature and pressure having now been ascertained, it only remains to divide the former by the latter to know the specific gravity of the gas. Thus, suppose the weight of the exhausted globe to be 2000 grains; that of the globe filled with dry air 2060, and with exsiccated gas 2040 grains; the weight of the volume of air equal to the contents of the globe would be sixty, and that of the same volume of gas forty grains; hence, $40 \div 60 = .6666$, the specific gravity of gas, air being taken as unity.

Unless a number of specific gravities are determined at the same time, it is indispensably necessary to ascertain the weight of the air contained in the globe previous to each determination. Care should be taken that the temperature of the room in which the balance is placed does not vary more than about one degree between the several weighings of the globe, as otherwise a considerable error will be introduced into the experiments. The globe should also be protected, as much as possible, from the heat radiating from the body of the operator during the several weighings.—*Clegg.*

Much time and space might be occupied in discussing the merits of the several apparatus to be employed in the analysis of gases, but this seems to the Editor to be quite unnecessary. The best plan will be to place before the reader the improved apparatus of FRANKLAND and WARD, which resembles that of REGNAULT and REISET in mechanical arrangement, although it differs entirely in the mode adopted for the measurement of the gaseous volumes.

The instrument, which is represented by the accompanying figure, consists of the tripod, A, furnished with the usual levelling screws, and carrying the vertical pillar, B B, to which is attached, on the one side, the movable gutta-percha mercury trough, C, with its rack and pinion, *a a*, and on the other the glass cylinder, D D, with its contents. This cylinder is thirty-six inches long, and four inches internal diameter; its lower extremity is firmly cemented into an iron collar, *c*, the under surface of which can be screwed perfectly watertight upon the bracket plate, *d*, by the interposition of

a vulcanized caoutchouc ring. The circular iron plate, *d*, is perforated with three apertures, into which the caps, *eee*, are screwed, and which communicate below the plate with the T-piece, *E E*. This latter is furnished with a double-way cock, *f*, and a single-way cock, *g*, by means of which the tubes cemented into the sockets, *eee*, can be made to communicate with each other, or with the exit-pipe, *h*, at pleasure.

F G H are three glass tubes, which are firmly cemented into the caps, *eee*. *F* and *H*, which are only slightly shorter than the glass cylinder, are each from 15^{mm} to 20^{mm} internal diameter, and are selected of as nearly the same bore as possible, to avoid a difference of capillary action. The tube, *G*, is somewhat wider, and

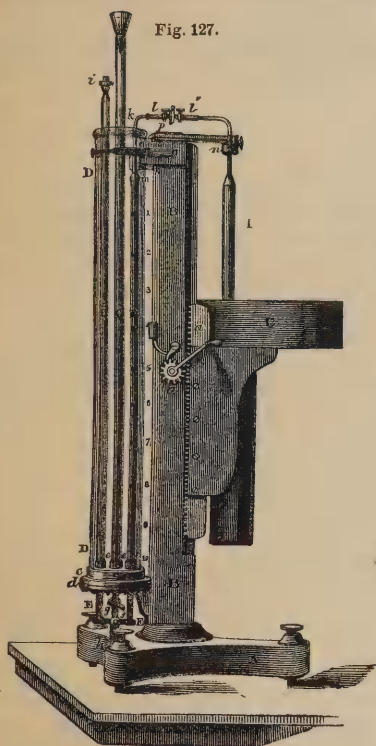


Fig. 127.

may be continued to any convenient height above the cylinder. *H* is accurately graduated with a millimetre scale, and is furnished at top with a small funnel, *i*, into the neck of which a glass stopper, about 2^{mm} in diameter, is carefully ground. The tube, *F*, terminates at its upper extremity in the capillary tube, *k*, which is carefully cemented into the small steel stopcock, *l*. *F* has also fused into it at *m* two platinum wires for the passage of the electric spark. After this tube has been firmly cemented into the cap, *e*, its internal volume is accurately divided into ten perfectly equal parts, which is effected without difficulty by first filling it with mercury from the supply-tube, *G*, up to its junction with the capillary attachment, and then allowing the mercury to run off through the nozzle, *h*, until the highest point of its convex surface stands at the division ten, previously made so as exactly to coincide with the zero of the millimetre scale on *H*; the weight of the mercury thus run off is carefully determined, and the tube is again filled

as before, and divided into ten equal parts, by allowing the mercury to run off in successive tenths of the entire weight, and marking the height of the convexity after each abstraction of metal. By using the proper precautions with regard to temperature, *et cetera*, an exceedingly accurate calibration can in this way be accomplished.

The absorption tube, *I*, is supported by the clamp, *n*, and connected with the capillary tube, *k*, by the stopcock and junction-piece, *l'p*.

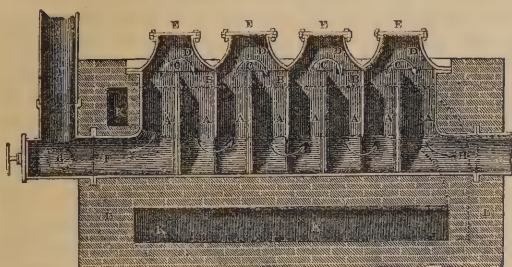
When the instrument is thus far complete, it is requisite to ascertain the height of each of the nine upper divisions on the tube above the lowest or tenth division. This is very accurately effected in a few minutes, by carefully levelling the instrument, filling the tube, *G*, with mercury, opening the cock, *l*, and the stoppered funnel, *i*, and placing the cock, *f*, in such a position as to cause the tubes, *F H*, to communicate with the supply-tube, *G*. On now slightly turning the cock, *g*, the mercury will slowly rise in each of the tubes, *F* and *H*; when its convex surface exactly coincides with the ninth division on *F*, the influx of metal is stopped, and its height in *H* accurately observed; as the tenth division on *F* corresponds with the zero of the scale upon *H*, it is obvious that the number thus read off is the height of the ninth division above that zero point. A similar observation for each of the other divisions upon *F* completes the instrument.

Before using the apparatus, the large cylinder, *DD*, is filled with water, and the internal walls of the tubes, *F* and *H*, are, once for all, moistened with distilled water, by the introduction of a few drops into each, through the stopcock, *l*, and the stoppered funnel, *i*. The three tubes being then placed in communication with each other, mercury is poured into *G*, until it rises into the cup, *z*, the stopper of which is then firmly closed. When the mercury begins to flow from *l*, that cock is also shut. The tubes *F* and *H* are now apparently filled with mercury, but a minute and imperceptible film of air still exists between the metal and glass; this is effectually got rid of by connecting *F* and *H* with the exit-tube, *h*, and permitting the mercury to flow out until a vacuum of several inches in length has been produced in both tubes. On allowing the instrument to remain thus for an hour, the whole of the film of air above-mentioned will diffuse itself into the vacuum, and will become visible as a minute bubble in each tube, on allowing the vacuum to be filled up from the supply-tube, *G*. These bubbles are, of course, easily expelled, on momentarily opening the cock, *l*, and stopper, *i*, whilst *G* is full of mercury. The absorption-tube, *I*, being then filled with quicksilver, and attached to *l* by the screw clamp, the instrument is ready for use.

In localities where a constant supply of water from street mains can be had, the temperature of the water in the cylinder, *DD*, can be maintained perfectly constant by allowing a continuous stream, direct from the main, to flow into the bottom of the cylinder, and make its exit near the top. By this arrangement it has been proved, in an extensive series of experiments, that the temperature of a cylinder supplied from the Manchester high-pressure mains varies so very little in twelve hours, that it scarcely requires correction in the most delicate experiments,

while those which are movable are open at the top, so that the gas can be made to pass alternately up and down the several chambers, *over* the *loose*, and *under* the *fixed* diaphragms. Open covers to the compartments are indicated at D, and are closed by lids or

Fig. 130.



plates, E. To one end of the apparatus is attached a D-shaped flanged pipe, F, into which the pipes leading from the retorts are fixed, either vertically by the pipe I, or horizontally by the mouth-piece G, as may be required. The outlet pipe of the apparatus, by the hydraulic main, and thence to the gas-holder, is seen at H. K K are flues, by means of which heat is applied, and L L designates the brickwork in which the whole apparatus is set.

On the gas passing through the heated prepared charcoal, it is freed from a large amount of foreign compounds, partly by chemical, partly by mechanical action, and deposits a residuum, which possesses the properties of, and may be used as, a pigment. The gas thus purified has a much greater illuminating power than that submitted to the ordinary process of depuration.

The claim of the patentee is—1. For the separation of the impurities from coal-gas, by passing it through charcoal saturated with lime-water, and heated as described; and, 2. For the formation of a residuum, or deposit, derived from the gas, which may be used as a pigment, or color.

For the removal of the ammonia and the sulphide of hydrogen by one and the same process, a new method of purification has been adopted, and is one well worthy of confidence. The screens of the purifiers are covered with a mixture of carbonate of lime and sulphate of iron, which, subsequently exposed to the air, become carbonate of iron and sulphate of lime; and by the absorption of oxygen, the carbonate of iron leaves its carbon, and becomes partly sesquioxide of iron. The gas, streaming through this mixture—sesquioxide of iron and sulphate of lime—gives up its sulphide of hydrogen to the oxide of iron, forming sulphide of iron and water, while the carbonate of ammonia—contained also in the impure gas—decomposing the lime-salt, forms sulphate of ammonia and carbonate of lime.

When the purification is completed, and the mixture has done its work, it is exposed to the air, and the sulphide of iron absorbing oxygen, is converted into a basic sulphate of iron. Hence, the same mixture as at first is obtained, namely, carbonate of iron and sulphate of lime, with the addition of sulphate of ammonia, which may be washed out and preserved, while the

residue is employed over and over again. By this elegant process, the noxious sulphur compounds are utilized in the fabrication of sulphate of ammonia, and the mixture seems never weary of performing its duty; hence, not only is the februation performed at one process, but the noxious ingredients are converted into compounds of much value.

Another method of removing ammonia may be noticed: it consists in spreading on the screens superphosphate of lime, consisting of bones decomposed by sulphuric acid; the addition of ammonia to this, makes it a powerful and excellent manure.—*Clegg.*

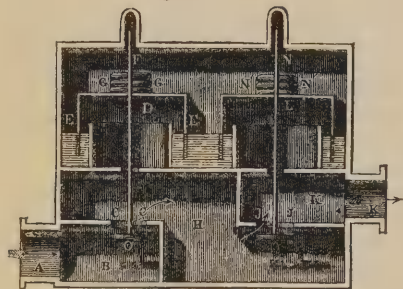
CHISHOLM'S METHOD.—CHISHOLM'S method for the purification of gas consists in combining or mixing together the peculiar red earthy or ochry-looking substances found mingled with peat and the subsoil of peat, with hydrate of lime, or the mixed hydrates of lime and magnesia obtained from magnesian limestones, and their combination or mixture. He then introduces into the vessel, known to gas-makers as the dry-gas purifier, this mixture, and the foul gas passes through it until it is rendered pure; such purity being ascertained by the application of the tests usually employed by makers of gas for that purpose. The red earthy or ochry substance above alluded to, is composed chiefly of the oxides and salts of iron and manganese, and it is principally to these metallic matters that the purifying agency of the compounds is due; therefore, the greater the quantity of these oxides this earthy matter contains, the better is it adapted to the purpose for which the patentee uses it; and although the exact proportion of lime to be added is not material, yet the greater the amount of metallic matters there may be contained in the red or ochry earthy matters aforesaid, the more lime, or lime and magnesia, must be used; for every three parts by weight of metallic matters in this earthy matter, one part of lime by weight is preferred. Instead of the above red earthy matter, there are sometimes employed in the same way and proportion, the fine red sandy gravel so general around London in the neighborhood of chalk beds, or the red clay which is so common around Rugeley and other districts, or the phosphate or subphosphate of iron, known by these names to all geologists, and common in many boggy districts. All these, or any of them, he uses precisely in the way or combination described with respect to red earthy peat matters already alluded to; and he adds, that when these substances or mixtures, or any of them, have ceased to purify the gas from sulphide of hydrogen and other impurities, their powers may be again in part or altogether renewed or restored by passing or forcing through them a current of air, or by merely exposing them to the atmosphere, after which they may be used over and over again, or many times in succession.

POOLE'S PATENT.—POOLE took out a patent for improvements in regulating the flow and pressure of gas and other fluids. He remarks, that it is often desirable to deliver aeriform fluids at a certain uniform pressure, and various means have before been resorted to for effecting this object; accordingly his invention consists of combining the use of two or more governors or regulators, which, acting independently and in succession, are alleged to accomplish the desired object more completely

than has been done heretofore. The description of governors or regulators which are preferred for this purpose, are those where inverted vessels are used, working in quicksilver or other fluid, and connected to the induction valves. Supposing the apparatus to be arranged for regulating the supply of gas or other aeriform fluid, the main or supply pipe, where the regulation is to take place, is arranged to communicate in succession with two or more chambers, each having a governor or regulator, and so that no gas can pass from the main or supply-pipe to the furthestmost chamber, without having passed through, and been regulated more or less perfectly by, the previous regulators or governors; by which means the gas, supposing it to come up to the first governor or regulator at a pressure exceeding that at which it is desired to deliver it at, will act on the governor, and tends to close the valve, and thereby restrict the passage of the gas into the first chamber; the gas then passes from the first chamber or governor into the second, and, if it be still at an excessive pressure, it will be again retarded in its passage, and so on, according to the number of governors or regulators combined and caused to act in succession.

Fig. 131 shows a vertical section of an apparatus combined according to this patent, having two regulators or governors acting in succession; but other apparatus may be made with more than two, to act in succession in a similar manner. The form of regulator or governor preferred, is that where an inverted vessel is employed fixed to the valve, the action of which is to be regulated; but the form of the parts may be

Fig. 131.



varied, so long as two or more regulators or governors are combined to act in succession. No claim, however, is made to the governors or regulators separately, when two or more are not combined to act on and regulate the same supply. A is the inlet for the gas or aeriform fluid; B is a chamber, the opening, C C, out of which is capable of being more or less closed by the valve, O, which is on the stem, F, to which the inverted vessel D is fixed, the edges of which dip into mercury or other suitable fluid at E E; there being weights, G G, on the vessel D, according to the degree of pressure it is desired to regulate or bring the supply of gas or other aeriform fluid to, when it passes away at the outlet, K. The gas or other aeriform fluid coming into the chamber, B—above the desired pressure—will, to some extent, be regulated by its acting on the first regulator by raising the vessel, D, which will also raise the valve, O, in the compartment, B,

towards the opening, C C, till the quantity of the gas allowed to pass into the chamber, H, of the apparatus will be brought to nearly the desired pressure. The gas or aeriform fluid in the chamber, H, passes through the opening, J J, into the compartment, K, and acts on the inverted vessel, L, which is affixed to the stem, N, by which the valve, O, in the chamber, H, will be more or less closed, according as the pressure of the gas or aeriform fluid in the chamber, H, is more or less in excess of the pressure at which it is desired the gas or aeriform fluid should go off at the outlet, K. It would be well to state, that usually the same amount of pressure or weight, N N, is applied to the inverted vessel L, as there is by the weights, G G, to the vessel D, such being believed to be the best mode of working when using such apparatus. The vessel L, like the vessel D, dips into mercury or other liquid at its lower edges. By using a succession of regulators or governors, any want of correctness of the regulation of the first will be compensated for by the succeeding ones.

MICHAEL'S PATENT.—GEORGE MICHAEL, who has also taken out a patent for improvement in the manufacture of gas, remarks in his specification, that in the present state of progress in the different arts which co-operate together in the construction of gas-works, he thinks the power of the manufacturer may be increased, and the gas produced more economically than by the present mode, without employing large numbers of fine strong men to destroy their health, by charging red-hot retorts, through very narrow apertures, with small quantities of coal, and to perspire during twelve hours in front of an intolerably hot radiating surface. He proposes to substitute for the sinews of these men the action of steam-power; and, with this intention, he amplifies considerably the usual dimensions of a retort, in order to obtain in one distilling apparatus as much, if not more, heated surface as is now to be found in a whole bed of sixteen retorts twenty feet long; this he does for the purpose of having the floors of huge retorts all upon one and the same level, in order that the same steam apparatus used for charging and drawing one of them may perform the same operation for the others, by simply moving such apparatus upon rails in front of the retorts.

The dimensions in the clear which he prefers giving to these huge retorts are thirty feet in length, two feet in height, and about nine feet in width, the top being parallel to the floor, so that the transverse section of the interior of the retorts represents an elongated rectangular figure. These retorts are built with fire-bricks; but he observes, that if he only cemented the bricks together with fire-clay, as is usually done, the working of the retort would depend on the regular action of the exhaustor—that is to say, that should the exhaustor cease to work, the gas would pass through the joints of the bricks, an occurrence which would place a gas-work in jeopardy. To meet this great difficulty, the bricks of which the retort is made are laid in a vitreous cement, which, when subjected to the heat necessary for making gas from coal, forms a glaze, and renders the retort impermeable to gas. The best way to prepare this compound is, to pound and carefully mix together a double, treble, or a more compound fusible

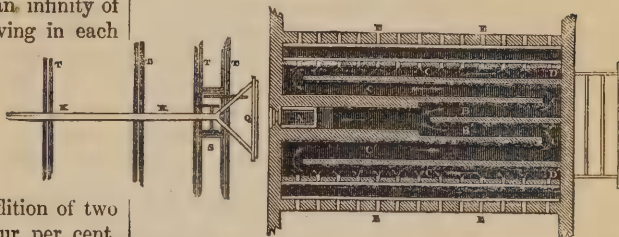
silicate, in which silica, lime, potassa, soda, magnesia, oxide of iron, oxide of manganese, or bichlorate of soda, may be usefully employed; but should local circumstances not admit of this, the good effect produced by potassa, soda, or better, bichlorate of soda, in the composition of the cement intended to become vitrified, must not be lost sight of. It is evident that this cement must be formed into a paste with a small quantity of water, so as to be easily used by the bricklayer.

It will be obvious to all practically acquainted with the manufacture of porcelain, earthenware, or glass, that the idea of setting the bricks of the retorts in a vitreous cement can be carried out in an infinity of different ways, according to localities, giving in each place the preference to the cheapest of the articles here above noticed. For instance, in London, and in many other towns, recourse can at once be had to a compound silicate, which is a refuse from the glass paper manufactories—namely, the glass dust—to which an addition of two per cent. or more of manganese, and four per cent. or more of borax, can be made to facilitate the fusion of the aforesaid glass dust. In other places it may be cheaper to employ potassa or soda as a cement between the bricks, the silica and alumina of the fire-bricks, when heated, combining with the alkali and forming a vitreous glazing cement, and so on in a variety of other ways.

MICHAEL'S huge retort is furnished at each end with a cast-iron mouth-piece plate, contrived for receiving a luted lid, which is firmly secured by cotters. This retort is provided with two or more orifices at the top, by which the charge of coal is introduced by tilting waggons running on proper railways; the coal so introduced into the retort is then spread equally over the bottom by the aid of a rake, which forms the head of a rack worked by a steam-engine. The charge of coal preferred to work off in such a large retort is six tons, forming a layer of ten inches deep. When the charge is worked off, the mouth-pieces are to be opened by unfastening and hoisting the lids, and the charge of coke is pushed out in one cake by the assistance of the steam-rack, the head or rake of which being for this purpose turned upside down, so as to act with its head and not with its teeth. Such coke, if it be desired, may be received in an oven capable of being closed, and there treated with this intention by the admission of air and an injection of steam, leaving one opening for abducting the products. One great peculiarity in the construction of these huge retorts is, that they are well isolated from contact with any of those parts of the construction which are liable to cool, either by radiation or by contact with the soil; this isolation is obtained by preserving round the retorts a circumambient empty space, in which the products of the combustion in the fire-places are caused to decant their heat at different stages in their perambulation, before finally passing under the immediate foundation of the retort on their way to the main flue, which is constructed outside the foundations of the retorts, or nearly so.

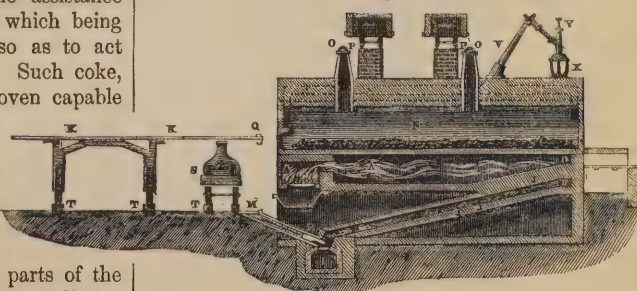
The patentee then proceeds with the technical description of the construction of a retort, such as that referred to in the drawings—Figs. 132 and 133. The products of combustion, on leaving the fireplace, divide into two parts, at B and B'; one follows the course, B, C C C, till arriving at the vertical flue, D, through which it descends into the chamber, F, which is common to these, and to those products of the combustion which have followed the course, B', C' C' C', D'. During such course, the products of combustion emit part of their

Fig. 132.



heat from the orifices, E E E E, through which they ascend round the retort, so that in reality, by this phenomenon of decantation, there are formed two inverse currents on the sides of the retort, the hottest ascending, which, after having parted with a portion of its heat, will become descending; and the constant repetition of these effects will have for result the keeping of the sides and top of the retort at the same temperature as its floor or bottom. The drawings show distinctly how the under floor, the sides, and the top of the retort are constructed, for allowing this phenomenon of decantation of heat to produce its full effect everywhere round the retort. Particular stress is laid on this system of construction, which offers every possible facility to the working out of that law of nature, according to which the hotter parts of the gaseous products have a tendency to rise, and the colder to descend. It is according to the same principle that the products of combustion left in the chamber, F, are caused to descend along an inclined

Fig. 133.



plane in the six flues, G G, before entering the lower chamber, H, which delivers them through one aperture to the horizontal chimney, I. The orifice last spoken of is commanded by the damper, R, which regulates the draught of the fireplace. This damper is worked in an inclined flue, the entrance of which is to be covered by the tile, M, in front of the retort. The six inclined flues leading to the

chamber, H, are connected together sideways by the openings, J J.

The under floor of the retort is composed of three parts, differing one from another in their construction—that is to say, the floor of the retort, which is formed by bricks on edge, is separated from the fireplace by an arch of nine inches thickness, from the subsequent main flue by an arch of four inches and a half, and from all the divided flues by flat bricks two inches and a half thick, and eight inches long, laid in six parallel rows, the joints of such rows corresponding to the centre line of five rows of pillars.

Charging and Drawing of Retorts.—The interior of retort, N, receives the charge of coal through the openings, O O, which are shut by luted caps, P P, movable at will; the coal is brought to the retort-house in trucks, so arranged that when tilting their contents fall at once into a movable funnel placed for the time being in the openings, O; these dispositions are required for charging the retort quickly; and, when well adapted, as indicated in the accompanying drawings, the retort can receive its charge of six tons of coal in less than six minutes, provided that the coal be spread at the rate it falls down by proper mechanical power. The apparatus to which preference is given for producing this effect is composed of a cast-iron rake, Q, which forms the head of a rack sliding in a cast-iron frame, K K; this receives its motion from a steam-engine, S, fitted to the frame; the motion is transmitted by the ordinary mechanical contrivances. In order that the same steam apparatus may be rendered serviceable for the working of twenty-four retorts, or more, the frame here spoken of rests upon a system of wheels, T T, rolling upon rails parallel to the front of the retorts. The steam is adducted by a pipe which runs in a casement surrounded by sand or other non-conductor, the full length of the beds of retorts; this pipe is provided with small outlet branches and cocks between each two retorts, for the purpose of delivering the steam to the engine of the steam-power rake, through a movable connecting pipe. When the gas is worked off, and the charge is ready to be withdrawn, the lids of the retorts are moved, and the coke is pushed out of the retort in one lump by the action of the steam-rake, the head of which—namely, the rake—is for that purpose turned upside down by swivelling it round a collar. By this contrivance the teeth of the rake are spared, and its head, which is shaped like a strong rib, performs the work of clearing the retort. It is well to observe, that, in order to prevent the teeth or the rib of the rake wearing out the brickwork, they are kept at half an inch distance from the floor or bottom of the retort by friction rollers, suitably placed for bearing the weight of the apparatus. There are also friction rollers fitted on the sides of the rake for guiding its movement along the sides of the retort.

When the retort is at work, the gas passes off through the ascension pipe, V, and enters the hydraulic main, X, through the plunger, Y, which is suspended to a screw, and can be moved up and down for the purpose of transforming at pleasure the hydraulic main into a dry main by suppressing the dip, which contrivance is very valuable for relieving the retorts from all pressure.

Mr. ALEXANDER CROLL has taken out a patent for freeing gas from its ammonia, and a part of the sulphide of hydrogen, producing at the same time chloride of ammonium. He introduces a solution of the chloride of zinc into a vessel, upon the same construction as a wet lime purifier; on admitting the gas, double decomposition ensues; an insoluble sulphide of zinc, and a solution of chloride of ammonium, are produced. The gas must be further purified with lime in the usual way.

The specifications of a great number of other patents for alleged improvements in gas-making might be given; but as they are not of much interest, and probably of too little usefulness ever to be adopted, the Editor deems it unnecessary further to allude to them, which would only exhaust the patience of the reader with a series of dry details. In conclusion, the Editor has to express his thanks for the courtesy and information rendered to him by Mr. SAMUEL EDWARDS, formerly of the Liverpool Gas Works.

GELATIN.—*Gélatine*, French; *Gallerte*, German; *Gelatin*, Latin.—Skin, the tissue of bones, cartilages, and many analogous animal tissues, possess the well-known property of yielding to boiling water a substance capable of becoming jellied by the cooling of the menstruum. This was for a long time regarded as a peculiar organic principle, and was known by the name of *gelatin*; but, latterly, MULLER found it to consist of gelatin, properly so called, and of another particular product, which he denominated *chondrin*. It is generally assumed, though not perhaps on very sufficient grounds, as BRANDE remarks, that the gelatinous textures do not contain ready-formed gelatin, that that substance does not, in fact, pre-exist in the animal kingdom, but that it is generated by the action of hot water upon the membranous tissues.

The historical information connected with this subject is very limited. *Ichthyocolla*—the Latin synonym for *isinglass*, derived from two Greek words, signifying *the glue of fish*—is repeatedly mentioned by DIOSCORIDES and PLINY; the latter writer attributes the discovery of it to DÆDALUS.

PREPARATION.—Gelatin is obtained by subjecting fragments of hoofs, horns, hides, bones, the feet of calves, cows, sheep, *et cetera*, to the action of boiling water or steam. The resulting menstruum is skimmed and strained, so as to effect the removal of floating fatty bodies, and of any deposit which might be formed; then allowed to gelatinize by spontaneous decrease of its temperature.

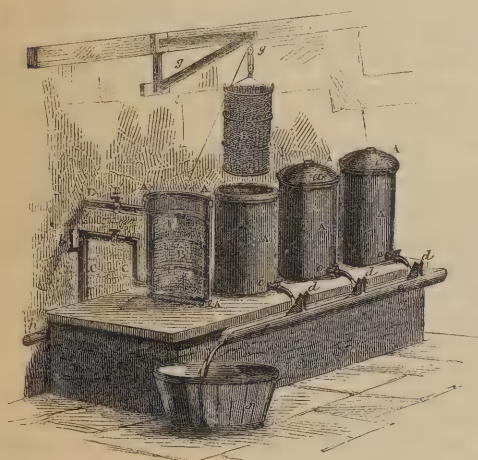
It may also be procured from shavings of hartshorn, the product being tasteless, and having the advantage of being entirely free from fatty and oleaginous matters.

When gelatin is used as an article of food, the material should be of the best description, and quite fresh. Bones intended for this purpose ought to be well preserved in brine, or to be dried in a stove. Their gelatin is best extracted by the combined action of steam and a current of water percolating the fragments. Cast-iron cylinders are generally used in this part of the process. A vertical section of one of these is represented in Fig. 134, where A A A show the exterior cylinders, containing a basket or cage, B, filled with

bruised bones; *c c* the pipe conveying steam to the interior; *d*, a pipe for the introduction of water, provided with a stopcock, *E*, for regulating the quantity of the supply, and to which is accurately fitted a tube of tinsplate, *F*, closed at the inside end, and perforated on its under side with small holes, so as to allow of the percolation of the water: this tube is inserted in its proper place after the bone-cage has been introduced.

The cylinders, represented by *A A A A*, are elevated about twenty inches from the floor, and secured in their respective positions by screws; *a a* are the lids, in which are tubulures or valves; a thermometer is placed at *b*; the stopcocks, for withdrawing the gelatinous menstruum, are shown at *c c*; *d d* are small

Fig. 134.



gutters of tinsplate; *e e*, the main conduit of discharge into the cistern, *f*; *g g*, blocks and tackle for raising the bone-basket; *h*, the main steam-pipe.

When a pure jelly is required, the cylinder, after being charged with bones, is wrapped in a strong, coarse woollen material; as soon as the fatty matters cease to flow, the stopcock, *E*, which admits the cold water, is closed, as also those at the bottom of the cylinders, *c c c*, which are to be opened only at the end of every hour, but to such an extent only as to let the gelatinous solution run out, without allowing any steam to escape. The menstruum is subsequently strained, and poured into shallow vessels of tinsplate, or upon slabs of marble, slate, or compact and polished stone, to solidify. It is finally cut into shreds, *et cetera*, as may be thought proper. This is, however, only one method of manufacturing gelatin; and others, for which patents have been obtained, will be given in a subsequent part of the present article.

PROPERTIES.—When *pure*, gelatin is colorless, transparent, hard, and endued with great but variable coherence, according to the kind of tissue from which it is obtained. It is inodorous and insipid. Its specific gravity is greater than that of water. It has a neutral reaction. When heated, it softens, diffuses a peculiar odor, enters into a state of semi-fusion, bends, tumefies, and then exhales the odor of burnt horn. In the air it takes fire with difficulty, smokes, flames only some

instants, and leaves a bulky charcoal difficult to incinerate, the ashes of which consist principally of phosphate of lime. By dry distillation, gelatin gives much carbonate of ammonia, and yields in general the ordinary products of the distillation of nitrogenized substances.

In cold water it softens, intumescs, becomes opaque, but does not dissolve. A liquid which contains one-hundredth part of its weight of gelatin becomes viscous on cooling, but when it has only the one-hundred-and-fiftieth, the menstruum remains fluid. These phenomena, however, vary with the temperature. In winter the jelly is much more readily formed than in summer. If the solution of the gelatin is effected too quickly, the jelly obtained is less firm. Moreover, the result varies, not only in gelatin obtained from different tissues, but also with that obtained from the same tissue taken from animals of various ages.

It differs also according to the care which has been taken in the preparation of the gelatin; when its solution has been exposed to a temperature higher than 212°; and when it begins to sour, it loses in part the property of becoming jellied. The same happens when its solution is heated and cooled several times. If gelatin be left a long time in the open air, at a temperature of 60° to 68°, it becomes ammoniacal, and putrefies, diffusing a very fetid smell. The addition of a certain quantity of acetic acid prevents the putrefaction without destroying its adhesive power.

Gelatin is not sensibly soluble in alcohol, and when the latter is poured into its solution, lukewarm and somewhat concentrated, it coagulates in a white coherent, elastic, and slightly fibrous mass, which adheres to the vessel with much force. Like dry gelatin, it softens in cold water without dissolving in it. On evaporating the alcohol, there remains a thin transparent coating, very soluble in cold water, but which is not capable of being jellied. Common gelatin, in a dry state, treated with alcohol, gives up to it a certain quantity of fatty matter, and some substances of an extractive nature. It is perfectly insoluble in ether and in oils, both fat and volatile.

Gelatin, when in the jellied state, and treated with alcohol, undergoes a dehydration, under the influence of which it contracts much. It was by this means that GONNOR succeeded in remarkably reducing the size of a print obtained in a very hydrated film of gelatin, and transferring it, so reduced, to stone, from which he obtained a new impression, quite similar to the first, but more or less diminished.

By taking these prints, on the contrary, with gelatin very little hydrated, and afterwards steeping them in water, a dilatation of the plate is obtained, which enlarges the figures with the same regularity.

THENARD observed, that if chlorine be passed into a somewhat concentrated solution of gelatin, each bubble is surrounded with a white elastic matter, which follows it to the surface of the liquid, and which, at the moment when the bubble bursts, leaves a white glutinous matter, capable of taking a chatoyant appearance by malaxation. Only a small quantity of chlorine is required to precipitate all the gelatin, and, when this body is in excess, the deposit becomes of a light yellow, the liquor containing free

hydrochloric acid, and only a very small quantity of animal matter remaining in solution. Gelatin, combined with chlorine, is insoluble in water and alcohol; it reacts as an acid, a property of which it may be deprived by macerating and washing it with tepid water. It exhales the odor of chlorous acid, which it evolves when heated at 212° , a brownish residue remaining. MULDER states that it consists of one equivalent of gelatin $= C_{13}H_{10}O_6N_2 + Cl_2O_3$. When acted upon by ammonia, nitrogen is disengaged, chloride of ammonium formed, and unaltered gelatin separated. An opalescent, gelatinous body is simultaneously produced, the composition of which is represented by the last-mentioned chemist as three equivalents of gelatin $= 3(C_{13}H_{10}O_6N_2) + 2(Cl_2O_3)$. MULDER has also examined two additional chlorous compounds of gelatin, the first being $4(C_{13}H_{10}O_6N_2) + Cl_2O_3$; the other, $5(C_{13}H_{10}O_6N_2) + 2(Cl_2O_3)$. Much doubt exists with regard to the correctness of these results. Iodine and bromine do not give rise to any synonymous combinations.

Concentrated sulphuric acid produces a very remarkable alteration in gelatin, converting it into *sugar of gelatin*, *leucin*, *et cetera*, which will be subsequently noticed.

Nitric acid, aided by heat, transforms gelatin into oxalic acid.

Concentrated acetic acid renders softened gelatin transparent, and then dissolves it; the solution does not become viscid, but preserves its adhesive property. Diluted acids, on the other hand, do not prevent gelatin giving a coagulum on cooling.

The alkalis when dilute, and even concentrated ammonia, do not deprive it of the property of becoming jellied, but render the solution turbid by causing a precipitate of phosphate of lime. Softened gelatin dissolves at the ordinary temperature in concentrated aqua potassæ, leaving a white residuum, which is composed principally of phosphate of lime. If the solution be exactly saturated with acetic acid, and evaporated, it does not become glutinous; the gelatin, altered and combined with acetate of potassa which remains after the evaporation, is soluble in alcohol. Sulphuric acid precipitates from this menstruum sulphate of potassa, combined with modified gelatin; and if the precipitate be dissolved in water, and the liquor left to spontaneous evaporation, it crystallizes to the last drop. The aqueous solution of the salt is abundantly precipitated by the infusion of nut-gall, by chloride of mercury, and by the sesquisulphate of iron. Hydrate of lime does not alter the solution of gelatin, which dissolves much of it. The same may be said of phosphate of lime; hence the reason why so large a quantity of this salt occurs in the glue of commerce. No subsidence is occasioned in dissolved gelatin by the addition of neutral sesquisulphate of iron, until the menstruum has been boiled, when a flocculent reddish-yellow precipitate falls, consisting, according to MULDER, of three equivalents of gelatin combined with six equivalents of oxide of iron, and one of sulphuric acid. DUMAS states that gelatinous menstrea are not thrown down either by the neutral or basic acetate of lead, but, according to GMELIN, the latter causes the forma-

tion of a copious subsidence. If a gelatinous menstruum be gradually mixed with a solution of chloride of mercury—corrosive sublimate—a cloudiness is produced which quickly disappears. This effect continues till a certain quantity of the reagent has been added, when the gelatin is at once precipitated as a white, coherent, and very elastic coagulum. The behavior of gelatin with nitrate and subnitrate of mercury is synonymous. Protochloride of tin causes a brown flocculent subsidence, but the bichloride gives no reaction.

Silver and gold salts do not precipitate gelatin, but by the influence of solar light a portion of the metal is reduced. It is thrown down by sulphate of platinum in brown viscous flakes, which blacken on the filter, and are afterwards easily pulverized. E. DAVY regards this salt as an infallible test for the detection of gelatin, even in the presence of albumen, and in solutions so dilute as to be unaffected by tannic acid.

Tannic acid is a valuable and delicate test of the presence of gelatin. When added to a solution containing only one-five-thousandth part of gelatin, nebulosity is immediately apparent. When more concentrated gelatinous menstrea are treated with tincture or infusion of galls, a dense, white, caseous subsidence occurs, which, on desiccation, becomes brownish-yellow, agglutinates, and forms a hard, brittle mass, easily reduced to powder.

From the investigations of MULDER, it appears that several definite and permanent combinations of gelatin with tannic acid are capable of being formed. On commingling the pure solutions of these bodies, a neutral combination, containing one equivalent of gelatin, one of tannic acid, and two of water, is formed. According to DAVY, the compound of gelatin with oak-tannin consists of—

	Centesimally.
Gelatin,	54
Tannic acid,	46
	<hr/> 100

M. SCHIÉBEL, who obtained nearly the same results, says that one hundred parts of gelatin precipitated with a large excess of a solution of extract of oak-bark in nine parts of water, combined with 118.5 parts of tannic acid. When, on the contrary, he mixed a very dilute solution of extract of oak-bark with the solution of gelatin, without precipitating the whole of the latter, the deposit, which occupied a considerable time in subsiding, contained 59.25 per cent. of tannic acid. The gelatin was combined, in each of these cases, with different proportions of tannin, which are to each other as 1.0, 1.5, and 2.0.

Gelatin, says DUMAS, unites with various quantities of tannins derived from other sources, but never to a less extent than sixty per cent. when the precipitated menstruum contains tannin in excess.

It would sometimes be important, in researches relative to animal chemistry, to be able to separate tannin from gelatin, but this has not been effected. A dilute solution, either of caustic alkali or a carbonate, extracts much of the tannic acid, and leaves a gelatiniform, mucilaginous, swollen mass, which, with the aid of heat, dissolves in alkali like gelatin; but it is found in this case, that the solvent employed for

removing the tannic acid has also taken up a certain quantity of gelatin, and if the mass in question be digested with water, a little of the gelatin dissolves out, while the remainder is converted into that combination of gelatin and tannin which has been already mentioned as so slow in depositing.

COMPOSITION.—Ultimate analyses of gelatin have been made by numerous chemists, but with different and ill-agreeing results, the foremost among them being those of MULDER, SCHERER, and GOUDEVER: the formulæ proposed to represent its composition are, consequently, equally diverse. That, however, adopted by LÖWIG appears to approach nearer to the atomic combinations which have been examined, and to agree better with experiment than any other, and is adopted in the following tabulation:—

	Centesimally represented.				
	At. weight.	Theory.	Mulder.	Scherer.	Scherer. GoudEVER.
13 Eqs. Carbon,...	78	50.00	50.04	50.4	50.78
10 Eqs. Hydrogen, 10	6.41	6.47	6.9	7.15	6.72
5 Eqs. Oxygen,...	40	25.64	25.13	23.8	23.75
2 Eqs. Nitrogen,...	28	17.95	18.36	18.9	18.32
1 Eq. Gelatin,...	156	100.00	100.00	100.0	100.00

Sugar of gelatin, to which allusion has already been made, was discovered by M. BRACONNOT. This chemist triturated one part of pulverized gelatin with double its weight of concentrated sulphuric acid, and set the mixture aside for twenty-four hours. At the end of this time the color of the liquid was not deepened. He then added eight parts of water, and subjected the menstruum to ebullition for another twenty-four hours, keeping up the quantity of water. On diluting the fluid, saturating with carbonate of lime, filtering and evaporating, a sirup was produced, which, when allowed to remain quiescent for a month, deposited granular crystals strongly adherent to the bottom of the vessel. These were edulcorated with weak alcohol, and purified by repeated crystallization.

Sugar of gelatin possesses a marked saccharine taste, very nearly allied to that of grape sugar. It is soluble in water, but not in alcohol. An aqueous solution, if kept in admixture with yeast, exhibits no sign of fermentation. According to BOUSSINGAULT, the aqueous solution of gelatin sugar gives no precipitates with sulphate of copper, acetate of lead, or the nitrates of mercury and silver.

Nitric acid decomposes sugar of gelatin, giving rise to a peculiar compound, which BRACONNOT designated *nitrosaccharic acid*, but which it would be useless to describe here.

The composition of sugar of gelatin is as under:—

	Centesimally.		
	At. weight.	Theory.	Mulder.
8 Eqs. Carbon,	48	34.04	34.06
9 Eqs. Hydrogen,	9	6.38	6.49
7 Eqs. Oxygen,	56	39.72	39.61
2 Eqs. Nitrogen,	28	19.86	19.84
1 Eq. Crystallized } gelatin sugar, }	141	100.00	100.00

Leucin, previously mentioned as being one of the products of the decomposition of gelatin by sulphuric acid, has been shown by MULDER to be formed also during the putrefaction of casein.

Leucin has a pearly lustre. It is friable, tasteless, inodorous, and greasy to the touch, and sublimes before fusion at about 340°. It is soluble in about twenty-eight parts of water at 65°, and in six hundred and fifty-eight parts of alcohol, of specific gravity 0.828, at the same temperature. A saturated alcoholic solution becomes turbid on cooling. It is insoluble in ether, and is anhydrous, and neither acid nor alkaline.

Further, leucin, as BRANDE states, is soluble without decomposition in concentrated sulphuric and hydrochloric acids. Chlorine decomposes it, forming hydrochloric acid and other products, among which is a brown resinoid substance, and a red volatile fluid. It absorbs hydrochloric acid gas, forming with it a mono-atomic combination. Its composition, as determined by MULDER, is as follows:—

	Centesimally		
	At. weight.	Theory.	Mulder.
12 Eqs. Carbon,	72	55.39	55.53
12 Eqs. Hydrogen,	12	9.23	9.22
4 Eqs. Oxygen,	32	24.62	24.74
1 Eq. Nitrogen,	14	10.76	10.51
1 Eq. Leucin,	130	100.00	100.00

USES.—Gelatin is employed for making jellies and blanc-manges. Considered medicinally, it is emollient and demulcent, and for this end is dissolved in water or milk, and rendered palatable by the addition of acid and sugar. Latterly, it has come into considerable use in pharmacy for the formation of capsules intended to conceal the nauseous odor and taste of medicinal preparations enclosed in them. It has likewise been used for coating pills, and certainly offers advantages not to be derived from the now almost obsolete practice of covering them with gold leaf. In the laboratory it is employed as a test for tannic acid.

PATENTS.—Numerous patents have been taken out for the manufacture of gelatin. Several of these are of importance, and will be briefly noticed.

In 1839, a patent was granted to GEORGE NELSON for improvements in the preparation of gelatin. The products of the process are of two kinds, which the patentee denominates as gelatin of the first and second quality. The best sort is opaque, and is by preference made from cuttings of the hides of beasts or of the skins of calves. The inferior variety is procured from *glue-pieces*, freed from hair, wool, and fleshy and fatty matters. The *modus operandi* is essentially the same in both cases, and is as follows:—The cuttings being well washed are macerated in caustic alkali at a temperature of 60°, until they are partially softened. Ten days is the period named as required to effect this. They are then placed in close vessels, and permitted to remain until a thorough softening—ascertained by passing a fork through them—is effected. They are now washed in a revolving cylinder, through which a current of water passes; exposed in a well-closed chamber to the action of sulphurous acid; submitted to pressure to remove the adhering water; and subjected to the action of steam at about 150°, till they are, as far as possible, dissolved. The menstruum is then strained, and set aside at a temperature of 100° to 120°, for the impurities which may have remained to subside; then

poured upon slabs of slate or marble to the depth of about half an inch, and allowed to remain there till it has sufficiently solidified, when it is cut, and washed to remove all traces of acid. It is subsequently redissolved by means of a steam-bath at the temperature of 85°, and finally re-solidified, and exsiccated by exposure to dry air upon nets.

C. R. ROPER, for whom a patent was sealed in April, 1845, prepares gelatin from bones or ivory, broken into small pieces in a digester. To each hundred-weight of material is added six gallons of water, and the vessel being closed, steam is admitted at a pressure gradually raised to thirty-two pounds per square inch for three and a half hours, when the charge is withdrawn. If the bones were in a pulverulent state, it would be requisite that the gelatin should be pressed out from the residuum; but if they were merely broken into fragments, this would not be necessary. The product is now run into shallow tins or pans to solidify, and finally placed on nets to dry in the usual manner.

The specification also includes the flavoring of the gelatin with essences of lemon or almonds, for the preparation of jellies or blanc-manges.

In 1846, ARNEY took out a patent for the preparation of gelatin in powder, and free from water, so that it is not so liable to become mouldy, while it is reduced to such a state that it readily dissolves in water upon the application of heat. Ordinary gelatin is subjected in a stove-room to a temperature which ranges from 150° to 212°, and when the moisture is entirely dissipated, it is broken to pieces, and ground, in a mill of any ordinary kind, to a fine powder. The patentee claims, secondly, the application of gelatin in a powdered state, by means of a particular method of sweetening and flavoring, from which jellies may be prepared by dissolving it in water, and blanc-manges by infusing it in milk. He also applies his powdered gelatin, when mixed with farina or starch, or starch vegetal flour, and flavored with essence of meats, culinary herbs and spices, in the way set forth in the specification, for the purpose of thickening, enriching, and flavoring soups, gravies, *et cetera*.

In 1844, Messrs. J. and G. Cox of Edinburgh patented a process, by which they obtain a perfectly pure substance, possessing a gelatinising force superior to that of isinglass.

Shoulders and cheeks of ox hides, which are preferred by the patentees, are thoroughly cleansed in water, after which they are cut into pieces by a machine similar to that used for cutting straw, and then subjected to the action of a paper-maker's pulp-mill. By this process, the gelatinous fibre is well washed and cleansed, as a stream of water flows through the mill during the whole operation, carrying off all the impurities. The material is next pressed between rollers, mixed with fresh water sufficient to effect its solution, and heated to a temperature varying from 150° to 212°. By these means a superior gelatin is speedily produced, and it is said that the gelatinising power is not weakened by a lengthened exposure to heat.

When a very pure product is desired, the grain and flesh are removed as completely as possible from the hide pieces, the albuminous matters being thus separated.

After that portion of the process already noticed has been gone through, the liquid gelatin is placed in a steam-bath, and when heated to a temperature not exceeding 160° or 170°, fresh ox blood is added, in the proportion of one gallon to seven hundred of the gelatin. As the temperature increases, the albumen of the blood becomes coagulated, partly rising as a scum to the surface of the menstruum, the other portion descending to the bottom. When the magma has all ascended, the heat is lowered, and it is removed, and the purer liquor allowed to settle for about an hour, when it is run into coolers, where it congeals, and is then cut out into any convenient way and dried, *in vacuo*, by a process similar to that for the evaporation of saccharine menstrua.

By another mode of concentration, the gelatinous solution is run upon a steam-heated surface—say pipes of half an inch diameter, placed within one-eighth of an inch apart—to the depth of about an inch. The exsiccation is then completed in the open air.

A patent was granted, in 1847, to G. P. SWINBORNE, for improvements in the manufacture of gelatin by the following process:—Hides or skins, or those parts of them known as glue-pieces, are cut into shavings, or thin slices or films, by any suitable instrument; these are then soaked in water, which is changed two or three times each day, until no smell or taste can be detected either in the water or in the shavings, which are then removed, subjected to heat with water sufficient to cover them when pressed down in any suitable vessel. The gelatin, thus dissolved, is strained, subjected to slight pressure, and run in thin films upon a smooth surface of slate or other material to *set*, and then placed on nets to dry in the ordinary way, and finally cut into shreds.

A fish gelatin is also prepared by the same method from cod sounds, which forms a good and cheap substitute for isinglass for clarifying liquids.

ISINGLASS.—*Colle de poisson*, French; *Fischleim*, German; *Ichthyocolloia*, Latin.—The repeated mention by DIOSCORIDES and PLINY of *ichthyocolloia* has already been noticed.

Isinglass is obtained from the air-bag, or sound, as it is sometimes termed, of various fishes, many of which are still unknown. The finest kinds are produced by species of the *Acipenser*, and some other genera, as the *Morrhua*, *Silurus*, and *Gadus*.

The method of preparing the air-bags for sale, differs considerably, according to the country in which it is conducted. The commercial *pipe*, *purse*, and *lump* isinglass consist of the bag desiccated, but unopened. The *leaf* and *honeycomb* kinds are examples of the bladder cut open and dried unfolded; in the *staple* and *book* varieties, it is folded, while in the *ribbon* isinglass, it is rolled out. It is *picked* or *cut* before importation into Great Britain.

DESCRIPTION.—For a delineation of the various kinds of isinglass, the Editor holds himself indebted to Dr. PEREIRA. The very able dissertation of that pharmacologist on the various fishes from which isinglass is prepared, must, however, be omitted, as out of place here.

1. RUSSIAN AND SIBERIAN ISINGLASS.—The isinglass produced in the Russian empire is principally

obtained from the sturgeons. These cartilaginous fishes constitute the genus *Acipenser*. But this is not the only genus from which isinglass is obtained in Russia, for it is also procured from the *Silurus glanis*, which Dr. ROYLE suggests may be the source of the Samovey isinglass of commerce. BRANDE thus describes the preparation of Russian isinglass:—The swimming bladder is cut open, washed, and then exposed to the air with the inner silvery membrane turned upwards. The latter is then stripped off and placed in damp cloths, or left in the outer covering, and prepared or kneaded. It is then taken out of the cloths, and either merely dried—*leaf* isinglass—and twisted in a serpentine manner, between three pegs, into the shape of a horse shoe, heart, or lyre—*long* and *short staple*—or folded in the manner bookbinders fold printed sheets of paper—*book* isinglass.

Dr. PEREIRA observes in a foot-note to the above account of BRANDE, that though it agrees with the statements given by PALLAS, GMELIN, GEORGI, and TOOKE, there must be some inaccuracy in it. The immersed membrane of the swimming bladder is insoluble, though, according to BRANDE's view, the innermost is the gelatinous membrane. According to T. W. C. MARTIN, the swimming bladders are first placed in hot water, carefully deprived of adhering blood, cut open longitudinally, and exposed to the air, with the inner delicate silvery membrane upwards. When dried, *this fine membrane is removed* by beating and rubbing, and the swimming bladder is then made into different forms.

Several kinds of leaf isinglass, says BRANDE, are imported from Russia. The finest kind is that from Astrakhan, one variety of which is said to be obtained from the Beluga—*Acipenser huso*. These are imported from St. Petersburg. The Samovey leaf is an inferior kind brought from Taganrog. Sisane leaf is the produce of a small fish, each piece measuring only about two and a half inches each way, and weighing about a drachm; it looks like pieces of dried bladder, marked by two fibrous or muscular bands. Kroski isinglass is in small circular membranous discs. Long staple isinglass is of fine quality, and is the produce of the Oural. It is usually imported loose; at times it is strung on ropes, and this latter kind is preferred. Of short staple, three varieties are known: the finest is from the Oural, and is distinguished by the name of Patriarch, but it is very scarce. The Astrakhan short staple is one of the best kinds. The Samovey short staple is of inferior quality. Two sorts of book isinglass are met with; that from the Oural is excellent, but the Samovey product is little regarded. Siberian purse isinglass is of moderately good quality, and is in general demand. A small kind on strings, in a necklace form, is sometimes imported.

2. **BRAZILIAN ISINGLASS.**—This is imported from Para and Maranham, and, according to GUIBOUT, is sometimes denominated Cayenne isinglass. The fishes which produce it are not known, but it is obvious, from a superficial examination of the commercial specimens, that they must have been obtained from at least several species or genera. YARREL suggests the genera *Pimelodus* and *Silurus* as the sources of it.

It comes over in the form of *pipe*, *lump*, and *honeycomb*.

Pipe Brazilian isinglass must have been procured from a large fish. It is prepared by drying the swimming bladder unopened, and in some cases this is found distended with air. Each air-bag or *pipe*, as it is called, is from ten to twelve inches in length, and two or two and a half inches broad, weighing about five ounces, in shape somewhat conical, tapering at one extremity, but broader at the other, where on each side is a cæcal prolongation. It is devoid of smell. Lump Brazilian isinglass consists of two swimming bladders placed side by side, considerably separated at one end, but communicating with each other at the diverse extremity. When perfect, each specimen bears some resemblance to that of a torpedo. A perfect, though not very large lump, measured eight inches in length, and at the greatest latitude, five inches. Its weight is about six and a half ounces. It consists of three portions, separated by constrictions. The largest portion is five inches broad, and three and a half inches in length, flattish in front, rounded posteriorly. It consists of two sacs, placed one on each side. The middle portion is oblong, three inches in length, and two in breadth. This is also formed of two sacs, communicating with the preceding portion. The third portion is oblong, one and a half inches long, and three-fourths of an inch wide. This consists of one sac only, into which both sacs of the middle portion open.

Honeycomb Brazilian isinglass appears to be the largest quantity of the lump variety split open. The latter is sometimes softened, and rolled out into thin ribbons, in this country. On account of its deeper color and less solubility, Brazilian isinglass is not in demand for domestic use; though, as it is sold in the cut state, it is probably largely intermixed by shopkeepers with the finer kinds of Russian isinglass, and sold as such. As it is moderately cheap and soluble, it is in extensive use for fining by brewers, who are the principal consumers of this variety. When digested with boiling water, it leaves a large proportion of undissolved white matter of a starchy consistence.

3. **New York Isinglass.**—Occasionally, ribbon isinglass is imported from New York. It is in thin strips of several feet long, and from an inch and a half to two inches in width. It is less soluble than Russian isinglass, and affords a dark-colored solution. Dr. J. V. C. SMITH states that it is obtained from the air-bladder of the common Hake—*Gadus merluccius*—which is macerated in water for a short time, and is then taken out and subjected to pressure between two iron rollers, by which it is elongated to the extent of half a yard or more. It is then carefully dried, packed, and sent to market. The common cod—*Morhua vulgaris*—yields a poorer kind of isinglass; but the hake only is known to the extensive manufacturers as fit for their purposes.

4. **Hudson's Bay Isinglass.**—Dr. PEREIRA was unable to ascertain from what fish this isinglass is procured. It comes over in the purse form. One specimen measured twelve inches in length, and three and a half in diameter; its weight is one ounce and a half. It is of a light yellow color, translucent, and free from

taste and smell. The inner lining of the sac, which may be readily stripped off, is insoluble in water; the remaining membrane dissolves in boiling water.

5. *East India Isinglass*.—It appears that, for a long period, this has been exported from Calcutta to China, but it has only recently occupied the attention of Europeans. It is probably the produce of a species of *Polynemus*. But, according to Dr. ROYLE, the fishes which Dr. BUCHANAN named *Bola*, and several species of *Silurus*, especially *S. raita*, also yield isinglass. Most of the specimens of Indian isinglass examined by Dr. PEREIRA had an unpleasant fishy odor, which rendered them totally unfit for household use, and greatly deteriorated their value for domestic purposes. A sample of East Indian purse isinglass, examined by Dr. PEREIRA, consisted of an unopened swimming bladder, flattened and dried. Its shape is oval-oblong, its length nine inches, its breadth three and a half inches, its weight seven and a half ounces. It has a strong fishy smell, and is of a dark color.

Another kind—East India leaf isinglass—is the sac merely laid open and dried. It is eight or nine inches long, six or seven inches broad, and about three-tenths of an inch thick. A third variety—East India rolled leaf isinglass—which Dr. PEREIRA received from Dr. ROYLE, appears to have been formed by rolling out the preceding kind into thin plates. One specimen was about eighteen inches long, three and a half inches wide, and one-tenth of an inch thick. Some of the sheets are covered with a thin film of chalk.

Picked East India isinglass is in small shreds, two or three inches long, and tapering at the extremities. It is hand-picked in India by the natives.

Manilla isinglass has been imported recently as *thin cake*. It is white and clean, and is equal in quality to Brazilian or Samovey book. The fish which yields it is found in the river of Manilla, and on the coasts of the Philippines, Luconia. It is smaller than the Brazilian, but greatly resembles the lump variety of that kind, and the fish is probably an allied species.

6. *Cod Sounds*.—These, in the dried state, are brought from Scotland, and used as a substitute for foreign isinglass. They are, however, usually preserved soft by salting, and dressed for the table.

Para Isinglass.—A substance has lately been imported under the name of isinglass, which, on examination, proves to be, not the air-bag, but the dried ovary of a large fish.

It consists of bunches—somewhat resembling those of grapes—of ovoid or rounded masses, attached by peduncles to a central axis; by immersion in water, the latter is found to be a convoluted membrane, to one side only of which these ovoid masses are attached. When soaked in water, the fishy odor of this so-called isinglass is very obvious. The ovoid masses are *ova*, are highly vascular on the surface, and are filled with an animal substance of a yellow color. In general appearance, they resemble the vitellus of a shark or ray.

The *Sudis gigas*, a large osseous fish, upwards of six feet in length, is found at Para. Its flesh is eaten by the lower classes in a dried and salted state, and its swimming bladder constitutes one of the kinds of

Brazilian isinglass imported into London. It is probable that the ovary of this fish constitutes the false isinglass in question. If not from this fish, it is probably obtained from some allied genus—as *Amia*—of highly organized osseous fishes.—*Pereira's Materia Medica*.

PROPERTIES AND COMPOSITION.—The properties of isinglass are nearly the same as those of gelatin.

Isinglass was first analysed by Dr. JOHN, but his results are very questionable. They are as follow:—

	Centesimally.
Gelatin,	70.0
Osmazom,	16.0
Membrane insoluble in boiling water,	2.5
Free acid, and salts of potassa and soda,	4.0
with some phosphate of lime,	7.5
Water,	100.0

It appears that the Bengal isinglass yields, on analysis, gelatin, albumen, osmazom, a trace of odorous oil, and a small amount of inorganic matter. The quantities of the first two mentioned principles contained in three several samples of isinglass were respectively:—

	Centesimally.		
	I.	II.	III.
Gelatin,	86.5	90.9	92.8
Albumen,	13.5	9.1	7.2
	100.0	100.0	100.0

USES.—The more common kinds of isinglass, especially the coarse Brazilian, are used by brewers for fining beer, and have been noticed in their application for that purpose. They are also employed for the clarification of wines, and various other liquids.

Court Plaster is formed by brushing a solution of isinglass, mingled with a little tincture of benzoin, over black sarsenet. LISTON's isinglass plaster is similarly made with oiled silk.

Isinglass also enters into the composition of those preparations known as *marine glue*, *diamond cement*, *et cetera*. The latter is made by dissolving isinglass in dilute alcohol. These ingredients are put in a bottle loosely corked, which is then placed in a vessel containing boiling water, and simmered for about an hour. When cold, it should be an opaque, milk-white, hard jelly; it is re-dissolved by immersion in warm water, the cork of the bottle having been previously loosened. The addition of a little spirit is required, after some time, to replace that lost by evaporation.

A better article than this may be obtained by soaking fine isinglass in cold water; when it has swelled out, spirit is added, and the bottle containing these set in a pan of cold water, which is gradually brought to the boiling point, when the isinglass becomes one uniform pulp, free from lumps or fibres.

These preparations have a tendency to become mouldy, which may be diminished or removed by the addition of a few drops of any essential oil.

ADULTERATION OF ISINGLASS.—The quality of cut isinglass is estimated, says Dr. REDWOOD,—1. By its color; that which is cut fine by machinery being, *ceteris paribus*, the whitest and generally most esteemed. 2. By the odor emitted after breathing upon it; that being the best which is least disagreeable in this respect. 3. By the extent of its solubility in water. 4. By the con-

sistency, transparency, and flavor of the jelly which it gives. This practical method of examination is that alone by which slight shades of variance may be discovered; yet a difference of flavor, which only a practised palate, or careful comparison with an approved specimen could detect, is often important in an article intended for the diet of the fastidious invalid, and a slight superiority in this respect will, therefore, command a much increased price.

WARINGTON and REDWOOD have shown that sheet gelatin is rolled between sheets of isinglass in the moistened state, so as to form a ribbon in which the two substances would be united.

This may be detected by means of the microscope, the separate strata being in many cases clearly discernible. The amount of inorganic matter in the product is also a clue as to whether it is or is not adulterated, since isinglass gives an ash of a *reddish color*, amounting only to a half per cent., while gelatin gives, according to REDWOOD, not less than three per cent. of *white ash*.

They may also be distinguished from one another, says Dr. REDWOOD, by means of caustic potassa. When cut isinglass is macerated in a cold solution of caustic potassa, it will speedily become transparent, and, after the lapse of a few hours, if occasionally stirred, it will be dissolved, forming a clear and colorless solution. After allowing this to stand for some time, a *very slight* flocculent precipitate will be deposited, which, in operating on twenty or thirty grains of isinglass, will be scarcely perceptible. *Cut gelatin*, by the same treatment, becomes opaque; even those specimens which were so, to a certain extent, previously, will assume increased opacity after immersion. The gelatin ultimately dissolves, as does the isinglass; but the solution is not transparent, and after some time a *copious* flocculent deposit is formed.

A sample of hand-cut isinglass, examined by WARINGTON, had a great deal of acid adhering to it, which he considered to arise either from the acid having been used for the purpose of improving an inferior isinglass, so as to render it saleable, or from its admixture with gelatin prepared by means of an acid.

GLUE.—*Colle forte*, French; *Tischlerleim*, German. —Glue is an impure desiccated gelatin, obtained from various sources. The principal substances employed are scraps of ox and other thick hides, which afford the strongest product; the debris of the tan-yards, of leather-dressers, morocco-leather manufacturers, *et cetera*. The tendons and intestines of many animals, rabbit skins deprived of their fur, scraps of parchment, old gloves, and many other apparently worse than useless matters, all contribute their quota in the manufacture of glue.

When the fresh glue-yielding substances are not to be immediately employed, it is always requisite to submit them to some antiseptic treatment till they are required for use.

This preservation often forms the base of a particular branch of industry, which has for its object to prevent the fermentation of the raw materials, and to dry them to avoid the expenses of transport. These results are obtained by simply macerating them during

fifteen to twenty days in milk of lime, which is repeatedly renewed. After taking them from the lime bath, they are spread in the open air to drain and dry. This desiccation is accelerated by turning them over with a fork several times a day. When sufficiently dried, the materials are packed up and sent to the glue factory.

The calcareous liquor serves to dissolve the blood and some soft parts; it attacks the epidermis, and predisposes the tissue to be more easily converted into gelatin. Before employing these glue-yielding materials, the manufacturer is in the habit of completing these effects by again immersing them in a weak milk of lime, which frees them still further from any soluble animal impurities. When they are much swollen and easily penetrated, they are several times rinsed in water to remove the excess of calcia. They are then spread upon hurdles, being turned occasionally to carbonate the free alkaline earth, which might subsequently be injurious to the glue. It is not necessary, however, to dry the material, as when put into the boiler it dissolves faster when in a soft or tumefied state.

Formerly the glue pieces, having been cleansed as above described, were thrown loose into the caldron, which was of copper, rather shallow in proportion to its area, and flat-bottomed. Above the true bottom there was a false one of copper or iron, perforated with numerous holes, and standing upon feet three or four inches high, the animal matters being thus upheld from contact with the fire.

Now, however, the material is placed in a wide-mouthed bag or net, made of rope, and spread open in the caldron, which contains a light framing of iron, to prevent the bag adhering to the sides or bottom. Water is then added, and gradually brought to ebullition. As the animal substances decrease in bulk, fresh additions are made, the whole being occasionally agitated or pressed down by means of poles.

The progress of the operation is readily ascertained by withdrawing a sample of the menstruum, and setting it aside for a few minutes to cool. If a clear and consistent jelly be obtained, the boiling has been carried to a sufficient extent, and the mouth of the glue-bag having been securely tied up, it is slowly raised by appropriate machinery, until it comes in contact with, or is partially coiled round, a large beam immediately above the caldron, which expels the fluid. In this state it is left to drain. The solution in the boiler will require evaporation before it is sufficiently concentrated for making glue.

The contents of the bag are subjected to ebullition for a second and a third time, and by this means afford *size*. When the resulting solutions are too dilute for either glue or size, they are employed instead of water for extracting the glue from fresh materials; the refuse in the bags, after all available matter has been extracted, is sold for manure, and every particle of animal substance is turned to account.

When sufficiently concentrated, the glue is transferred from the caldron to the *settling-back*, where such a temperature is maintained, that its fluidity is preserved. The impurities by this means subside, and should the manufacturer wish a very fine product, he

can also at this time add such fining or clarifying agents as he may prefer.

The glue is run off hence into wooden *coolers* or *boxes* about six feet in length, two in depth, and one in breadth. The apartment in which this is done ought to be as cool and dry as possible, to favor the solidification of the gelatinous menstruum, and the floor should be kept scrupulously clean, so that should any glue escape it may be recovered.

Having become a firm jelly, the glue is cut out into cubic masses, each of which is deposited in a kind of wooden box, open to the back in several slits or divisions, of a size corresponding to the thickness which the cakes of glue are required to have. It is then cut into slices by passing a brass wire stretched in a frame, like that of a bow-saw along the slits. The resulting cakes of glue are deposited upon nets, which are stretched in wooden frames, and are thus removed to the sheds, where they are placed in piles, due intervals being allowed for the circulation of the air. They are turned two or three times a day.

The drying of the glue, says Dr. URE, is the most precarious part of the manufacture. The least disturbance of the weather may injure the product during the first two or three days of its exposure. Should the temperature rise considerably, the gelatin may become soft and unshapely, so much so as to run through the meshes upon the pieces below, or to get attached to the strings, and surround them so as not to be separable without plunging the net into boiling water. If frost supervene, numerous cracks may be formed in the cakes, from the congelation of their water. Such pieces must be remelted. Even a slight fog produces, upon newly-exposed glue, a serious deterioration; the damp condensed upon its surface occasioning a general mouldiness. A thunderstorm sometimes destroys the coagulating power in the whole laminæ at once; or causes the glue to *turn* on the nets. A wind too dry or too hot may cause it to exsiccate so quickly, as to prevent it from contracting to its proper size without numerous cracks and fissures. Thus, as TOMLINSON remarks, the manufacture is subject to many vicissitudes, and can only be profitably and conveniently carried on in temperate and equable weather. The drying, however, is not entirely finished in the open air. When the glue is about three parts dry, it is removed into lofts, where, in the course of some time, the hardening is completed. But, as the surfaces of the cakes become mouldy and soiled, it is necessary to scour them with a brush and hot water, and set them up to drain. They are then finally desiccated in a stove-room at an elevated temperature, which, when they have once become solid, only serves to harden and improve them.

In France, a considerable quantity of glue is made from bones, which are digested in hydrochloric acid, for the purpose of removing the phosphate of lime.

The following is the *modus operandi*:—It is proper to observe that all bones do not answer for this manufacture. Only spongy bones can be used; the ribs, the back-bone, the lower jaw-bone of animals, and the horns, are those which yield the greatest amount of gelatin. The bones are broken as small as possible by means of an axe. Some hydrochloric acid of

36° Twaddell is mixed with a quantity of water, so as to reduce the mixture to 13°, which can be ascertained by means of the acidimeter. The crushed bones are put into a vessel, and the above-mentioned preparation poured over them so as to cover them completely. The vessel is covered close with a wooden lid, and the bones are thus left to macerate for thirty hours. When this period has elapsed, it must be seen if the bones are softened; for otherwise, if the acid was deficient in strength to extract from them the lime and alkali, in that case it would be requisite to change the vessel, and to give them a new maceration with a mixture of 9° Twaddell strength. When sufficiently prepared they are withdrawn, and thrown into a bath of weak lime-water, where they are left to steep eight days; they are then removed, washed with fresh water, and put to steep in a fresh portion of water daily for ten or twelve days, for the purpose of removing from the bones the acid which may have penetrated them—then dried. These glues or pastes are now good for the market, and sell at about fifty shillings the six hundred pounds.

This, says Dr. URE, is a poor article, possessing little cohesive force. It dissolves almost entirely in cold water, which is the best criterion of its imperfection.

PROPERTIES.—Glue is commercially judged of by its color, and freedom from cloudy or black spots when held up before the light.

The better sorts of glue are transparent, especially the thin cakes of *Salisbury glue*, which are of a clear amber color. The chemical characteristics of glue are similar, as a matter of course, to those of pure gelatin.

According to SCHATTENMANN, fresh glue dries much more readily than glue that has been once or twice melted. He states that dry glue absorbs different quantities of water in proportion to its quality, and on this property he has proposed a method of testing it.

Fresh glue contains water of composition, or water more intimately united with the glue than that which it acquires during the melting. The combined water of dry glue disappears in the course of successive meltings and solidifications.

Glue in thin laminæ is usually of better quality than that which is in thick ones, even when made from the same material, because the former admit of a more rapid desiccation than the latter.

In applying SCHATTENMANN'S test, dry glue is immersed for twenty-four hours in water at a temperature of about 60°. A jelly is thus formed, the qualities of which will fairly represent those of the glue. For example, the finest ordinary glue, or that made from white bones, absorbs, in the time specified, twelve times its weight of water, so that a plate weighing three grammes produces thirty-nine of fine elastic jelly. Glue from dark bones takes up nine times its weight of water, and a soft brown jelly is produced, devoid of elasticity and consistency, and falling to pieces when handled.

Well-dried glues are much less hydrometric than badly made ones, or those fabricated from inferior materials. The latter are liable to putrefaction.—Tomlinson.

APPLICATIONS.—The common, but important use of

glue in carpentry, cabinet-making, *et cetera*, is well known.

There was formerly a large consumption of it for the sizing of paper; but since this has been made without manual labor, it is almost wholly disused for this purpose.

The latter employs it in the preparation of his felt; and the letterpress printer, in conjunction with molasses, as a flexible and cleanly covering for his inking rollers.

At the beginning of this century, glue was introduced in Germany for making moulds for casting, but it was not employed in this country till the year 1826, when DOUGLAS FOX used it for taking casts of anatomical preparations, calcareous concretions, vegetal substances, *et cetera*. He first mixed it with treacle, for the purpose of giving to it more elasticity, but this discolored all white surfaces, and the plan was abandoned.

In 1844, FRANCHI formed a series of casts in plaster composition, in imitation of ivory; and, in 1846, the Society of Arts in London awarded to him a prize. The nature of the material was unknown at the time, but it was subsequently shown to be pure gelatin. The inventor has since employed it for modelling very intricate and ingenious devices.

STATISTICS.—A very large amount of glue, manufactured in England, is undoubtedly passed off as Russian; yet, nevertheless, a considerable quantity is imported. The returns of imports and exports, from the years 1850 to 1855, are subjoined. The reader cannot fail to notice the large decrease in the quantity imported during 1855, owing to the hostilities with Russia :—

	1850.	1851.	1852.	1853.	1854.	1855.
	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.
Imports,.....	1305	1323	1625	3359	4905	781
Exports,.....	—	1	—	46	19	—

The quantity of isinglass imported, principally from the dominions of the Tzar, during the years 1850–5, was as under :—

IMPORTS.					
1850.	1851.	1852.	1853.	1854.	1855.
Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.
2009	2387	2056	1730	1881	1567

And the exports during the same period were :—

1850.	1851.	1852.	1853.	1854.	1855.
Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.
78	145	117	252	72	205

The imports and exports of gelatin for the years 1850 to 1855 inclusive, were as under :—

	1850.	1851.	1852.	1853.	1854.	1855.
	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.
Imports,.....	449	295	271	275	269	268
Exports,.....	—	1	2	1	—	3

The quantity imported is gradually lessening, owing, most probably, to the great improvements which have been effected in the British manufacture during the last few years.

GLASS.—*Verre*, French; *Glas*, German; *Vitrum*, Latin.—The discovery of glass is, without contradiction, one of the most important services which accident or chemistry has rendered to civilization. Without speaking of the economical uses of this compound, and considering it only with reference to its applications in the

study of natural phenomena, it is impossible to doubt the singular influence it has exerted on the progress of science. It is chiefly by its aid that astronomy has attained a perfection so wonderful; by it also naturalists have been enabled to study under the microscope a host of phenomena which heretofore escaped notice. But perhaps of still greater importance is the use which is made of it by chemists in their experiments. It requires no profound chemical knowledge to recognize the fact, that to glass is chiefly owing the present advanced state of the sciences, so fruitful in marvellous applications. Every one, says LIEBIG, is familiar with most of the properties of this curious substance; its transparency, hardness, destitution of color, and stability under ordinary circumstances: to these obvious qualities one may add those which especially adapt it to the service of the chemist, namely, that it is unaffected by most acids or other fluids. At certain temperatures it becomes more ductile and plastic than ware, and may be made to assume in the flame of a common lamp the form of every vessel needed in the laboratory, and of every apparatus required by experimenters.

The use of glass in our windows, remarks TOMLINSON, instead of the *louvre* boards of old, has introduced a degree of comfort into the meanest dwelling which previously did not appertain to the costliest palace. By means of this contrivance the light is filtered from the wind, the rain, and the cold; the one can be enjoyed without being inconvenienced by the other; and one can, in conjunction with the improved methods of warming, create an in-door climate, adapted to the desires and feelings of the dwellers. The employment of glass in many domestic articles of furniture contributes to cleanliness and health, for the slightest soil on glasses or decanters is revealed by this most transparent material, and the purity of the water and other liquids contained in them is physically tested by the same means. Even the mirror, adorning the rooms, reminds one of the necessary attention to personal appearance, which self-respect, as well as respect for society, demands.—*Tomlinson*.

The great Dr. JOHNSON has appositely remarked, that it might contribute to dispose one to a kinder regard for the labors of his fellow, if he were to consider from what unpromising beginnings the most useful productions of art have probably arisen. Who, when he first saw the sand or ashes, by casual intension of heat, melted into a metalline form, rugged with excrescences and clouded with impurities, would have imagined that in this shapeless lump lay concealed so many conveniences of life, as would, in time, constitute a great part of the happiness of the world? Yet, by some such fortuitous liquefaction was mankind taught to procure a body, at once in a high degree solid and transparent, which might admit the light of the sun, and exclude the violence of the wind; which might extend the sight of the philosopher to new ranges of existence, and charm him, at one time, with the unbounded extent of material creation, and at another with the endless subordination of animal life; and what is of yet more importance, might supply the decays of nature, and succour old age with subsidiary sight. Thus was the first artificer in *glass* employed, though

without his knowledge or expectation. He was facilitating and prolonging the enjoyment of light, enlarging the avenues of science, and conferring the highest and most lasting pleasures: he was enabling the student to contemplate nature, and the beauty to behold herself.

It is not a little remarkable that glass, which is applied so extensively and to so many purposes, and the varying properties of which exercise so marked an influence in its different applications, has, notwithstanding, never been the subject of a series of decisive experiments, calculated to establish the theory of its fabrication. Not that this theory has not been nearly, if not wholly elucidated; but that it is scarcely to be looked for in the works published on glass. The greater part of these were written at a period when the part which silicic acid performed was not defined or understood; and among the recent works on the subject, KNAPP'S is the only one which discusses it in a thoroughly scientific manner.

Definition.—It is stated in the *Encyclopedia Britannica*, that the general term *glass* is employed by chemists to denote all mineral substances which, on the application of heat, pass through a molten state into hard and brittle masses, and which exhibit when broken, though not always transparent, a lustrous fracture. The glass of commerce, however, to which the present article will be restricted, or the transparent and artificial substance which is usually distinguished by this name, is produced by the igneous fusion of silicious earth with certain alkaline earths or salts, or with metallic oxides.

The etymology of the word has been much disputed. It is derived by some from the Latin *glacies*, ice, its resemblance to which is thought to have suggested the title, and *glacies* may be a contraction for *gelacies* from *gelu*, frost. Others have remarked, that the common Latin designation of this substance is *vitrum*; and as the Romans applied this term, in common with the word *glastum*, to the plant which is now called woad, they have deduced it from the latter of these, either because the ashes of this plant were used in the manufacture of glass, or because it exhibited something of the bluish tinge which is procured from woad. *Glassum*, the name given to amber by the ancient Gauls and Britons, has also been assigned as the origin of the word. But none of these etymons appears very satisfactory. The most plausible theory is that which derives the term from the Saxon verb *glis-nian*, or the German *gleissen*, which are probably contractions of the Anglo-Saxon *gel-ixan*, to shine, to be bright. This view is in a great degree confirmed by the sense in which the term glass and its derivatives are employed by our older writers, who frequently apply it to shining or glittering substances, without reference to color or transparency.—*Encyclopedia Britannica*.

HISTORICAL NOTICE.—In the most remote ages the art of blowing glass into bottles, making it into vases, tinging it to imitate precious stones, melting it in huge masses to make pillars, rolling and polishing it into mirrors, and staining it in parts, were all perfectly known. As stated by some authorities, Egypt, the parent of so many collateral arts, is to be looked to as its source. According to others, its discovery origi-

nated with the Israelites, who set fire to a forest, and the heat becoming so intense as to make the nitrate of soda and sand melt and flow along the mountain side, they afterwards imitated artificially what had first been effected by accident. If PLINY is to be credited—an author, whose version of the subject has so often been reproduced with all the gravity of history—the discovery of glass was made by some Phœnician soda merchants, who, having landed on the banks of the river Belus, served themselves with blocks of soda to support the vessel in which they prepared their food, and these masses melting with the heat, transformed into glass the sand on which they rested. When one knows the temperature necessary for the making of glass, and has seen the interior of a glass furnace in operation, this story will be rejected as fabulous. Chance had doubtless its share in the invention of glass; but there might have been found among the arts known to the ancients, phenomena better fitted to awaken the attention of an observant spirit. The pottery manufacture and the extraction of metals require the employment of violent and sustained fire, which is sufficient to give rise to fusible silicates, more or less analogous to glass. That an intelligent potter might have attempted to reproduce at pleasure the vitreous tears which formed accidentally upon his products; that by dint of repeated trials he might have been led to remark the influence of ashes on the clay, and that thus he might have succeeded in producing glass, is easily conceived. However this may be, the anecdote related by PLINY ought to be ranked with those idle tales or mere conjectures by which the ancient commentators sometimes attempted to fill the gap created by the silence of history, and which were afterwards transformed into articles of faith by some mistake of a copyist, or by some blunder of a new commentator. It is a point, however, on which there can be no doubt, that glass was known to the Phœnicians, who for a long time retained the monopoly of it, favored by the union of natron, sand, and fuel, in a country situated on the shores of the sea.

There are several references to glass in the Bible. BALLANTYNE remarks that the Hebrews must have become acquainted with glass while in Egypt, and in consequence of their proximity to the Phœnicians; and it is now generally believed that these two nations had the merit of originating and establishing its manufacture. It is a remarkable circumstance that glass lenses have been found during the recent researches in the ruins of Nineveh. The Athenian ambassadors, in order to give an idea of the magnificence displayed at the court of the great king of Persia, said that they drank in cups of glass and gold. Some writers affirm that the Egyptians, in some instances, sealed up their dead in a coating of glass; and glass houses are said to have been not uncommon in that wonderful country. Some authors ascribe, with very plausible reason, the discovery of glass-making to the priests of Vulcan at Thebes and Memphis, the greatest chemists in the ancient world. The Egyptians are also known to have made enamels of divers hues which they applied on pottery, magnificent specimens of which are still extant, and are called Egyptian porcelain. These are chiefly covered with a

beautiful blue or green tinge, and groups of flowers or other designs are traced in black. Glass beads and other ornaments made of that substance, skilfully manufactured and beautifully tinged, have been found adorning mummies, which are known to be upwards of three thousand years old. It is certain that Tyre, Sidon, and Alexandria were long celebrated for their glass, and furnished the greater proportion of that used at Rome. Under the Roman empire the Egyptians still preserved their superiority in the art of glass-making, and it is said that AURELIAN caused them to pay their tribute in that manufacture. ADRIAN mentions that he had received drinking-glasses of various shades from a priest of a famous temple in Egypt, and gives instructions that they are not to be used but on the greatest occasions, and on the most solemn feast days. To these places the art was exclusively confined for some centuries, and glass was used as an article of luxury, being chiefly in the form of urns or drinking cups of the most elaborate workmanship, and exquisitely embellished with raised, chased, or ornamented figures. The Barberini or Portland vase, composed of a deep azure glass, with figures of a delicate white opaque substance raised in relief, is a splendid specimen, and was found in the tomb of ALEXANDER SEVERUS.

Sir J. G. WILKINSON adduces three distinct proofs that the art of glass-working was known in Egypt before the exodus of the children of Israel from that land, three thousand five hundred years ago. At Beni Hassan and at Thebes are paintings representing, in a very rude form, glass-blowers at work; and from the hieroglyphics accompanying them, it is found that they were executed in the reign of a monarch who occupied the throne at about that period. It is certain, moreover, that at that time images of glazed pottery were common, the vitrified material of which is of the same quality as glass; and, therefore, the mode of fusing, and the proper proportions of the ingredients for making glass, must have been already well known. Lastly, Sir J. G. WILKINSON adduces the instance of a glass bead about three-quarters of an inch in diameter, which Captain HENRY found at Thebes, and which contains in hieroglyphic characters the name of a monarch who lived fifteen hundred years before CHRIST. The knowledge of the manufacture probably travelled from Egypt to Greece, thence to Rome and modern Europe; and successive improvements have not only brought the art to a high degree of excellence, but have led to its subdivision into several kinds, such as flint-glass, plate-glass, window-glass, and green or bottle-glass making.—*Dodd.*

The art of glass-making seems to have been introduced into Italy by the Romans after their conquests in Asia, in the time of CICERO, and the first glass-works there were said to have been near the Flaminian Circus. It is highly probable that the workmen were imported from Egypt. The use of glass seems to have rapidly extended, and to have become very common. One of the emperors in the third century of the Christian era says, that he was disgusted with an article so mean and vulgar as glass, and that he would only drink from vessels of gold. By this time the manufacture of glass was so considerable that an impost was laid on

it, and it was extensively employed in the decorations of buildings. In glass mosaics particularly were combined the most brilliant colors.

From the circumstance of colored glass beads and amulets having been found among Druidical remains in this country, says BALLANTYNE, it has been argued by PENNANT and others, that the art of making glass was known in Britain before its invasion by the Romans. It can hardly be believed, however, that a people who had made very trifling advances in civilization, and who, it is known, were entirely unacquainted with any other art, should be found not only conversant with the use of glass, a complicated and highly ingenious process, but should excel in it; for the beads and amulets spoken of are of exquisite workmanship, and beautifully colored in imitation of the rarest and most precious stones. There seems little doubt, therefore, that the ancient Britons procured these in their traffic with the Syrians, who visited this island, as the modern Britons and other civilized nations visit the South Sea islands, to drive a trade with their savage inhabitants in toys and trinkets, giving these in exchange for skins or other natural productions. By whatever means, however, these ornaments came into Britain, it is certain that they were in extensive use, though principally for superstitious purposes, long prior to the Roman invasion, as they are found in barrows or tumuli of a much older date. One at Stonehenge, in particular, on being opened, was found to be filled with them.

Glain Neidyr, or druidical glass rings, generally about half as wide as our finger rings, but much thicker, have frequently been found. The vulgar superstition regarding these was, that they were produced by snakes joining their heads together and hissing, when a kind of bubble like a ring was formed round the head of one of them, which the others, continuing to hiss, blew upon till it came off at the tail, when it immediately hardened into a glass ring. Success was thought to attend any one who was fortunate enough to find one of those snake stones. They were evidently beads of glass employed by the Druids, under the name of charms, to deceive the vulgar. They are usually of a green hue, but some of them are blue, and others variegated with wavy streaks of blue, red, and white.

Glass utensils have been found in Herculaneum, which city was destroyed by an eruption of Mount Vesuvius in the reign of TITUS. A plate of glass also found there has occasioned much speculation as to its uses. Similar plates, to which PLINY gives the name of *vitrea camerae*, seem to have been employed in a manner not now very well understood, as panelling for their rooms. It is certain that two panes of glass were found in a window in Herculaneum.

In the reign of TIBERIUS, a company of glass manufacturers established themselves in Rome, and they had a street assigned them near the Porta Capena. The articles of their manufacture were few in number, and of inferior quality; neither did they make rapid improvements in their art, notwithstanding the large prices which were then given for glass of foreign manufacture in the imperial city. In the year 220, they had increased so much in importance, and the product was so considerable, that an impost was laid on it by

ALEXANDER SEVERUS. DION CASSIUS and PETRONIUS ARBITER concur in their account of the discovery of malleable or ductile glass by a celebrated Roman architect, whose success in the restoration to its position of a portico which leaned to one side, had roused the envy and jealousy of TIBERIUS, and occasioned his banishment from Rome. Thinking that his discovery would disarm the Emperor's wrath, the artist appeared before him bearing a glass vessel, which he dashed upon the ground. Notwithstanding the violence of the blow, it was merely dimpled, as if it had been brass. Taking a hammer from his breast, he then beat it out into its original shape; but instead of giving him the reward which he had expected, the Emperor ordered the unfortunate artisan to be beheaded; remarking, that if his discovery were known, gold would soon be held of as little value as common clay. This is probably another version of the story told by PLINY, of an artificer who made the same discovery, and whose workshop was demolished by those who had an interest in preventing the introduction of an article which would lower the value of gold, silver, and brass. Although it might not be justifiable to give unqualified discredit to these tales, yet the knowledge at present possessed would restrict the possibility of such a discovery within the narrowest limits. The union of the properties of malleability and vitrification seems to be incompatible. Some metallic substances, by the application of intense heat, are reduced to the state of glass, but at the same time lose their malleability; which fact would seem to imply that it is impossible to communicate the latter property to glass. The extraordinary stories above-mentioned have, however, been rationally enough explained by modern chemists. It has been observed by KUNCKEL, that a composition having a glassy appearance, and sufficiently pliant to be wrought by the hammer, may be formed; and by NEUMANN, that, in the fusion of chloride of silver, a kind of glass results, which may be shaped or beaten into different figures, and may be pronounced in some degree ductile. BLANCOURT mentions an artist who presented a bust of ductile glass to the Cardinal RICHELIEU; but he does not seem to have been more fortunate than his predecessors; for he was doomed to imprisonment for life, for the *politic reason*, as BLANCOURT with much simplicity observes, which led the Cardinal to fear lest the established interests of French glass manufacturers might be injured by the discovery. From expressions used by BLANCOURT in other parts of his work, it is thought that by malleable glass, such as was produced by this artist, he understood some composition similar to those which KUNCKEL and NEUMANN discovered, and was not very exact in limiting the term to that vitreous substance which is now generally understood when glass is mentioned.

The precise period at which the making of window-glass was introduced, is not now certainly known. Roman windows were filled with a semi-transparent substance called *lapis specularis*, a fossil of the class of talcs, which readily splits into thin smooth laminae, or plates. This substance is found in masses of ten or twelve inches in breadth, and three in thickness; and,

when sliced, very much resembles horn, instead of which it is to this day often employed by lantern-makers. The Romans were chiefly supplied with this article from the island of Cyprus, where it abounds. So good a substitute for glass is it said to have been, that, besides being employed for the admission of light, it was also used in the construction of hothouses, for raising and protecting delicate plants; so that, by using it, the Emperor TIBERIUS had cucumbers at his table throughout the whole year.

There is no positive mention of the use of glass for windows before the time of LACTANTIUS, at the close of the third century. But the passage in that writer which records the fact, also shows that the *lapis specularis* still retained its place. Glass windows are distinctly mentioned by St. JEROME, as being in use in his time. A century later, the windows of the church of St. SOPHIA at Constantinople are represented, by PAULUS SILENTIARIUS, as being filled with glass. After this period, frequent mention is made of them. JOANNES PHILIPPINUS states that glass was fastened into the windows with plaster.

BEDE asserts that glass windows were first introduced into England in the year 674, by the Abbot BENEDICT, who brought over artificers skilled in the art of making window-glass, to glaze the church and monastery of Wearmouth. Other authorities attribute the introduction of this luxury to Bishop WILFRED, junior, who died in 711. It would thus appear, that glass windows were first seen in England either about the seventh or the beginning of the eighth century. The use of window-glass, however, was then, and for many centuries afterwards, confined entirely to buildings appropriated to religious purposes; but, in the fourteenth century, it was so much in demand, though still confined to sacred edifices and ornamental purposes, that glazing had become a regular trade. This appears from a contract entered into by the authorities of York Cathedral in 1338, with a glazier, to glaze the west windows of that structure; a piece of work which he undertook to perform at the rate of sixpence per foot for white glass, and one shilling per foot for colored. Glass windows, however, did not become common in England till the close of the twelfth century. Until this period they were rarely to be found in private houses, and were deemed a great luxury, and a token of great magnificence. The windows of the houses were, till then, filled with oiled paper or wooden lattices. In cathedrals, these, and sheets of linen, supplied the place of glass till the eighth century; in meaner edifices, lattices continued in use till the eighteenth.

The glass of the Venetians was superior to any made elsewhere, and for many years commanded the market of nearly all Europe. Their most extensive glass-works were established at Murano, a small village in the vicinity of Venice; but the produce was always recognized as Venetian glass. Baron von LOWHEN states that, so useful were the glass-makers at one period in Venice, and so great the revenue accruing to the republic from their manufacture, that, to encourage the men engaged in it to remain in Murano, the senate made them all burgesses of Venice,

and allowed the nobility to marry their daughters; whereas, if a nobleman married the daughter of any other tradesman, the issue were not reputed noble.

The skill of the Venetians in glass-making was especially remarkable in the excellence of their mirrors. BECKMANN, who has minutely investigated the subject, is of opinion that the manufacture of glass mirrors certainly was attempted, but not with complete success, in Sidon, at a very early period; but that they fell into disuse, and were almost forgotten until the thirteenth century. Previously to this period, plates of polished metal were used at the toilette; and in the rudeness of the first ideas which suggested the substitution of glass, the plates were made of a deep black color to imitate them. Black foil even was laid behind them to increase their opacity. The metal mirrors, however, remained in use long after the introduction of their fragile rivals; but at length they wholly disappeared—a result effected chiefly by the skill of the Venetians, who improved their manufacture to such a degree, that they speedily acquired a celebrity which secured an immense sale for them throughout all Europe.

From Italy the art of glass-making found its way into France, where an attempt was made to rival the Venetians in the manufacture of mirrors. The first essay was unsuccessful; but another, made under the patronage of the celebrated COLBERT, in which French workmen who had acquired a knowledge of the art at Murano were employed, had better fortune. But a few years afterwards, this establishment, which was situated in the village of Tourlaville, near Cherbourg, in Lower Normandy, was also threatened with ruin by a discovery or rather improvement in the art of glass-making, effected by one ABRAHAM THEVART. This improvement consisted in casting plates of much larger dimensions than it had hitherto been deemed possible to do. THEVART's first plates were cast at Paris, and astonished every artist by their magnitude. They were eighty-four inches long and fifty inches wide, whereas none previously made exceeded forty-five or fifty inches in length.

In 1695 the two companies, THEVART's and that at Tourlaville, united their interest, but were so unsuccessful, that in 1701 they were unable to pay their debts, and were, in consequence, compelled to discharge most of the workmen, and abandon several of their furnaces. Next year, however, a company was formed, under the management of ANTOINE D'AGINCOURT, who re-engaged the discharged workmen; and the works realized considerable profits to the proprietors—a circumstance which is attributed wholly to the prudent management of D'AGINCOURT.

Early in the fourteenth century, the French government made a concession in favor of glass-making, by decreeing, that not only should no derogation from nobility follow the practice of the art, but that none, save gentlemen or the sons of noblemen, should venture to engage in any of its branches, even as working artisans. This limitation was accompanied by a grant of a royal charter of incorporation, conveying important privileges, under which the occupation became eventually a source of great wealth to several families of distinction.

It has been said that the manufacturing of window-glass was first introduced into England in the year 1557. But a contract quoted by HORACE WALPOLE proves that this article was made in England upwards of a century before that period. This curious document is dated 1439, and bears to be a contract between the Countess of WARWICK and JOHN PRUDDE of Westminster, glazier, whom she employed, with other tradesmen, to erect and embellish a magnificent tomb for the Earl, her husband. JOHN PRUDDE is thereby bound to use no glass of England, but glass from beyond seas; a stipulation which, besides showing that the art of making window-glass was known and practised in England in the fifteenth century, seems also to indicate that the article made was inferior to what could be obtained from abroad. The finest sort of window-glass was first made at Crutched Friars, London, in 1557. The first flint-glass made in England was manufactured at the Savoy House, in the Strand; and the first plate-glass, for looking-glasses, coach windows, and similar purposes, was manufactured at Lambeth by Venetian workmen, brought over in 1670 by the Duke of BUCKINGHAM. From that period the English glass manufactories, aided by the liberal bounties granted them in cash upon glass sold for export, became powerful and successful rivals of the Venetian and French manufactories. The bounty on glass exported, which the government paid to the manufacturer, was not derived from any tax by impost or excise previously laid; for all such were returned to the manufacturer, together with the bounty, thereby lessening the actual cost of the article from twenty-five to fifty per cent., and enabling the English exporter to compete successfully in foreign markets. This bounty provision was annulled during the premiership of Sir ROBERT PEEL, together with all the excise duty on home consumption.

The art of glass-making was introduced into Scotland in the reign of JAMES VI. An exclusive right to manufacture it within the kingdom, for the space of thirty-one years, was granted to Lord GEORGE HAY in the year 1618. This right his lordship transferred in 1627, for a considerable sum, to THOMAS ROBINSON, merchant-tailor in London, who again disposed of it for two hundred and fifty pounds to Sir ROBERT MANSELL, vice-admiral of England. The first manufactory of glass in Scotland, an extremely rude one, was established at Wemyss, in Fife. Regular works were afterwards commenced at Prestonpans, Leith, and Dumbarton.

Crown-glass is now manufactured at Warrington, St. Helen's, Eccleston, Old Swan, and Newton, Lancashire; at Birmingham, Hunslet, near Leeds, and Bristol. It is also fabricated of excellent quality on the Tyne and Wear. Great improvements have recently been made in the manufacture of crown-glass, and it is asserted that this article, as made in England, is superior in quality to that of any other nation.

According to BALLANTYNE, the manufacture of glass was introduced into the American States in 1790, by ROBERT HEWES, a citizen of Boston, who erected a factory in the then forest of New Hampshire. The chief aim of Mr. HEWES was to supply window-glass, but he did not succeed. Another attempt was made in 1800, when a factory was built at Boston for making

crown window-glass; but this was also unsuccessful, till a German named LINT, in 1803, took charge of the works, and the state of Massachusetts agreed to pay the proprietors a bounty on every table of window-glass they made, after which the manufacture was carried on successfully, the glass steadily improving in quality, and becoming famed through all the States as Boston window-glass. The same company erected new and more extensive works at Boston. The mystery attached to the art of glass-making followed it into America. The glass-blower was considered a magician, and myriads visited the newly-erected works, looking on the man who could transmute earthy and opaque matter into a transparent and brilliant substance, as an alchemist who could change base metal into gold.

Since the manufacture of flint-glass originated in the Eastern States, there have been above forty companies formed from time to time, nearly thirty of which have proved failures. There are now ten in operation, two of which are at East Cambridge, three at South Boston, one at Sandwich, three near New York city, and one at Philadelphia. Forty-eight thousand tons of coal, six thousand five hundred tons of silica, two thousand five hundred tons ash, nitrate of soda, *et cetera*, and three thousand eight hundred tons of lead, are annually consumed in the manufacture of flint-glass.

In the vicinity of Pittsburgh, in the Western States, are nine manufactories of flint-glass, and ten of window-glass, and in the river towns are fifteen window-glass factories.

There is good reason for supposing that the art of staining or painting glass is coeval with the art of making glass itself, since, as will be afterwards seen, it is difficult to make it without color. The possibility of subjecting this propensity to the will of the manufacturer must have very obviously presented itself, although it certainly requires much art and chemical knowledge to produce perfect specimens of this description of manufacture. This perfection seems, however, to have been attained at a very early period. It is certain that the art was known in Egypt three thousand years ago. The beautiful imitations of precious stones found adorning mummies which are known to have existed for that time have been already noticed; and frequent mention of specimens of Eastern workmanship of consummate beauty are met with, upon which great value was placed. Allusion has also been made to the fact, that the Emperor ADRIAN, whilst at Alexandria, was presented, by an Egyptian priest, with two glass cups, which sparkled with hues of every kind, and which had been used in the service of the temple—a present so highly prized by the Emperor, that he ordered them to be produced only on festivals and great solemnities. The works of CAYLUS and WINKELMANN furnish some striking instances of ancient skill in the formation of pictures by means of delicate glass fibres of various hues, which, after being fitted together with the utmost nicety, were conglutinated by fusion into a solid mass. The art of combining the various tints, so as to produce pictures in the manner now practised, is comparatively of recent date. The earliest specimens of this kind of work discover a factitious joining of different pieces of glass, differently tinted, and so ar-

ranged as, by a species of mosaic work, to produce the figure or figures wanted. The various pieces are held together generally by a vein of lead, run upon the back of the picture, precisely at their junction.

But modern ingenuity has superseded this clumsy expedient; and every color used in painting can now be introduced into one entire sheet. For a long period the pictured glass used in cathedrals was merely painted on the surface, the art of incorporating the tints with the glass by fusion, the method now practised, being unknown till the beginning of the fifteenth century. This great improvement is ascribed to a painter of Marseilles, who went to Rome during the pontificate of JULIUS II.; but his discovery went no further than the producing of different colors on different pieces of glass, and having them afterwards united in the old fashion. This art was, at a later period, greatly improved by ALBERT DURER and LUCAS of Leyden, the latter of whom brought it nearly to the state of perfection in which it now exists.

The first painted glass executed in England was in the time of King JOHN; previous to this, all stained or painted glass was imported from Italy. The next notice of it occurs in the reign of HENRY III. The treasurer of that monarch orders that there be painted, on three glass windows in the chapel of St. JOHN, a little Virgin Mary holding the Child, and the Trinity, and Saint John the Apostle. Some time after he issues another mandate for two painted windows in the hall.

Even at this early period, however, England boasted of eminent native artists in glass painting, amongst the first of whom was JOHN THORNTON, glazier of Coventry. This person was employed, in the time of HENRY IV., by the dean and chapter of York cathedral, to paint the eastern window of that splendid edifice; and for the beautiful and masterly workmanship which he exhibited in this specimen of skill, he received four shillings per week of regular wages. He was bound to finish the work in less than three years, and to receive, over and above the weekly allowance, one hundred shillings for each year; and if the work was finished to the satisfaction of his employers, he was to receive, on its completion, a further sum of ten pounds. It must be recollected that the value of money was at that time much higher than in modern days.

From this period downwards there have been many skilful native artists, although the Reformation greatly impeded the progress of the art, by banishing what was deemed the ungodly ostentation of ornamented windows from churches; indeed, so serious was this interruption, that the art had nearly altogether disappeared in the reign of ELIZABETH. Amongst the most eminent glass painters who first appeared upon the revival of the art, were ISAAC OLIVER, born in 1616, and WILLIAM PRICE, who lived about the close of the seventeenth century. This last person was for many years the only glass painter in England. He is said to have discovered, what is to this day a desideratum in the art of glass staining, the secret of producing a rich, clear, bright, and transparent red, the most difficult to strike, and the most expensive of all the hues employed in glass painting. But PRICE having died soon after making this discovery, his secret was never divulged. This

artist was succeeded by a person at Birmingham, who, in 1757, fitted up a window for Lord LYTTLETON, in the church of Hajely. To him succeeded one PECKIT of York, who attained considerable eminence in the art.

During all this time, however, and indeed until a comparatively recent date, painted glass was regarded as too costly and too magnificent an article to be otherwise employed than in decorating religious edifices, or the palaces of nobles; and even in the latter case was but sparingly used. Modern improvement has now placed this beautiful ornament within the reach of very ordinary circumstances; and when this is considered, it must excite a strong feeling of surprise to find how little so elegant a luxury is even yet in demand. The art of staining glass is now practised with very great success. The colors of modern artists, notwithstanding what is often urged to the contrary, equal in variety and richness those of the ancients; and, with the superior knowledge which is now possessed of the principles of drawing, and of bringing several colors together on a single sheet, encouragement alone is wanting to attract artists of talent and inventive genius to the pursuit of the art, and to carry it to a greater degree of excellence than it has ever reached in the hands of their predecessors.—*Encyclopædia Britannica*.

NATURE AND COMPOSITION OF GLASS.—The researches of BERZELIUS having removed all doubts concerning the acid character of silica, the general composition of glass now presents no difficulty of conception. This substance is the product of fusion at a high temperature of silica, or silicic acid, sometimes of boracic acid, with different salifiable bases, as potassa, soda, lime, magnesia, baryta, oxide of lead, oxide of tin, protoxide of iron, protoxide of manganese, alumina, and the sesquioxide of iron, and binoxide of manganese; the product solidifies after fusion in the form of a transparent mass, which is either colorless or not, according to the ingredients which it contains; it combines a great degree of hardness with the property of resisting the destructive action of air, water to a certain extent, and even that of the more powerful chemical agents.

It is well known that silica acts the part of a powerful acid at the temperature of a red heat, and is capable of expelling carbonic acid, hydrochloric acid, *et cetera*, from compounds, and combining with the bases named above, giving rise to solid combinations. Glass, in short, is a true salt—a silicate, and is an artificial production of a similar character to those compounds which occur so abundantly in nature; it differs, however, from these in one essential particular, that it possesses a distinctly non-crystalline structure; or is, as it is scientifically termed, *amorphous*. Glass, as is well observed by KNAPP, may be said to bear the same relation to a natural silicate of like composition, that melted sugar does to the ordinary crystallized substance.

Special Effect of the Different Constituents.—Although, in a purely chemical view, the potassa, soda, lime, oxide of lead, alumina, and oxide of iron, perform the same part, it is, nevertheless, very evident that, in practice, the employment of one of these bodies cannot be substituted indifferently for that of one or other of its analogues. There necessarily results in the product differences of fusibility, of ductility, of hardness, *et cetera*,

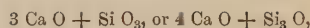
which must be taken into consideration. Hence the necessity of classing glasses according to their composition and properties. This classification will be given afterwards. In the meantime, the characteristic effect of the different constituents on the nature of the glass may be briefly stated:—

The *silicates of soda and potassa* are the most fusible, and so much the more in proportion to the greater amount of the alkaline bases. One part of silica with two to three of potassa or soda, produces a glass which is fusible at a cherry-red heat, and soluble in cold water. Equal parts of alkali and silicic acid—silica—form a glass readily fusible, but imperfectly soluble. One equivalent of soda or potassa combined with six equivalents of silicic acid, and therefore represented by the formula,



yield a compound fusible only by the heat of a very powerful forge. Potassa is more efficacious than soda in rendering the glass easy of fusion. A more brilliant lustre results from the use of soda, but at the same time a bluish-green tint is communicated to the glass. No coloring action is exerted by potassa; but the brilliancy of the glass is somewhat diminished by it.

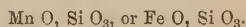
The *silicates of lime* are much less fusible than those of the alkalis. The most fusible of the former, represented by the formula $\text{Ca O} + \text{Si O}_3$, requires for its fusion the violent heat of a forge. The others, represented by



are only softened at the same temperature; the corresponding *silicates of magnesia* are not more fusible. Lime increases the hardness of the glass, and adds more to its lustre than the alkalis, without coloring the produce.

The *silicates of alumina* are still more refractory than the preceding. The least infusible, represented by $\text{Al}_2 \text{ O}_3$, 3 Si O_3 , is scarcely softened in the heat of a furnace. Of all the ingredients, alumina exerts the most powerful effect in increasing the difficulty of fusion.

The *silicates of the protoxides of iron and manganese* are more fusible than those of lime and magnesia, especially when they consist of one equivalent of each ingredient, thus—



The silicate of protoxide of iron has a dark-green color, but may be decolorized by bringing it to the state of a silicate of the sesquioxide; this is effected by adding a small quantity of binoxide of manganese. Care must be taken not to add it in excess, for in this case it would communicate a violet color to the glass. The binoxide, Mn O_2 , when added in small quantity, is converted into protoxide, Mn O ; but if any excess has been employed, it becomes reduced at a red heat to sesquioxide, $\text{Mn}_2 \text{ O}_3$, and produces a deep amethystine red glass.

The *silicates of the oxides of lead* are the more fusible in proportion to the greater amount of the base. With equal equivalents, the silicate of lead, $\text{Pb O} +$

SiO_2 , melts at a red heat. In fact, oxide of lead exerts a directly opposite action to alumina, being a prominent ingredient in the easily fusible varieties of glass, which are also characterized by great softness, a high brilliancy, perfect absence of color, and by the property of refracting light more powerfully than any other kind. The silicates of the oxide of zinc present analogous properties.

Baryta also exerts a similar, although less energetic action than lead.

These different silicates react on one another, and reciprocally modify each other; in composition, they become more stable, less fusible, and less subject to crystallize. Hence the advantage of the complex proportions employed in the glass and crystal manufactures.

When *boracic acid* is added, it forms boro-silicates, often more fusible, more ductile, easier to work, and producing less waste, especially in table-ware and plate-glass manufacture. M. PAYEN remarks that the experiments undertaken by MM. MAES and CLEMANDOT on crystal, with a base of oxide of zinc, yielded products remarkable for their whiteness, their transparency, their hardness, and the brilliant reflection of their cut faces.

In the words of KNAPP, it follows, as a general conclusion, from what has been stated, that those varieties of glass which possess the highest degree of lustre and power of refraction, will also be the softest—that is, the most easily scratched. They are likewise those which exhibit the highest specific gravity—from 2.8 to 3.6—and, as might be deduced from that circumstance, they—at least as far as the colorless glasses are concerned—are those which contain bases with a very high atomic weight—oxide of lead, baryta. Those bases, on the contrary, which render the glass hard and durable, appear to produce little lustre or power of refraction. The specific gravity of these varieties lies between 2.37 and 2.56. Strictly speaking, the alkalies, lime, and oxide of lead, are the only bases expressly contained in the mixture for the manufacture of glass, without reference to the different coloring and decoloring matters. Magnesia sometimes accompanies the lime, and enters, but in small quantity only, into the composition of the glass. Alumina and oxide of iron are, in like manner, only casual constituents, being contained as impurities in the other ingredients. Even in those cases where these two bases enter in large quantities into the composition of glass, they are never expressly added to the mixture; but are always derived from the impure materials. Thus, in the manufacture of ordinary bottle-glass, where color is of no moment, substances containing iron and alumina are employed. The origin of the small quantity of alumina which is found in glass that should properly be free from it, must be traced to the sides of the pots or crucibles in which the glass has been fused.—*Knapp*.

The metallic oxides which have not been mentioned, as those of gold, silver, copper, give rise to a great variety of intense colors, and are consequently used in the manufacture as pigments.

Commercial varieties of Glass.—Before proceeding to a more minute inquiry into the physical and chemi-

cal properties of glass, as these are affected by differences either in the ingredients or their properties, or in the processes followed, it will be proper to place before the reader a summary view of the characters and composition of the different varieties of glass, as preliminary to a more detailed exposition, not only of the special properties, but also of the special manufacture of each of these varieties.

There is much difficulty in dividing the glasses according to any definite principle. One of the simplest arrangements is given by TOMLINSON, as follows:—

1. Silicate of potassa and oxide of lead. Examples:—*Flint-glass, crystal, and strass*.

2. Silicate of soda and lime; or silicate of potassa, soda, and lime. Examples:—*Common window, English crown, and plate*.

3. Silicate of potassa and lime. Examples:—*Foreign crown, refractory Bohemian glass*.

4. Silicate of soda, lime, alumina, and oxide of iron. Example:—*Coarse green wine-bottle glass*.

The following arrangement, somewhat similar to that proposed by KNAPP, will form the basis of that adopted in the present article, beginning, as a general rule, with the coarser, and advancing by a pretty regular gradation to the finer or rarer varieties.

1. BOTTLE-GLASS, or what is more properly described by the German term *Hohlglase*, or *Hollow glass*, comprises all glass worked into the form of vessels or tubes. According to the purity of the *metal*, which is the technical term given to glass in the fused state, this variety is subdivided into different qualities, such as—*Ordinary bottle-glass*, consisting of silica, potassa or soda, lime, alumina, and oxide of iron; *glass used for medicinal bottles*, consisting of silica, soda, lime, some alumina, and a very little protoxide of iron; *white bottle-glass* for bottles or phials, tumblers, tubes—containing silica, soda or potassa, and lime. It is evident, therefore, that under the general term *Bottle-glass* or *Hohl-glass*, are included different vitreous compositions. Its distinguishing characteristic, as applied to ordinary bottle-glass, is the presence of protoxide of iron; and therefore it may be described, in general terms, as a silicate of potassa or soda, of lime, of alumina, and oxide of iron.

2. WINDOW-GLASS, including *English crown* and *cylinder* or *sheet-glass*: this is a silicate of potassa or soda, lime, and alumina.

3. PLATE-GLASS, composed of silica, soda, or potassa, lime, and a little alumina. This variety only differs from the preceding by the greater purity and freedom from color of the materials.

4. FLINT-GLASS, used for grinding, *et cetera*, composed of silica, potassa, and oxide of lead.

5. CRYSTAL, for optical purposes and table-ware, consists of silica or boracic acid, potassa, and more lead than the preceding. In short, it is a simple flint-glass, formed with very pure materials.

6. STRASS, or the substance composing the imitation of precious stones, known as paste, consists of silica, potassa, with a still larger amount of oxide of lead, and colored by various materials.

7. ENAMEL, a silicate and stannate or antimoniate of potassa or soda, and of oxide of lead. It may be other-

wise described as composed of silica, soda or potassa, and oxide of lead,—rendered opaque by oxide of tin or antimony.

8. **SOLUBLE GLASS**, which is a simple silicate of potassa or of soda, or a mixture of these two silicates.

The manufacture, the distinguishing properties, and the special applications of these different kinds of glass, will be described afterwards. *Strass* and *enamel* have been already treated under the latter head, and will, therefore, be only briefly alluded to in the present article. The *soluble glass*, which is used only for special purposes, such as a protective varnish for pictures, a fireproof coating for building-materials, *et cetera*, is scarcely entitled to be ranked as a true glass; but its character and applications will be stated in a future page. In the meantime, the following tables, which are given by KNAPP, with notes by RICHARDSON and RONALDS, will be found useful for reference, as showing the proportional composition of the more important glasses according to different analysts of high authority:—

BOTTLE-GLASS.

Variety of Glass.	Analysts.				
	Berthier.			Dumas.	
	1.	2.	3.	4.	5.
Silica,	60.0	60.4	59.6	53.55	45.6
Soda,	3.1	3.2	—	—	—
Potassa,	3.1	3.2	3.2	5.48	6.1
Lime,	22.3	20.7	18.0	29.22	28.1
Magnesia,	—	0.6	7.0	—	—
Baryta,	—	0.9	—	—	—
Oxide of manganese,...	1.2	—	0.4	—	—
Alumina,	8.0	10.4	6.8	6.01	14.0
Oxide of iron,	4.0	3.8	4.4	5.74	6.2
Oxide of manganese, ...	—	—	—	—	—
Relation between the oxygen of the acid, and the total amount of oxygen contained in the bases,.....	5 : 2	?	7 : 3	2 : 1	4 : 3
Relation between the oxygen in the bases with one equivalent of that element, and that contained in the bases with three equivalents of oxygen,...	4 : 3	?	2 : 1	2 : 1	1 : 1

No. 1—Glass from Souvigny. No. 2—From St. Etienne. No. 3—From Epinac. No. 4—From Sèvres, near Paris. No. 5—From an unknown glass-house, but of French manufacture.

BOHEMIAN GLASS.—The Bohemian flint-glass is distinguished from the others by containing no lead.

Mr. ROWNEY has lately analysed the Bohemian hard glass tubing, so indispensable to chemists in the prosecution of researches in organic chemistry, and finds it to be essentially a silicate of lime and potassa, in which the oxygen in the silicic acid is to that contained in the bases as 6 to 1. Analysis yielded:—

	Centasimally represented.
Silica,	73.0
Potassa,	11.5
Soda,	3.0
Lime,	10.5
Magnesia,	—
Alumina,	—
Sesquioxide of iron,	2.0
Oxide of manganese,	—
	100.0

It may, however, be remarked, that this tubing is by no means of uniform composition, as all who have been much occupied with organic analysis will have found to their cost; some tubes being much more fusible than others.

The opal is very similar to hyalite, *muller glass*, a hydrate of silica. The composition is remarkable: it is a simple silicate of potassa, which, from being imperfectly melted, remains semi-transparent, with pieces of quartz dispersed through the mass. It does not attract moisture, and is not attacked by boiling water. It differs from FUCH's soluble glass, by containing ten per cent. more silica.

The Venetian contains also traces of magnesia and phosphoric or boracic acid; the crystals appear disseminated through the mass, which is of a yellow tint, and transparent in thin sheets. The tin and iron obviously assist in the formation of the crystals of metallic copper, after which the tin becomes silicate of the protoxide, otherwise the glass would become opaque.

MEDICINAL GLASS.

Variety of Glass.	Analyst—Berthier.			
	1.	2.	3.	4.
Silica,	71.6	62.5	69.6	62.0
Soda,	—	—	3.0	16.4
Potassa,	10.6	10.5	8.0	—
Lime,	10.0	16.2	13.0	15.6
Magnesia,	—	—	0.6	2.2
Alumina,	3.0	4.5	3.6	2.4
Oxide of manganese,	0.3	1.2	—	—
Oxide of lead,	1.5	2.5	1.6	0.7
Relation between the oxygen of the acid and the total amount of oxygen in the bases,	6 : 1	7 : 2	9 : 2	5 : 1
Relation between the oxygen in the bases with one equivalent of that element, and that contained in the bases with three equivalents of oxygen,	2 : 1	7 : 3	3 : 1	9 : 1

All the varieties were of French manufacture.

DIFFERENT VARIETIES OF WHITE GLASS.

Variety of Glass.	Analysts.				
	Berthier.	Gros.	Dumas.	Berthier.	Dumas.
	1.	2.	3.	4.	5.
Silica,	71.7	71.6	69.4	69.2	62.8
Soda,	12.7	11.0	11.8	15.8	22.1
Potassa,	2.5	—	—	3.0	—
Lime,	10.3	10.0	9.2	7.6	12.5
Magnesia,	—	2.3	—	2.0	—
Oxide of manganese, ...	0.2	0.2	—	—	—
Alumina,	0.4	2.2	9.6	1.2	2.6
Oxide of iron,	0.3	3.9	—	0.5	2.6
Relation between the oxygen of the acid, and the total amount of oxygen in the bases,	6 : 1	6 : 1	4 : 1	4 : 1	5 : 1

1. Specimen of a goblet from Neufeld in Bohemia. 2. Specimen from the same place. 3. Bohemian glass. 4. Specimen of easily fusible French glass tubing. 5. Specimen of crown-glass.

WINDOW-GLASS.

Variety of Glass.	Analysts.								
	Dumas.							Richardson	Cowper.
	1.	2.	3.	4.	5.	6.	7.	8.	9.
Silica,	69.65	69.25	68.55	68.65	68.5	68.0	69.0	66.37	71.4
Soda,	15.22	11.30	12.88	17.70	13.7	10.1	11.1	14.23	15.0
Lime,	13.31	17.25	16.17	9.65	7.8	14.3	12.5	11.86	12.4
Alumina,	1.82	2.20	2.40	4.00	10.0	7.6	7.4	8.16	0.6
Relation between the oxygen of the acid, and the total amount of oxygen in the bases,	4:1	4:1	4:1	4:1	7:2	7:2	7:2	7:2	9:2

The numbers from 1 to 6 are of French origin; numbers 7, 8, and 9 are English.

The specimen was analysed by COWPER, manufactured by Messrs. CHANCE of Birmingham, and is remarkable for containing more silica and less alumina than any of the other varieties. Mr. COWPER also found 0.3 oxide of iron, and 0.3 oxide of manganese in this sample.

PLATE-GLASS.

Variety of Glass.	Analysts.				
	Berthier.	Tassaers	Dumas.		Berthier.
	1.	2.	3.	4.	1.
Silica,	72.0	76.0	75.9	73.85	68.6
Soda,	—	—	—	5.50	6.9
Potassa,	17.0	17.0	17.5	12.05	8.1
Lime,	6.4	6.0	3.8	5.60	11.0
Magnesia,	—	—	—	—	2.1
Alumina,	2.6	—	2.8	3.50	1.2
Oxide of manganese, ...	—	—	—	—	0.1
Oxide of iron,	1.9	1.0	—	—	0.2
Relation between the oxygen in the acid, and the total amount of oxygen in the bases,	6:1	?	7:1	7:1	5:1

The last specimen was Venetian, the others were French glass.

CRYSTAL.

Variety of Glass.	Analysts.				
	Berthier.		Dumas	Faraday.	
	1.	2.	3.	4.	5.
Silica,	59.2	56.0	51.4	56.0	51.93
Potassa,	9.0	6.6	9.4	8.9	13.67
Lime,	—	—	—	2.6	—
Alumina,	—	1.0	1.2	—	—
Oxide of lead,	28.2	34.4	37.4	32.5	33.28
Oxide of manganese, ...	1.0	—	—	—	—
Oxide of iron,	0.4	—	0.8	trace	—
Relation between the oxygen of the acid, and the total amount of oxygen in the bases,	8:1	8:1	6:1	6:1	6:1

1. From London, intended for optical instruments. 2. From Veneche in Belgium. 3. From Newcastle. 4. Of unknown origin. 5. From England.

The oxide of lead which is used in the manufacture of crystal, is not the protoxide commonly known as *massicot*, and represented by the formula PbO , but *minium*, which is a sesquioxide, Pb_2O_3 ; for, as BAR- RUEL remarks, one may depend on the latter not being mixed with metallic lead, which almost necessarily happens with the *massicot* of commerce. The object of employing oxide of lead in this kind of glass is to increase the density, and, consequently, the refractive power, which gives the glass a peculiar lustre or brilliancy.

FLINT-GLASS, STRASS, AND ENAMEL.

Variety of Glass.	Analysts.			
	Faraday.	Dumas.	Dumas.	Dumas.
	Flint-glass from Guinand.	Strass manufactured by Donald Wiedland.	Enamel.	
Silica,	44.3	42.5	38.5	31.6
Potassa,	11.75	11.7	7.9	8.3
Lime,	—	0.5	—	—
Alumina,	—	1.8	1.0	—
Oxide of lead,	43.05	43.5	53.0	50.3
Oxide of tin,	—	—	—	9.8
Relation between the oxygen in the acid, and the total amount of oxygen in the bases,	9:2	4:1	7:2	7:3

The following analyses by PELIGOT are given by RICHARDSON and RONALDS as quite recent:—

	Bohemian glass.	Bohemian opal-glass.	Venetian aventurine.	Bohemian mirror-glass.
Silica,	76	80.9	67.7	67.7
Potassa,	15	17.6	5.5	21.0
Soda,	—	—	7.1	—
Lime,	8	7	8.9	9.9
Alumina,	1	8	—	1.4
Oxide of tin,	—	—	2.3	—
Oxide of lead,	—	—	1.1	—
Copper,	—	—	metallic 3.9	—
Oxide of iron,	—	traces	3.5	—
	100	100.0	100.0	100.0

Chemical Constitution of the Different Glasses.—From a careful inspection of the preceding tables, it will be seen that all the constituents of the different varieties of glass are in a state of chemical combination. It follows that the individual constituents must be united in equivalent proportions; and though these relations are sometimes difficult to trace, in consequence of different oxides replacing each other, still, the regularity of the composition is always shown by the existence of a simple relation between the collective amount of oxygen in the bases, and that contained in the silica or silicic acid. The combination in definite proportions is rendered more obvious, as KNAER observes, when the empirical formulæ are deduced from the composition in 100 parts. Thus, by referring to the numbers of the columns in the preceding tables, the composition in 100 parts of each of the glasses specified, will be represented as follows:—

Bottle-glass, No. 5,	corresponds to	$\text{KO} + 8 \text{CaO} + 2 \text{Al}_2\text{O}_3 + \text{F}_2\text{O}_3 + 8 \text{SiO}_3$;
Window-glass, No. 2,	"	$3 \text{NaO} + 5 \text{CaO} + 12 \text{SiO}_3$;
Plate-glass, No. 1,	"	$2 \text{NaO} + \text{CaO} + 6 \text{SiO}_3$;
White Crown-glass, No. 5,	"	$\text{KO} + \text{CaO} + 3 \text{SiO}_3$;
Crystal, No. 2,	"	$\text{KO} + 2 \text{PbO} + 8 \text{SiO}_3$;
Flint-glass, No. 2,	"	$6 \text{KO} + 9 \text{PbO} + 20 \text{SiO}_3$;
Strass, No. 1,	"	$3 \text{KO} + 9 \text{PbO} + 16 \text{SiO}_3$; <i>et cetera.</i>

KNAPP further justly remarks, that although more probable suppositions may be formed with reference to the manner in which the silica is divided amongst the bases, and although the preceding calculations do not lead to any rational formulæ, yet the knowledge of the empirical composition for any species of glass, as represented in the examples above given, is nevertheless a very valuable guide in mixing the ingredients for its manufacture, and of great service in improving or correcting the prescribed rules.

Comparative Fusibility of the Glasses.—Under the influence of a cherry-red heat and upwards, the different kinds of glass are all capable of being first softened and then undergoing a complete fusion. At the same time, the difficult fusibility of the bi and tri silicates, or those in which the acid preponderates, and the opposite properties of those which contain a larger proportion of base, are very important facts in connection with the manufacture of glass. Silicic acid *per se*, is perfectly infusible in every furnace, but it acquires the property of fusibility in a greater or lesser degree, according to the quantity of base with which it is mixed. Glass-makers, in short, call all the bases *fluxes*, and are well aware that the work is facilitated and fuel saved by increasing the amount of flux in the mixture; but, at the same time, they know that the addition of flux cannot exceed a certain limit without detriment to the durability of the glass. When glass is attacked by reagents, under ordinary circumstances, it is always a result of the removal of base; but this is a subject for future consideration. As already stated, glasses with a lead base are the most fusible, and the more so in proportion as they contain a more considerable quantity of oxide of lead. Common glasses, on the contrary, are less so, the more lime and alumina they hold. Thus, strass, flint-glass, and crystal, are more fusible than common or window-glass, and the latter is a little more so than bottle-glass.

Imperfect Fluidity of Glass.—The possibility of casting or moulding glass, as well as its purification, depends upon the fact that at very intense heats the so-called *metal* is tolerably fluid, though still possessing a consistence which may be compared to that of weak sirup. In this state the heavier impurities are enabled to subside to the bottom, while the bubbles of gas, which too often form flaws in glass, rise by their levity to the surface. At a brisk red heat, on the contrary, the metal is only in a semi-fluid state, and on this peculiar and valuable property depends the possibility of working it into every variety of form. In this state it is an exceedingly tough, thick mass, possessing great ductility, and capable of being drawn out into the finest threads, or blown into the form of the thinnest hollow spheres. In short, it is evident that the usual methods of working glass by *blowing*, and of soldering different pieces together by simple pressure or contact,

would be quite impracticable, unless the mass possessed these properties.

BRITTLINESS.—When glass has been heated to the softening point, and exposed to a rapid cooling, it is very brittle; when, on the contrary, it is submitted to a slow cooling, it becomes capable of resisting pretty severe shocks without breaking, and it stands equally well sudden variations of temperature. These phenomena have been compared to the tempering of steel; and although the explanations which have been given of them are not quite satisfactory, yet it will be necessary to enter into some details, on account of the practical importance of the subject. The metamorphosis has been attributed to unequal crystallization. It will be seen afterwards that the particles of glass always exhibit in the fluid state a tendency to arrange themselves in a regular manner, and form crystals. Now, when the mass is cooled suddenly, no time is allowed the particles to follow this tendency, and they are forced, as it were, against their inclination to remain in that relative position towards each other which they assumed during the working, or, in other words, to form an amorphous mass. This forced relative position of the particles is greatest where the glass has been rapidly cooled; the interior of the mass is, therefore, not so subject to it as the surface, and this latter also contracts in a greater degree. The outer layers are, consequently, in a state of tension, with reference to those in the interior. It is obvious, from these facts, that there must be a want of uniformity in the attractions of the particles of glass for each other; that a tendency to subvert the force of cohesion has been induced, which the slightest impulse from without will be sufficient to call into action. This circumstance perfectly explains the brittle nature of glass, which sometimes rises to a very extraordinary degree. For example, if one takes a little melted glass, and allows it to fall, drop by drop, into cold water, each drop will suddenly solidify, and will take a form generally spheroidal or ovoidal, terminated by a tail which ends in a rapidly tapering point, *a*, as represented in Fig. 135. The surface of this drop of glass is harder than ordinary. But by merely breaking off the point, the

Fig. 135.



tension is called into play, and the whole mass flies to pieces, or rather is instantly converted into a fine powder, with a slight detonation. These little articles are known, from their great brittleness, under the name of *Rupert's drops*.

The effect is explained by DUMAS, by supposing that by the immersion in cold water the surface of the glass is suddenly solidified, the central parts being still fire-

red, and consequently much dilated. When these last become solidified and cooled down, they must have retained points of adherence to the surface, and consequently occupy a larger volume than that which agrees with the temperature to which they are reduced; the central molecules are, therefore, more distended than usual, and exert a powerful contracting force on the surrounding parts. At the instant when a part of the envelope or outer portion is broken, the molecules which had been retained by it briskly contract, draw in with them all the others, and thus determine a multitude of points of rupture; as this effect is instantaneous, each fragment is shot with force, and drives the air before it; this fluid, therefore, undergoes a sudden dilatation and contraction, from which results the detonation that is heard.

The same effect is produced under another form, in what is termed the *Bologna* or *philosophical phial*—Fig. 136. This is a kind of short tube, thick, and closed

Fig. 136.



at one end, which is obtained at crystal manufactories, by blowing a small portion of glass to judge of the state of the metal in the pots during the melting. These tubes are very thick, for they must be sufficiently so to allow of appreciating exactly the tint of the glass. They are exposed to a rapid cooling, because the object which they are intended to serve does not require that any care should be taken in that respect.

This cooling is even accelerated by shaking in the air the rod which supports the small tube. The latter is then, in point of fact, in a state very analogous to that of the Rupert drops, and DUMAS explains their remarkable brittleness in the same manner. The interior parts have undergone a slow, and the exterior parts, on the contrary, a rapid cooling; and when these tubes are struck, even very strongly, on the outside, they do not break, while the slightest stroke on the inside is sufficient to make them fly in pieces, with a detonation similar to that which occurs in the case of the Rupert drops. A small marble, a bit of glass allowed to fall into the interior of the tube, is sufficient to make it burst asunder.

Phenomena more or less analogous to these happen with glass vessels of some thickness, which are sold for common uses. By slight variations of temperature, such as occur when they are carried from a room without a fire into a warm room, it sometimes happens that these glasses suddenly burst without any apparent cause. It is obvious, that the thicker the glasses, the more readily will effects of this kind be produced. Tubes of glass somewhat thick, and especially those which are of unequal thickness, are also very subject to split, and usually the crack is prolonged through the whole length of the tube. But glass tubes are not submitted to that particular operation, the object of which is to render glasses less liable to break by sudden changes of temperature. This operation is termed *annealing*, and consists in submitting the glass to a very slow refrigeration. The details of the process will be described in connection with the general arrangements of the glass-house and its furnaces, among which the annealing arch or oven takes an important place.

It would seem that the ordinary annealing of glass, whether it be that the operation is badly performed, or that it has not a durable effect, always leaves something to be desired. For some articles, a method of annealing is employed which is very simple, but, at the same time, expensive, if required to be applied on a large scale. It consists in placing the glass vessels in a trough or pan, taking the precaution to separate them by a little hay or straw. The vessels and the pan are filled with water, and the liquid is brought to ebullition. The whole is then left to cool slowly. The vessels thus treated are, so to speak, insured against any rapid change of temperature, comprised within the interval of 180° Fahr., or thereabouts. By using a bath of water charged with some salt, an oil-bath, or a bath of fusible alloy, this method might be extended to higher temperatures.

The efficacy of the process rests on the great difference which exists between the conducting power of air and that of liquids. There is no doubt that in the operation of annealing in the air, different points of the surface are cooled at different rates, a circumstance which can never occur when the annealing is effected under a liquid mass. It is well known in laboratories, that vessels which have accidentally undergone an annealing of this kind, are thereby rendered very fit to support, without breaking, rapid changes of temperature.

On the whole, although the brittleness of glass is not entirely obviated by the most careful annealing, yet it is so modified that the vessels, with a little care, can be used for all ordinary purposes. Sudden change of temperature, or partial application of heat, will cause the fracture of unannealed glass quite as surely as a blow, by expanding it more at one part than another.

DEVITRIFIED, OR SEMI-CRYSTALLISED GLASS.—As excessive brittleness results from the sudden cooling of glass, so, on the other hand, when the fused metal is cooled too slowly, the amorphous state entirely disappears, the mass assumes a crystalline structure, and other changes occur which are termed *devitrification*. If the glass contain different bases, a partial separation takes place; the silica divides itself between the bases, and thus forms compounds of definite proportions which crystallize separately. In this case the intimate mixture of the materials which constitute the true glass is destroyed; the glass becomes *very hard, fibrous, opaque, much less fusible, a better conductor of electricity and of heat*. The first glass of this kind was produced and described by RÉAUMUR, and was termed by him *devitrified glass*.

The devitrification of glass is a general phenomenon, which exhibits itself in all kinds of glass, but especially in glass with several earthy bases, and more difficultly in plumbiferous glasses, or glasses simply alkaline. It is almost always produced by melting the glass, and allowing it to cool very slowly, or else by heating the glass to the softening point, and submitting it to a prolonged heat and a graduated cooling. The operation succeeds better in bottle-glass than in any others; then comes common green glass, next white glass, then simple glass, with a soda base; after this, flint-glass, and, lastly, simple glass, with a potassa base.

This property exerts so great an influence in the manufacture of glass, that it is difficult not to make an immediate application of it. It explains, indeed, why, in the making of bottles, so much care is taken to avoid the repeated reheating of the mass which is to be formed into that article. It would be thoroughly devitrified in a few seconds; the glass would become hard, difficult to fuse, and would present a multitude of solid grains disseminated in a matter still soft. One sees in the same manner why green glass, and even common white glass, and, still more so, bottle glass, can only be shaped by the lamp of the enameller when the work is performed with the necessary despatch. If he works so slowly that he is obliged to reheat several times the glass tube which he is blowing, the mass devitrifies, and all the phenomena show themselves which have just been described. In vain does he then try to blow a bulb—all the force of his lungs will not avail; the glass is no longer soft. Besides, the material then becomes rugous, semi-opaque, and almost infusible.

One can understand, on the same principles, how important it is to select with care glasses intended to be used in large and thick masses, such as those designed for the making of lenses for large optical instruments. The cooling of such masses is necessarily very slow, which induces the devitrification of the glass. It is almost impossible to succeed, therefore, except with glass having a base of lead and potassa, and glass with a base of potassa and lime. Indeed, these two kinds of glass, which constitute *flint* and *foreign crown* glass, are employed exclusively on the Continent for the making of objectives for achromatic telescopes.

The devitrification of glasses is a phenomenon of the greatest interest, and to which the attention of glass-makers cannot be too much directed. It will appear still more worthy of consideration when it is shown that, in virtue of its properties, devitrified glass is capable of replacing porcelain in almost all its uses. Thus, for the requirements of chemistry, one may make tubes, retorts, receivers, capsules, which resist the fire as well as vessels of porcelain, which are as impermeable as common glass, which resist acids very well, and which, in fine, may be obtained in a single piece, under a thousand diversified forms, which the moulding of porcelain could only furnish with difficulty. This is a business to be created, and a very important business, for it would furnish vessels of a wholesome, elegant ware, and at a comparatively low price.

To effect the devitrification of glass, RÉAUMUR selected common bottle or green glass. He filled the vessels with a mixture of roasted sulphate of lime and white sand, reduced to fine powder. He introduced them into an earthen box, which itself was filled with a similar mixture, taking care that the vessels were well isolated from each other, as well as from the sides of the box, the empty space being occupied with the plaster and sand. The box, thus prepared, fitted with a lid and luted, was carried into a pottery furnace, and left to itself during the whole duration of a firing. At the end of that time the glass was entirely devitrified.

The fracture of this glass is silky, and an attentive examination of it is sufficient to show how the phenomenon is produced. In fact, exactly in the middle of its thickness, the glass presents a brown line, and it is at this point that an infinite number of small crystalline needles meet, proceeding from the exterior and interior surface of the vessel. These needles, perfectly parallel to each other, are perpendicular to the surface of the glass, as well as to the plane passing through the line of junction, which itself follows all the variations of form in the glass. It may be added, that in glasses imperfectly devitrified the two surfaces exhibit similar needles, but too short to meet, and, consequently, separated by a greater or less breadth of common glass, which occupies the middle of the thickness of the plate or vessel. It is evident, therefore, that whatever cause determines the crystallization of the glass, acts first on the surfaces, and afterwards penetrates to the middle, till the crystals setting out from the two opposite points come to meet.

M. DARTIGUES was convinced that the gypsum and sand mixture was not indispensable, and that bottle-glass, heated only to redness during some hours, was entirely devitrified. Nevertheless, the potassa volatilizes during the devitrification, which indicates the utility of a silicious cement, which then performs the part of an absorbing body in the manner of the sulphuric acid in LESLIE's experiment for freezing water in a vacuum.

RÉAUMUR did not well understand the theory of the phenomenon of devitrification, and, subsequently, KEIR, PAJOT-DES-CHARMES, and some other observers, in examining and describing the crystallizations which sometimes occur in glass, were not more successful in perceiving the intimate connection between these two classes of facts. The researches of DARTIGUES as well as those of FLEURIAU DE BELLEVUE, ultimately placed beyond doubt the complete identity of these two phenomena.

Devitrification is therefore a crystallization of glass. Experience proves that glass, slowly cooled, almost always crystallizes when the passage from the liquid to the solid state is effected so gently as to allow the requisite molecular arrangements to take place. But it appears that, by applying this idea in an absolute manner to the devitrified glasses of RÉAUMUR, a grave error would be committed, which analysis teaches one to avoid. There exist, in fact, two distinct kinds of devitrified or crystallized glasses, resulting from different actions. 1. The first class embraces glasses which, by means of a prolonged heat, and sometimes by the aid of a suitable lute or cement, have arrived at a state of homogeneous combination, and have taken the crystalline form, losing some of their constituent principles. 2. The second kind comprises glasses which, by means of a solidification very slowly effected, are divided into two or more different compounds, some of which have preserved the uncrystallized state, while others have taken a regular crystalline form.

It is possible to discover by analysis what takes place in these two cases. The manner in which RÉAUMUR effected the devitrification has been already stated. In proceeding to examine its results, DUMAS

made the following analysis of a tube of bottle-glass devitrified by M. D'ARCET at the glass-work of La Garre at Paris :—

	Centesimally. Oxygen.	
Silica.....	52.0	= 27.0
Alumina.....	12.0	= 5.6
Sesquioxides of iron and manganese, ..	6.6	= 2.0
Lime.....	27.4	= 7.6
Loss, or potassa,.....	2.0	= 0.2
	100.0	42.4

Comparing this analysis with that of common bottle-glass, already given at page 191, it will be seen that the amount of the potassa is reduced to at least one-third or a half of the ordinary quantity. Moreover, this analysis shows that the sample analysed consisted of one equivalent of sesquisilicate of iron or of alumina, and one equivalent of bisilicate of lime or of potassa.

It is far from probable that the same result would be obtained for all analogous glasses, as regards the state of saturation of the silicates, or their proportion to each other; but it is certain that the potassa almost entirely volatilizes by the devitrification effected in RÉAUMUR's manner, and that the other products arrange themselves, either to constitute a single silicate, or to form several of them, which remain mingled.

D'ARCET found, it is true, that bottle-glass was devitrified without changing its weight. That might happen, in fact, when the oxygen, absorbed by the transition from the oxide of iron to the sesquioxide, is equal in weight to the potassa volatilized.

The chemical changes observed in the devitrification of *bottle-glass* consist, therefore,—1st. In the loss of a part or the whole of the potassa. 2nd. In the passing of a part or the whole of the protoxide of iron and of manganese to the state of sesquioxides. 3rd. In the formation of one or more definite and crystallized silicates, by means of the remaining products.

The second process of devitrification, which consists in the mass being broken up into different chemical compounds, presents itself sometimes alone, but often simultaneously with the preceding. DUMAS mentions

the curious results of an experiment made on the large scale, at the glass-works of Choisy-le-Roi, in which this process was observed to be quite distinct from the preceding. A glass was formed with 100 of sand and 40 of carbonate of soda, perfectly pure and dry. This glass being cooled rapidly, was transparent like ordinary glass. It was re-melted, and submitted to a slow cooling, that the solidification might take place tardily. A glass was thus obtained which was milky, grainy, and evidently devitrified in some places. The devitrified parts were re-melted, and rapidly cooled again after the melting, which furnished common glass once more. This glass, by a new fusion and a prolonged cooling, gave a glass better devitrified than it was the first time. Lastly, the portions which exhibited the most perfect devitrification, being again melted and quickly cooled, again yielded a glass endued with its ordinary characteristics.

This remarkable experiment sufficiently proves that, in the slow solidification of glass, a division of its elements is determined, in consequence of which a definite silicate crystallizes, and thus separates from the remaining mass.

DUMAS states that there existed in the cabinet of the Polytechnic School at Paris, a mass of glass detached from the bottom of a crucible. At the surface of it was an opaque crust, white, crystallized in needles, and of a uniform thickness of one or two lines. All the rest of the mass was of a perfect transparency, but in the interior of it might be observed a multitude of white and opaque prisms, similar to the exterior crust; partly isolated; partly collected in groups of two, three, four, *et cetera*, and forming stars; in some cases more numerous still, and then forming spheroids. The devitrification was therefore effected in this case at the surface, in consequence of the evaporation of the potassa, and in the mass itself, in consequence of the separation which resulted from a slow cooling. Subjoined is the analysis of the two kinds of glass contained in this piece by DUMAS, and that of another specimen by KERSTEN:—

	Kersten.				Dumas.			
	Crystalline portion.		Vitreous portion.		Crystalline portion.		Vitreous portion.	
		Oxygen.		Oxygen.		Oxygen.		Oxygen.
Silicic acid.....	58.8	30.54	60.39	31.40	68.2	35.46	64.7	33.64
Alumina.....	3.3	1.54	6.10	2.84	4.9	2.28	3.5	1.63
Lime,	20.2	5.77	13.40	3.83	12.0	3.43	12.0	3.43
Protoxide of iron,.....	3.5	0.80	3.10	0.70	—	—	—	—
“ manganese,.....	4.2	0.93	2.20	0.49	—	—	—	—
Magnesia,.....	0.5	0.19	0.40	0.15	—	—	—	—
Potassa,.....	2.7	0.45	14.41	3.05	—	—	—	—
Soda,.....	5.5	1.40			1.49	3.81	19.8	5.06

It is evident that, in the specimen analysed by DUMAS, the potassa had been separated from the glass at the instant of crystallization. It is equally manifest that while no simple proportion can be traced between the elements of the transparent glass, one observes, on the contrary, in the crystallized glass a clear and well-defined composition; for the oxygen of the alumina is about one-third of that of the potassa and of the lime, and the oxygen of these three bases is pretty exactly

the fourth of that of the silica. It is, therefore, a compound of one equivalent of quadrisilicate of alumina, and of three equivalents of quadrisilicate of soda or of lime, which corresponds to the composition of ordinary window-glass. More distinctly, in the specimen analysed by DUMAS, the oxygen in the silicic acid is to that of the alumina, and to that of the other bases together, in the following ratios:—

In the crystalline portion, as $35.46 : 2.28 : 7.24 = 18 : 1 : 3$
 In the vitreous matrix, as $33.64 : 1.63 : 8.49 = 15 : 1 : 5$
 For the former, $M_2 O_3, 6 Si O_3 + 9 (M O Si O_3)$
 For the latter, $M_2 O_3, 3 Si O_3 + 15 (M O Si O_3)$

In the specimen analysed by KERSTEN, the relations of the oxygen were as follow:—

In the crystalline portion, as $30.54 : 1.54 : 9.54 = 21 : 1 : 6$
 In the vitreous matrix, as $31.40 : 2.84 : 8.22 = 12 : 1 : 3$
 For the crystalline portion, $M_2 O_3, 3 Si O_3 + 9 (M O Si O_3)$
 For the vitreous matrix, $M_2 O_3, Si O_3 + 18 (M O Si O_3)$

These relations, as deduced from both analyses, render it probable that the two portions were distinct chemical compounds. It may, therefore, be assumed that when the glass is submitted to a slow solidification, there occurs a separation of the least fusible definite compound to which its elements can give rise—the latter then taking the crystalline state.

If the analyses of different glasses previously given had not solved the question, these last two would suffice to demonstrate that all the glasses are silicates in definite proportions, or, at least, mixtures of different definite silicates, dissolved the one by the other. Hence it may be inferred, that by sufficiently prolonging the time of the solidification of a vitreous mass, it would be possible to separate successively compounds more and more fusible, the alkaline base concentrating more and more in the successive residues. And hence, also, may be conceived what takes place in the solidification of lavas, which have so much analogy with the products now under consideration, and an explanation may be given of the formation of natural crystals, so diversified as they appear in their mass.

To sum up—in the words of DUMAS, to whom the Editor is chiefly indebted for what has been stated on this interesting subject—*devitrification is a crystallization of glass, due to the formation of definite compounds infusible at the temperature existing at the instant of the devitrification.* Sometimes this infusibility is produced by the volatilization of the alkaline base; sometimes by a simple division or separation, the alkali then passing into that portion of the glass which preserves the vitreous state. All glasses may therefore be devitrified, for all glasses are capable of passing to the state of definite, and consequently crystallizable, silicates. Glasses which contain at the same time indifferent oxides and basic oxides will devitrify better than others, by the tendency which the indifferent silicates and basic silicates have to combine in definite proportions. Lastly, devitrified glasses will possess very variable properties, for their composition itself will differ completely, according to the nature of the glasses and the circumstances of the devitrification. Thus, sometimes the devitrified glass will be crystallized in needles of considerable size, as happens with window-glass; sometimes it will be crystallized in very fine needles, or even simply transformed into an opaline mass, without appearance of crystals, as in the case of bottle-glass.

Specific Gravity of different kinds of Glass.—It is evident that the specific gravity of glass must depend on its composition. Alkaline calcareous glasses are the lightest; bottle-glass comes next; then plumbiferous

glasses. The following are the results of some experiments:—

	Specific Gravity.
Bohemian glass,.....	2.396
Crown-glass,.....	2.487
Saint Gobain plate-glass,.....	2.488
Cherbourg plate-glass,.....	2.506
Window-glass,.....	2.642
Bottle-glass,.....	2.732
Crystal, or common flint-glass,.....	2.9 to 3.255
Optical flint-glass,.....	3.3 to 3.6

The Editor finds several kinds of glass to give the following specific gravities:—

White flint-glass,.....	3.000
Bottle, common green,.....	2.715
Green-glass, St. Helen's,.....	2.654
Crown-glass,.....	2.520
Leith crystal,.....	3.189
Plate-glass, Ravenhead,.....	2.439

As regards crystal or flint-glass, the density may suffice to give a pretty exact idea of its composition. It is not so with the other kinds of glass, the differences of density of their constituent principles not being sufficiently marked.

LOYSEL attempted to establish formulæ which might permit of passing from the density to the composition, but they are altogether inapplicable. Little, if any, advantage is to be had from them, even for glasses containing lead. These relations vary from so many causes, that, to establish them in a positive manner, it would be necessary to limit oneself to certain glasses, and to deduce them from experiments so delicate and so numerous, that it would be better to have recourse to the ordinary methods of chemical analysis, the results of which will always be more reliable.

CHEMICAL PROPERTIES OF GLASS.—Among the chemical properties of glass, there are some which merit an attentive examination. DUMAS classes them as follows—namely, the effect of the air or of deoxidizing bodies; that of water; that of acids; and that of bases.

Action of Air or Oxygen.—Air or oxygen, cold or hot, provided they are dry, exercise no action on glasses. It is not so with moist air, as will be seen further on, especially with reference to soluble glass. In this case, however, the reagent is water.

Action of Deoxidizing Bodies.—It is evident that deoxidizing bodies may, on the contrary, act with the aid of heat on glasses which contain oxides of iron or of manganese, and especially oxide of lead. In fact, when plumbous glasses are heated with charcoal, or in a current of hydrogen, they very readily undergo a remarkable alteration. The oxide of lead is reduced, and the metal being set free, communicates to the glass a blackish tint. This effect is even so rapid, that one cannot operate on crystal at the enameller's lamp without blackening it greatly, except particular precautions be used. The plan which succeeds best consists in placing a little soap on the wick of the lamp; the flame suddenly assumes a different appearance, and no longer blackens the crystal. It is probable that the presence of the soap affects the capillarity of the wick, and diminishes the ascent of the oil.

Action of Water.—Water does act more or less on all glasses; and there is a great number which it tends to decompose into a soluble alkaline silicate, and

an insoluble earthy and alkaline silicate. It produces in some sort the same separation which would result from a slow cooling, or from the devitrification of the glass. Window glasses, or those which have an analogous composition, are altered in this manner, and very much so, by boiling water. This was long ago remarked by SCHEELÉ. So much is this the case, that water which is boiled for a long time in glass vessels becomes alkaline and turbid by the portion of earthy and insoluble alkaline silicate which forms the residue of its action, and which, detaching itself from the sides of the vessel, remains in suspension in the liquid. This effect is even so marked on crown-glass, plate-glass, and certain window glasses, that it is only necessary to reduce them to a fine powder, and to put them in contact with cold water, in order to impart to the water an alkaline reaction. Lastly, these same glasses have almost always so much of a hygrometrical property, as to become covered with a thin coating of water when they are exposed to the contact of moist air.

This action of water affords an explanation of a considerable number of phenomena occasionally observed on glasses, and chiefly on those with a base of lime and soda, or potassa. Every one knows that looking-glasses sometimes tarnish in the air. This result proceeds from the deposit of a film of hygrometrical water; the same is observed on the glasses of optical instruments. If the glass is well made, the effect proceeds no further; but if it is too alkaline, the deposited water gradually acts upon its surface, and thus produces a decomposition similar to that above-mentioned; in this case the glass is tarnished beyond remedy, or at least it must be repolished. Sometimes the tarnishing is scarcely perceptible, and yet a great alteration may have been produced on the surface. This is observed when one proceeds to heat the glass; its surface becomes detached in very thin lamellar scales, presenting a great regularity of fracture. The glass then remains completely deprived of its polish, wrinkly, and almost opaque. Glass-tubes, globes, retorts, and even measures or standing-glasses, which in laboratories are long exposed to moist air, very often exhibit the same phenomena. In this state the tubes, for example, can no longer be heated at the lamp without losing their polish. Watch-glasses are often observed in the same condition, and even the glasses of optical instruments. It appears, indeed, that glasses which have been polished are more liable to this effect than common glasses. It is well known that glass which has not been polished presents a harder and more brilliant surface, which seems due to the *tempering* it undergoes at the instant of cooling. It is possible, therefore, that polishing renders glasses more readily attacked, by exposing the interior part of the mass, and destroying the hard coat which secured it.

The windows of houses, offices, or public buildings, of an old date, often present a tarnished and unpolished surface, the origin of which must be attributed to a similar cause. When the hygrometrical water has attacked the glass, the slightest changes of temperature cause its surface to splinter, which thus becomes dull, devoid of polish, or at least cracked, and disposed to rise in scales by the least rubbing. This

effect may especially be remarked in the windows of stables; these, after some years, are always so much altered as to exhibit all the phenomena of the decomposition of light produced by thin plates; they become in fact iridescent, and sometimes in a manner very remarkable for the intensity and purity of the colors. This, however, is chiefly due to the ammonia, developed by thecrement and urine of the animals, attacking the silica. On the contrary, it is the weather or moisture which produces the remarkable alteration observed in old glass that is found in ruins or in tombs. Its surface is sometimes entirely decomposed; it has become opaque, and the slightest rubbing causes it to peel off in thin light pellicles, exhibiting all the colors of the rainbow. When the decomposed part is detached from the outer surface of a phial, one would suppose it to be cut; but it is not so: this appearance is due to the interior layer of the decomposed glass, which, by reason of its perfect opacity, reflects all the light which passes through the part still transparent. One finds here, therefore, but only in greater intensity, all the effects which may be so frequently observed on stable windows.

Action of Alkalies.—Since water *per se* is capable of acting on glass with so much energy, it will readily be conceived that *concentrated solutions of potassa and soda* must be capable of attacking it still more powerfully. This kind of reaction has not been much studied. At a red heat, not only potassa and soda, but all the carbonates and all the bases of that class, combine with the elements of glass to constitute glasses more basic. When carbonate is used, the carbonic acid is expelled. It may even be said that all the oxides not decomposable by heat, when heated with glass, combine with it, and thus form glasses transparent or opaque, colored or colorless, more or less readily acted on than the glass employed, according to the proportions. In general, when the proportion of oxide added is much increased, the glass is rendered soluble in acids. This is what is done in the analysis of glass, when it is heated with carbonate of soda, carbonate of baryta, or oxide of lead.

Action of Acids.—The acids, in their turn, should act on glasses with facility. Among these, the hydrofluoric acid must be classed by itself, its action being quite peculiar. The other acids tend to decompose glass, by seizing on the bases and setting the silica free.

Among the bottle-glasses, there are many which resist the action of wine, and which, nevertheless, are powerfully attacked by the nitric, hydrochloric, and sulphuric acids. Salts of lime, of iron, of alumina, and alum, are formed when sulphuric acid is used. This acid produces in the interior of the bottles crystalline nipples or pustules, the base of which ultimately pierces the vessel; these pustules are sometimes of the size of a bean; in all cases the silica set free assumes a jelly-like appearance.

A bottle-glass too rich in alumina is one of those which the acids most readily attack. DUMAS states that he has seen such glasses, which the bitartrate of potassa contained in the wine attacked so quickly that the alteration was perceptible at the end of a few days.

The salt of alumina produced discolors the wine, and imparts to it a disagreeable taste. The bottle becomes corroded, and a flaky deposit is detached from it. At the same time, crystals of different salts are deposited.

Glasses with a lead base are so much the more easily acted on in proportion as they are too rich in lead. Well-made crystal resists acids well. It is the same with window glasses; when too alkaline they are acted on very easily; when well-made, they resist. Moreover, when a glass loses its polish by heat, one may be sure that it is of a nature to be attacked by acids.

Special Action of Hydrofluoric Acid.—It has been stated that the hydrofluoric acid acts on glass in a special manner; and indeed, as this acid transforms the silica into water and fluoride of silicium, it follows that it must act on all glasses. Its action in fact would be always quick and complete, if the formation of a certain quantity of double fluoride of silicium and sodium, of potassium, or calcium, or lead—double fluorides, which are all insoluble, or only slightly soluble—did not diminish the contact, and, consequently, the effect produced.

The hydrofluoric acid, however, attacks glass rapidly when the action is exerted on a small surface, and much acid is employed. This property has been turned to account to etch glass; the acid is employed in a gaseous or liquid state, according to the occasion and the end proposed. The gaseous acid produces opaque traces; the liquid acid transparent ones. But the subject of etching on glass will be alluded to afterwards.

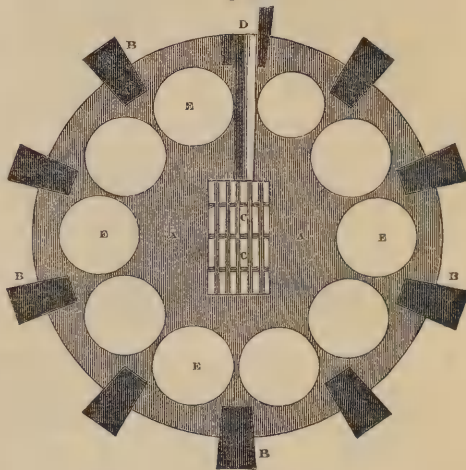
MANUFACTURE OF GLASS.—There are no reliable records of the processes employed by the ancients in the making of glass. But from the time when AGRICOLA described this art, the general arrangement of the furnaces, the mode of fabrication, and the nature of the materials employed, have undergone only modifications of detail, without any change in the general character of the process. No inconsiderable portion of works on the manufacture of glass is usually devoted to the arrangement and construction of the furnaces and pots, the tools employed by the workmen, and the dexterous mechanical operations by which the soft and ductile *metal* is shaped into the various forms that fit it for domestic use and the purposes of science and the arts. These subjects form so important a part of the glass manufacture, that they cannot be entirely omitted in the present work; but the Editor deems it his duty to discuss them as briefly as possible, devoting his principal attention to the chemistry of the manufacture. He will therefore dismiss, in a very few words, the construction of the furnaces, pots, and tools employed.

Glass-house and Furnaces.—The glass-house in which the processes of melting and blowing are performed, is usually built in the form of a truncated cone, open at the top, of sixty or eighty feet in height, and forty or fifty feet in diameter at the base. In the centre of the area is situated the melting furnace, capable of holding from five to ten glass-pots or crucibles for fusing the materials. The grate of the furnace is nearly on a level with the floor of the glass-house; and the ashpit or *cave* is a subterranean passage, extending from each side of the furnace to the exterior of the

building, so as to catch the wind from as many aspects as possible. The particular arrangements of the glass-house, and the construction of the furnaces, are somewhat varied according to the kind of glass prepared.

The plan of a flint-glass-house furnace is shown in the annexed engraving—Fig. 137—where the furnace is represented as containing ten pots, E E. There are as many flues, B B, as pots, one flue being placed between every two pots; and immediately abreast of each pot, and

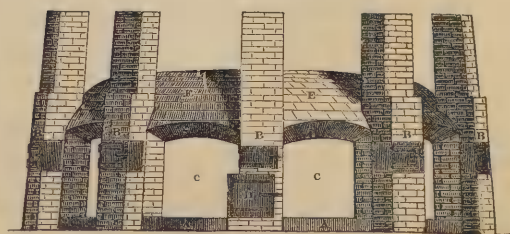
Fig. 137.



between two flues, is an aperture called the working hole, which is used for introducing the raw materials, and taking out the glass or *metal*. The coals are shovelled through a square hole, D, upon the grate, C C, in the centre of the furnace. The grate bars are supported by two strong iron sleepers, and are protected from the intense heat by being previously covered with a layer of clinkers or potsherds; but, as the furnace attains its maximum heat, sufficient clinkers are formed to serve the purpose. All round the grate-room a bank, A, is raised, termed the *siege*, on which the pots are placed, so that the fire lies, as it were, below the bottom of the pots, and in the centre of the furnace. The sides of the furnace are a little higher than the top of the pots, and the arch or crown is made as low as possible to be consistent with durability.

Fig. 138 is an exterior view of the brick dome, and Fig. 139 an interior sectional elevation of the same,

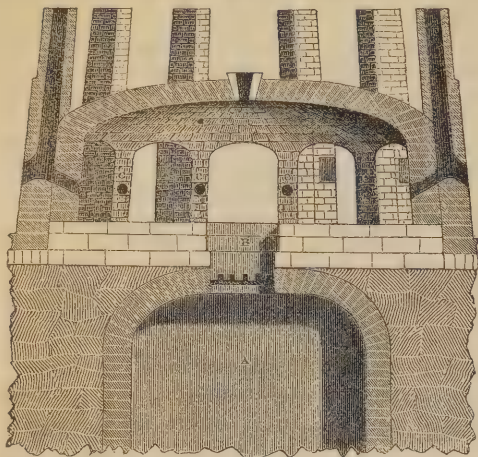
Fig. 138.



showing the position of the flues, arches, and cave. In Fig. 138, the letters A A indicate the sole of the furnace; B B, the flues; C C, openings or arches, which, after intro-

ducing the pots, are built up, leaving only working holes; **D** is the door for introducing the fuel; and **E** the roof or dome. In Fig. 139, **A** is the cave or air-tunnel below the furnace; **B**, pit of furnace, with grates below;

Fig. 139.



C C, flue or linner holes, through which the flame, not being allowed to issue from the centre, passes up the flues, discharging into the brick dome, and from thence into the funnel and chimney shaft.

The dimensions of a convenient flint-glass melting furnace are given by Mr. APSLEY PELLATT as follows:—A furnace for ten pots of thirty-six inches diameter is twelve feet seven inches in interior diameter, including the flues; the height to the inside of the dome is four and a half feet; each of the arches is three feet one inch by three feet three and a half inches to the highest part. The fire is regulated by the stoker or *teaser*—from the French, *tiseur*—who can raise the heat of the furnace to the highest pitch by opening holes at the bottom of the grate. A ten-pot furnace consumes from eighteen to twenty-four tons of coal per week.

RICHARDSON and RONALDS remark, that the construction of the melting-furnaces in a glass-house is attended with many difficulties, against which it is almost impossible to provide; and the wear and tear becomes a serious item to the manufacturer. The prevailing temperature of a glass furnace, about 20·000° Fahr., presents in itself a serious difficulty; but in cases where open pots are employed, this is materially increased by the volatility of the alkalis, which amounts to nearly twenty-five per cent. of the potassa. The binary compound of silicic acid and alumina becomes changed into a ternary one, through the action of the alkali when clay is employed, and into a silicate of potassa or soda where firestone is substituted; in each case a fusible compound results, which rapidly wastes away, and at last, both pots and furnaces become too much corroded for use. In ordinary cases, three years is the usual duration of these furnaces, except in flint-glass-houses, where they last longer, from the lower melting point of the materials, and the peculiar shape of the pots.

The sides of the furnace are constructed of bricks, formed in moulds made for the purpose. The best fire-clay, mixed with the remains of old pots coarsely ground, is the material employed for making these bricks; but these clays would be much improved for this and many other purposes, by the addition of some coarse sand, or ground pure sandstones. The roof is generally made of sandstone alone, of a coarse grit, and very porous. No cement is employed in the arch, the expansion of the stone, and the partial fusing of the interior surfaces afterwards, bind the whole sufficiently well together.

The crown and plate-glass furnaces are similar to the flint; they are placed also in the middle of the cone, but contain only from four to six pots, each of the capacity of half a ton of metal.

Besides the main or melting furnace, a glass-house contains a variety of furnaces and arches adjoining or around the inside of the cone, for different subsidiary operations. The *calcar arch*, for burning frit, now little used, is a common reverberatory furnace, about ten feet long, seven feet wide, and two in height. In crown-glass works there are also the *blowing furnace*, the *bottoming hole*, and the *flashing furnace*, besides an aperture in the latter termed the *nose-hole*. The uses of these will be explained in connection with the crown-glass manufacture. Lastly, the *leer* or annealing oven is one of the most important appendages of every glass-house. This is the name given to a low arch, open at both ends, in which the manufactured goods are allowed to cool gradually. The arch is usually about sixty feet in length, five feet wide, and not more than from one to two in height. Adjoining the door or receiving end is a small furnace on each side, by which the temperature at that end is maintained just short of a melting heat; but, as there is no other heating power, the arch or oven experiences less and less of the heat as the distance from the mouth is greater,

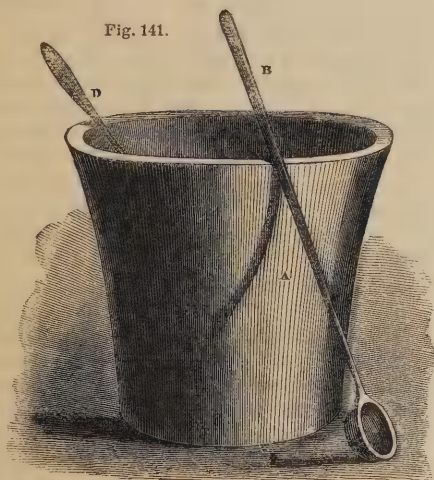
Fig. 140.



until, at the remote or discharging extremity, the temperature is scarcely higher than that of the atmosphere. There are usually from two to four of these annealing arches placed side by side, as represented in the above engraving, Fig. 140. Along the floor of each is a miniature railway, upon which two rows of iron

trays, called *leer pans*, travel from the hot to the cooler end, where they are taken out. The pans are moved slowly along the leer by means of an endless chain, or sometimes they are gradually pushed forward by the trays last put in. The fuel employed is coke, which imparts the most regular heat for annealing, and is the freest from smoke, the carbon of which, when coal is used, injures the color of the glass. The time required for proper annealing varies from six to sixty hours, the weighty articles requiring the most heat and time. The hotter the goods enter the arch the better, and on this account large articles, before being introduced, receive a final re-heating at the mouth of an empty pot, heated by beechwood, and called the *glory-hole*. Much of the success of annealing depends on the proper direction of the wind, which ought to pass over the fuel of the leer toward the leer chimney at the cooler end, so that the hot air may always radiate in the downward current upon the goods. When an upward or contrary current of wind drives back the heated air from the cool or chimney end toward the fuel at the upper end, where it comes into contact with the hot articles just introduced, great losses from breakage often occur.

Fig. 141.

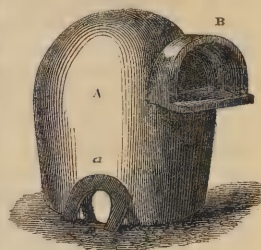


Kilns, which differ from leers in being closed at the further end, were formerly in general use for annealing goods intended for deep cutting, the kilns, when filled,

being carefully closed up along with the burning fuel. The time required for cooling in this case was usually about a week. To avoid so much delay, the kilns have been superseded by the use of iron covers or a bedding of sand in leers; also by lengthening the leer fire-places, and not filling the pans with glass too quickly.

THE POTS.—The crucibles, or pots, in which the vitreous mixture is melted, require every care to be taken in their preparation. Those used for bottle, crown, and plate-glass have the form of a truncated cone, A—Fig. 141—the narrow end being the base. Their depth is usually four feet six inches; their diameter at top, from four feet to four feet six inches, and at the bottom, about three feet four or six inches. In the same figure are shown the ladle, B, for taking out the glass, and the stirring rod, D. The pots for flint-glass are hooded or covered at the top, and have a mouth, B, in front like a muffle, as shown in Fig. 142; but those for crown, plate, and bottle-glass are open. The horse-shoe-shaped piece of fire-clay, *a*, is inserted in the mouth during the melting, to diminish the aperture.

Fig. 142.



Fine clay is the material of which the glass-pots are made, and it must be as pure and refractory as can be obtained, free from every trace of lime in any state, and sulphide of iron; and the less oxide of iron the better. The kind of slate clay dug out of the coal formation near Stourbridge, which contains very little, if anything, besides silicic acid and alumina, is decidedly preferred to all other compounds found in this country. The clay is mixed with varying proportions of the remains of the old pots, and the *tempering*, or previous preparation of the mixture, requires great attention. A certain quantity of the ground materials, after being mixed with water, is stored away in large wooden bins or receptacles, and turned over from time to time, during which a workman treads it under his naked feet. This *kneading* of the clay renders it very uniform and free from particles of air. The following is the composition of some of the clays employed:—

	Stourbridge. Richardson.			Stourbridge. Editor.		Rhuabon.
Silicic acid,.....	68.05	63.70	64.10	63.99	61.77	
Alumina,.....	18.85	20.70	23.15	20.84	18.97	
Lime,.....	.80	1.30	—	.30	1.53	
Magnesia,.....	—	—	.90	.94	.91	
Iron,.....	5.10	1.00	1.85	.75	.17	
Water,.....	6.00	10.30	10.00	11.67	14.79	
Loss,.....	1.20	3.00	—	1.51	1.86	

The proportions given by BARRUEL as most suitable for glass-pots of any description, are thirteen parts of crude aluminous clay, twelve parts of calcined silicious clay, and three parts of the remains of old pots. The last-mentioned material assists the more regular drying of the pots, and renders the whole body more porous, and less liable to crack by heat.

When the mass has been kneaded three times over until it acquires a pasty consistence, it is rolled into small pieces about the size of a sausage, and these wet rolls are placed together upon a wooden or leaden slab, to the thickness of four inches, to form the bottom. It is then turned up at the edges, and built, layer above layer, in successive rings, all formed by the eye of the

workman, without the use of a mould. When the pot has been finished, the sides are made smooth by means of small wooden scrapers.

After the glass pot is formed, it is allowed to remain for a considerable time in an apartment heated by a flue to a little above the ordinary temperature—about 80°—in order that it may be slowly dried in an equal manner throughout its whole thickness. Two or three years is the time allowed by some manufacturers for this gradual desiccation.

Before the pot is set in the furnace, it must be subjected to an annealing process, which consists in gradually increasing its temperature during several days to bright redness. This is usually done in a reverberatory constructed for the purpose, the fire in which must be raised very slowly, not more than a shovelful of coals being introduced at a time, and that at regular intervals. While at a bright red or even a white heat, the pot is quickly transferred, with the assistance of adequate machinery, into its seat in the hot furnace; a part of the face of which must be pulled down, to allow of the ready extraction of the old pot, and introduction of the new one. Before the pot is used, it is *glazed*, as it is technically termed, before being filled with materials; that is, some cullet or old glass is thrown into it, and spread over the sides in a molten state. This penetrates to the depth of a few lines into the substance of the pot, and forms a hard, difficultly fusible enamel, which protects the pot from the further action of the substances added.

The setting of a new pot is a very arduous undertaking, and is generally attended with great excitement, and even danger, on account of the intense heat to which the workmen are exposed. It is generally performed at the end of the week when the work of the glass-house is slackened, and all hands are required to be present to assist at the operation.

A good pot-maker, says Mr. HENRY CHANCE, with two assistants, can furnish three or four pots per week. After a careful drying of many months, they are made ready for the furnace, as has been stated, by a previous heating in a kiln or pot-arch. Here a small lump of coal, thrown against its side, tests the soundness of the pot. If, when struck, it rings well, its future is promising; but if it returns a dull sound, it will probably be short-lived in the furnace, though now and then such a pot will disappoint the bad opinions formed of it, and turn out a respectable pot after all.

The terrible task of setting these pots in the furnace, continues Mr. CHANCE, falls upon the glass-house crew, and the nicety with which these enormous vessels are adjusted in their place, in the teeth of a consuming fire, is, perhaps, that operation which, in the many marvels of glass-making, would most astonish a stranger to such scenes. The average duration of the pots, when thus fixed, is about seven weeks. Some attain the age of ten or twelve; while others, as every manufacturer well knows, terminate their existence prematurely, either from the naturally defective constitution of the pot, or from bad treatment in the pot-arch, or more frequently from its having been *starved*—that is, exposed to a current of cold air in the furnace, through the neglect of the attendant. The breakage of a pot often disturbs

the furnace to such an extent, that the breakage of others frequently follows, and many weeks will sometimes elapse before the disorganization thus produced can be rectified. The loss of the pot and the contained *metal* is nothing as compared with the injury which the glass in the surviving pots, and these pots themselves, are apt to sustain.

CRUDE MATERIALS FOR GLASS-MAKING.—The chemical or theoretical composition of the different varieties of glass has been already given at pages 191 and 192; but as it is quite impossible to obtain or prepare the ingredients in a state of chemical purity previous to fusing them together, it will be necessary to explain the sources from which the materials that go to constitute the different glasses are practically derived for the purposes of the manufacture.

Silica.—It has been stated that all true glasses are practically composed of silica, or silicic acid, in combination with at least two alkaline or earthy bases, and sometimes oxides of lead, zinc, and other metals. Silica, silicic acid, or teroxide of silicium— SiO_2 —is the principal ingredient. It is very abundant in nature, forming a principal constituent in rocks and stones, and existing in a free and almost pure state in flint, agate, chalcedony, rock-crystal, and quartz, the last two being its purest form. Formerly, flint—*silex*—calcined and ground, was used as the source of the silica, and hence the name of *flint-glass*. Sand, however, is now employed as the most general and economical source of silica, and renders the process of grinding unnecessary. At the same time the great variations in the purity of this material render requisite a careful selection for the different kinds of glass, and the manufacturer must choose such as the microscope and analysis show to be most suitable for his purpose. The finest English sands are from Alum Bay in the Isle of Wight, and Lynn on the coast of Norfolk. The French obtain a very superior sand from the forest of Fontainebleau, in the neighborhood of Paris; and Mr. H. CHANCE justly remarks, that to the purity of this and their other materials the superior color of their glass may be partly ascribed.

The sand, being always more or less impure when brought to the glass-works, is conveyed to an upper room, and thrown into a trough of water, where it is carefully washed. It is then placed in a trough over an oven, and, when partially dried, passes through holes into the oven. When quite dry, it leaves the oven in the state of fine, glittering white particles, like powdered quartz. These precautions are not necessary for bottle-glass.

Potassa and Soda.—The alkalies used in the manufacture of common colored glass, such as those used for green bottles, are obtained, as far as the potassa is concerned, from common *ashes*, and the soda from the *ashes of sea-plants*, or refuse soda. Better kinds of glass are made with crude potassa and soda-ash, and the best from purified potassa and soda-ash. Not more than thirty years have elapsed since crown and sheet glass were manufactured from the crude alkali obtained from kelp, the preparation of which for this purpose employed a large population on the Northern shores of Scotland and West of Ireland, and the abandonment of this material, when the duty was taken off barilla,

plunged whole districts into idleness and misery. The kelp was used simply in combination with sand—the kelp containing soda and potassa, and furnishing the necessary amount of lime; but the glass thus produced was of very variable, and often most inferior quality. The discovery of LE BLANC in 1792, which effected the conversion of common salt into carbonate of soda, was the commencement of a new era in the history of Continental flint-glass; but the introduction of carbonate of soda, prepared from salt, into the glass manufacture of England, dates only from the year 1831. Ultimately sulphate of soda was substituted, except for plate-glass, the manufacturers of which still adhere to the carbonate. The black bottles of Newcastle are made from common rock-salt, and sand from the bed of the river, with the carbonate of lime of the soap-works, and the tank waste of the alkali makers; but for all better kinds of glass the circuitous combination of silica and alkali is still found necessary. The carbonate of potassa is obtained chiefly from Canada and the United States, and requires a process of washing previous to use. The state to which it is brought by the process of cleansing is that of fine white grains, differing but little, to an unpractised eye, from the prepared sand.

Lime.—This substance, which forms an important constituent in flint-glass, may be introduced either as a carbonate, or slaked or burned. Limestone, however, that contains proto-carbonate of iron, must be excluded from the mixture for making white glass. The action of lime is to render the alkaline silicates insoluble, and when rightly balanced by the other ingredients, it promotes the fusion of the whole, and improves the quality, but when added in excess, the glass becomes hard and difficult to work, and subject to devitrification.

Lead.—The next substance in point of importance is lead, which forms the distinguishing ingredient in crystal or common flint-glass, optical glass, and strass. These glasses are fused from a mixture containing litharge— Pb O —or minium—red lead, $\text{Pb}_3 \text{O}_4$. Of these two compounds, the latter is preferred on account of its finer state of division, its pulverulent form, and because it is decomposed in the glass-pot into ordinary protoxide of lead and oxygen, which latter oxidizes, and removes many impurities, as, for example, charcoal. An excess of lead acts injuriously upon the melting vessels, and, besides inducing too great softness in the glass, gives it a yellow tinge.

Baryta.—This substance, in the form known as *heavy spar*— Ba O , S O_3 —is sometimes added to the constituents of common bottle-glass, to render it more easy of fusion.

Alumina.—The sesquioxide of aluminum— $\text{Al}_2 \text{O}_3$ —though seldom purposely introduced into glass, is always accidentally present, brought there by the action of the materials upon the clay of the pots in which they are melted. Alumina, if present in any quantity, is always an undesirable ingredient, as, by increasing the number of silicates, it renders the glass more liable to devitrification, it being well known that the more compound a glass is, the more does it display this tendency. Hence, bottle-glass, which contains a greater variety of bases than any other, is of all the most easily devitrified.

Iron.—Another unwelcome element is iron, which is

almost always present in the sand, in the sulphate of soda, when employed, and in the chalk, partly in the state of protoxide, the coloring effect of which is partially destroyed by other ingredients, to be afterwards mentioned.

Arsenic.—A little arsenic promotes the decomposition of the other ingredients, and tends to dissipate carbonaceous impurities not otherwise disposed of; but, in excess, it produces a milkiness in the glass, which time will increase.

Cullet.—Another substance is added—abundantly produced in every manufactory of glass—namely, a quantity of waste glass, or cullet, which, being more fusible than the raw materials, facilitates the melting. For this purpose, the waste glass in the glass-house, and that collected in the neighborhood, are carefully sorted, cleaned, ground, and incorporated with the mixture *for similar kinds of glass*. Great care must, however, be taken that no broken glass of an inferior kind is mixed with the ingredients for finer glass. The cullet not only incites fusion, but materially aids the union of the bases with the silicic acid.

Decoloring Materials.—It has been stated in the historical notice that every description of glass exhibits a tendency to color, which probably led to the idea of stained glass. This tendency is more or less developed, even when proper proportions and the purest materials for the mixture have been employed; and as any tinge is considered a defect in white glass, or that which is employed for windows and particularly in the finer kinds of glass, certain materials are employed with the special object of counteracting it. To this class of substances belong *binocide of manganese*, *arsenic*, already mentioned, and *nitrate of potassa*. The accidental elements which usually color the glass are *iron* and *carbon*, or carbonaceous matters, and in all cases the substances above-mentioned are employed to neutralize or counteract these by means of *oxidation*.

For example, if particles of carbon or soot from the fire or flame become mixed and surrounded with the melted glass, these, by their exclusion from the access of air, are prevented burning, and a brown or nearly black color is produced, which is removed by the conversion of the carbon into carbonic oxide through the influence of the oxidizing or decoloring material. The manner in which manganese acts on the protoxide of iron has been already explained—page 189—and is similar to its action on carbonaceous matters, which are thus removed in a gaseous form from the melted mass. A few ounces of the binocide of manganese are, therefore, usually added to the materials for making flint-glass, which is always required in a state of great purity; and, from the cleansing action of this material, it has received the familiar title of *glass-makers' soap*. It must, however, be used sparingly; for an excess of it produces a compound of silicic acid with sesquioxide of manganese, which communicates a lilac or amethystine color to the glass. The approved remedy for this, when the error has been committed, is to stir up the colored mass with a wooden pole, which reduces the sesquioxide to the protoxide, and the lilac color disappears.

Some manufacturers use manganese, on account of the reddish tinge it imparts to glass, expressly to disguise the bad green or yellow color produced by the other materials. In this case two tinged glasses are formed, which mask each other's defects, the green and red rays combining together, as supplementary colors, to transmit white light. Indeed, in plate-glass for fine windows, a slight excess of manganese is sometimes allowed, expressly to produce a delicate amethystine tint, which improves the complexion of persons who receive the light of day through the window.

Smalt, a blue glass, is sometimes used, like manganese, to mask the bad color produced by the other materials. Properly speaking, however, the decoloring agents are those which act by oxidizing the carbon or the protoxide of iron, and thereby actually expelling the lime. In this way nitrate of potassa reacts before the glass enters into perfect fusion; arsenious acid, arsenic acid, and their salts, exert their action at a temperature above the fusing point, and are volatilized.

Glass from Felspar.—The making of glass by means of felspar is an idea which naturally suggests itself to the mind, when one considers the ready vitrification of this mineral, and was suggested even long ago by M. GHÉRARD in the memoirs of the Academy of Berlin. According to this authority, the following mixture is proper for a window-glass, namely, two parts felspar, two parts sand, one part chalk, which would give, for the composition of the glass, supposing no volatilization of the potassa during the melting, nearly the following:—

	Centesimally.
Silica,	73
Alumina,	8
Potassa,	7
Lime,	12
	100

These ill-calculated proportions could only give a glass difficult to melt, and prone to devitrify. This, says DUMAS, is exactly what happened in an experiment made on the large scale by M. REY, under the eyes of CHAPTAL and ALLUT. The melting required a twice longer time than the usual, but it furnished a beautiful glass. The experiment was supposed to be a fortunate one; but when the crucible was cooled sufficiently to admit of the working of the mass, it was found quite opaque, milky, and clotty—in fact, devitrified. Must felspar, therefore, be renounced? It is difficult to admit this. If a mixture be made of one hundred parts of felspar, one hundred parts of Arcueil clay, or some analogous clay, and eighty of quicklime, or its equivalent in chalk, a glass of the following composition will be produced:—

	Felspar.	Clay.	Glass.	Or centesimally.
Silica,	66	63	129	46·3
Alumina,	18	37	55	20·0
Potassa,	16	—	16	5·7
Lime,	—	—	80	28·0
			280	100·0

—that is to say, a glass which, if the clay is free from iron, would be quite of the same nature and color as bottle-glass, and which would present advantages as well as disadvantages. As regards common window-

glass, or analogous glasses, felspar should be capable of entering into these in the proportion of one-third or one-fourth, without serious disadvantage. A glass would be produced which would differ from common glass only by the presence of four hundredths of alumina, and glasses are met with in commerce which contain this quantity and even more. Lastly, it is probable that by suitable additions of borax, boracic acid, or oxide of lead, one might get felspar itself to produce a glass endued with all the desirable qualities.

Glass from Volcanic Products.—DUMAS remarks that certain lavas, pumices, pitchstone, and other volcanic products, approach so closely to bottle-glass in their composition, that the possibility of turning them to account in this way cannot be doubted. The merit of the first attempts of this kind is due to CHAPTAL; and if these attempts did not succeed, this must be attributed to the time at which they were made, rather than to the idea itself, which is both good in theory and must be capable of succeeding in practice. The analyses will be sufficient to prove this:—

	Lipari pumice.	Basalt of Haseburg.	Basalt of Staffa.	Pitchstone of Mismal.
Silica,	77·5	44·5	48·0	73·0
Alumina,	17·5	16·7	16·0	14·5
Oxide of iron,	1·7	20·0	16·0	1·0
Soda, }	3·0	2·6	4·0	1·75
Potassa, }				
Lime,	—	9·5	9·0	1·0
Magnesia,	—	2·2	—	—
Water,	—	2·0	5·0	8·5
Hydrochloric acid,	—	—	1·0	·25
Loss,	·30	2·5	1·0	·25
	100·0	100·0	100·0	100·0

With pumice-stone, forge-scoriæ, chalk, and a little soda in proper proportions, bottle-glass might therefore be made. Basalt would require only the addition of a little chalk and soda. Pitchstone treated like pumice-stone would furnish it also.

The trials made by the directions of CHAPTAL succeeded so far as the matter examined by him was employed; but when another volcanic product came to be used, the results were bad, the proportions being deranged. A very simple analysis would have prevented all trouble, and would have preserved their proper rank to these volcanic matters, the excellent effects of which have been demonstrated by a sufficiently long experience.

It was in 1780 that CHAPTAL, then Professor of Chemistry at Montpellier, proposed the use of lava. M. DUCROS, a glassmaker in the environs of Alais, melted, with coal, the lava of the extinct volcano of Montferrier, without any addition, and made some bottles of it. M. de CASTLEVIEL, another glassmaker of the country, melted, with wood fuel, a mixture of sand, lava, and soda, and thus produced bottles lighter and stronger than those usually manufactured. These bottles had such great success that the demand could not be supplied. But at the expiration of four years, the bottles which were produced no longer resembled the first ones: they were much inferior; the manufactory lost its reputation, and was compelled to abandon the system which it had just tried with so much success.

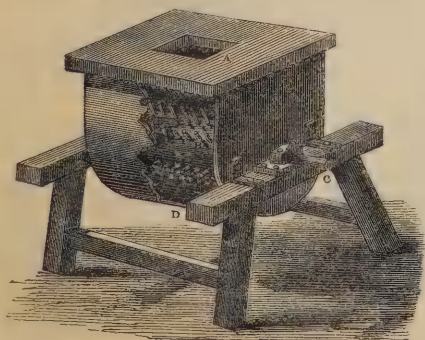
The nature of the lava, therefore, had changed, and

the same proportions being no longer suitable, an analysis alone could have guided the operator. It is with this that the process must be commenced, if it is intended to resume a manufacture, worthy, in so many respects, of being submitted to trials which the state of science would now render much easier. It was in consequence of taking a different course that M. de CASTLEVIEL failed, and that M. FOUGEROUX de BONDAROX, who appears to have been occupied in 1787 with the same subject, without any knowledge of the preceding facts, succeeded no better.

THE FUEL.—The fuel formerly employed in England in the making of glass was exclusively *coal*, but of late it has been found that, in London especially, many advantages result from using *oven-burned coke*, which produces less smoke and soot, and is, therefore, much better adapted for the finer glasses. Some glass-houses have all the requisite accommodation for making coke. In France both coal and coke are employed, and sometimes *wood*; but BARRUEL states that wood has been generally abandoned as being more costly, and producing less heat than coal, so that with the former the fusing and refining of the metal require longer time. In Germany *wood* is generally employed, and in some few places *peat*. Even the best air-dried wood would fall far short of producing the desired effect, in consequence of the amount of water which it still retains, and therefore it has been the practice on the Continent, from a very ancient period, to bake the air-dried wood in a particular kind of furnace until it begins to become brown, or until the whole of its water has been volatilized. Peat when used in the glass-house must be perfectly dry, and afford only a small amount of ash.

PREPARATION OF THE MATERIALS.—A great saving of time and fuel is effected by carefully grinding and intimately mixing the materials previous to the melting. For this purpose edge-stones and coarse sieves are essential in a glass-house. Until quite recently, the mixing and sifting were always performed by hand, and the operation was therefore imperfectly performed, the mixture so produced being little calculated to favor those chemical changes and mutual reactions of the materials which are necessary to the formation of a

Fig. 143.



homogeneous fluid transparent body. To obviate this disadvantage, a mixing apparatus, especially intended for crown-glass, has lately been contrived by Mr. CHANCE. This very simple machine, which is shown

partly in section in Fig. 143, is made entirely of wood, and consists of a semi-cylindrical chamber, with an opening, A, at the top, for introducing the materials, and another in the semicircular bottom at D, through which they are removed; B is a cylinder in which a number of oblique beaters are fixed, and the whole is made to revolve by a handle or by a shaft from the steam-engine connected with the axis, C. Mr. COOPER applied with the best effect a simple revolving wooden barrel, similar to those employed in the powder factories. The composition, when mixed, is termed *batch* or *frit*—the latter word being derived from the circumstance, that during the period when barilla, kelp, and other forms of crude alkali were in use, it was the custom to subject the materials to the preliminary operation of *fritting* or stirring them together under the heat of a reverberatory furnace, thereby effecting partial decomposition, and burning off any carbonaceous impurities; but the introduction of alkali prepared from common salt has, in most cases, removed the necessity of this treatment. One great advantage of fritting consisted in the partial union which it effected between the silicic acid and the bases, so that the latter were not volatilized in the furnace previous to the formation of the glass, and the pots and sides of the furnace were consequently less exposed to the injurious action of their vapors. With the purer materials now employed in the manufacture, the advantages gained by the operation are not generally considered sufficient to compensate for the loss of fuel incurred in producing the high degree of heat required to perform it.

MELTING.—The raw materials, consisting essentially of sand or silica as the base, and alkali as the flux or solvent, having been thoroughly incorporated with a suitable proportion of cullet or broken glass of the same kind, are introduced by means of a clean iron shovel into the melting-pot, which has been previously raised to a white heat. But the whole of the mixture is not introduced at once, for the mass of glass which a pot will hold occupies before fusion, in the state of frit, just twice the space of the melted glass. Not more than one-third of the mixture is therefore introduced at first through the working holes, the temperature is then raised to the maximum, and as the mass subsides by melting, a fresh quantity is introduced, until the pot is filled with melted glass. During the whole period of the melting or *found*, the stokers or *teazers* keep the furnace well supplied with fuel, so as to prevent any portion of the grates becoming uncovered, in which case a rush of cold air from below might split some of the pots. At the same time the *founders*—from the French, *fondeurs*—are engaged in noting the progress of the fusion, by taking from time to time proofs or drops from the pots, by means of a short rod, flattened at one end, and examining if any undissolved grains of sand are perceptible on refrigeration, and whether the mass, which still contains a quantity of air-bubbles, appears uniform throughout. So long as carbonic acid is evolved in abundance, or during the *boil*, the mass is agitated by the escape of the larger bubbles of gas in a manner most favorable to the operation, this motion answers the

purpose of stirring, and mixes the compounds of variable degrees of fusibility and density, which are at first produced, with each other; at a later period, when the disengagement of gas ceases, the denser compounds are apt to settle down at the bottom of the pot, where the temperature is about one-fourth lower, and is, consequently, incapable of preventing the deposition by the production of ascending currents. This evil is moderated on the Continent by stirring with the scooping ladle, or by thrusting a piece of arsenious acid to the bottom of the pot, and thus causing a forcible expulsion of vapor from that part of the vessel. At the close of the melting process, the contents of the pot are not by any means pure, or equally mixed. All the solid matter is dissolved, but the mass of glass is full of small vesicles of gas, presents a spongy rather than a dense appearance, and is not yet in a state fit for working. The surface is also covered by a layer of so-called *glass-gall* or *sandiver*, a melted mixture of salts, which have not been volatilized, nor combined with silica during the process of melting, and consisting chiefly of chloride of potassium—or sodium—and sulphates, which in consequence of imperfect vitrification have escaped decomposition.—*Knapp*.

The following, says RICHARDSON and RONALDS, has been found to be the composition of this saline matter, glass-gall or sandiver, which is skimmed off the surface of the melting materials, and is technically termed *salts*:—

Constituents.	German plate-glass.	Crystal- glass.	Bottle- glass.
Water,	1·65	·10	1·00
Sulphate of soda,	83·32	90·51	55·92
Sulphate of lime,	10·35	6·00	25·11
Chloride of sodium,	1·43	·04	·20
Carbonate of soda,	trace	—	—
Potassa,	—	—	trace
Insoluble matter,	3·25	3·35	17·77
	100·00	100·00	100·00

Glass-gall, when occurring in large quantity, is removed with ladles, and is employed on the Continent by saltpetre and alum manufacturers, or workers in bronze; in the varieties of glass prepared from purer or purified materials, where, instead of crude potassa, ashes, or soda, purified substances have been employed, either no glass-gall is produced, or that which appears is easily removed by volatilization.

FINING.—For some time the glass does not become transparent, the opacity being due to bubbles of air or gas, and to the lime and earthy impurities which do not fuse. The object of the *fining*, which is the last process in glass-making, properly so called, is the removal of these by the subsidence of the heavier particles to the bottom and the escape of gas at the surface. For this purpose the glass must be brought to the most fluid state possible, and the heat is therefore raised and sustained for some hours at the highest point. In Germany this part of the process is termed *heiss-schüren*, or *hot-covering*. In forty or forty-eight hours after charging, the vitrification is complete. When all the gas-bubbles have passed off, and the sandiver has become transparent and colorless, the temperature of the pot is lowered by diminishing the draught—a process termed *kalt-schüren*, or *cold-covering*—the object of which is to

bring the glass from a state of nearly perfect fluidity, in which it could not be worked, to that free viscid or plastic condition necessary for the working. For this purpose the bars of the furnace are plastered up. The great thickness of the walls, and the slow combustion of the fuel, which is supplied in moderate quantity, keep the furnace hot enough to retain the glass in a workable viscid state during the period in which the glass is blown or otherwise shaped into the required forms.

The reactions which take place in the pot or crucible are very easy to understand. For example, if the silica has been mixed with carbonate of soda and carbonate of lime, the silica, at a high temperature, seizes on the soda and lime, and the carbonic acid is disengaged. In the same manner, if silica has been mixed with carbonate of potassa and minium, this last returns to the state of massicot, and the silica then combines with it and the potassa. There is, therefore, in this case, first a disengagement of oxygen, then an elimination of carbonic acid.

These evolutions of gas which constantly accompany the production of glass, explain the presence of the *air bubbles* already mentioned as so frequently observed in the vitreous mass. To expel these, it has been stated that the temperature must be raised very high, that the glass may become quite fluid. But as the potassa and soda may be volatilized at this high degree of heat, one is obliged to introduce into the compositions much more potassa and soda than the glass is intended to retain.

This elevated temperature is also necessary in all cases where impure alkalis are used. The presence of the chlorides, and even that of the sulphates which melt without mixing with the glass, would occasion in the latter a multitude of white and opaque nodules disseminated through its mass. At a high heat both of these matters, being lighter than the glass, rise and float on the surface, constituting the principal portions of the glass-gall or sandiver above alluded to. It must be stated, however, that ever since the salts of soda have been sold at a low price, and are consequently generally used, very little glass-gall has been produced in the manufacture of the ordinary kinds of white glass; but in bottle-works this impurity always occurs, because crude sodas are employed.

FAULTS IN THE GLASS.—Notwithstanding all the precautions that may be taken, air-bubbles frequently remain, and generally exist in great number when the fining process has been obstructed by too great difficulty of fusion in the glass. They are technically termed *seed*, *blibe*, or *blister*.

Two further accidents to which the glass is liable are known as *threads* or *strings*, which are generally contracted during the blowing, when cold particles of glass drop into the viscid or imperfectly melted metal, and not having time to undergo fusion remain hard, and appear as unsightly projections from the blown vessels.

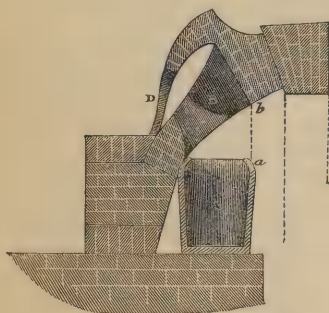
Waves and *striae* are faults of too common occurrence, arising from a want of homogeneity in the vitreous mass. The latter of these terms is applied to the effect produced when the density of the glass, in consequence of imperfect fusion, is not uniform throughout,

and all the parts, though equal in transparency, do not refract the light equally; and consequently, images of objects seen through the glass appear out of place or distorted. This fault is very objectionable in plate-glass for mirrors or windows, as well as in crystal or flint-glass for optical purposes. *Waves* are superficial and protuberant striæ, which always occur when the glass is blown too cold.

A not less serious evil, which is frequently a source of color in the glass, arises from the action of the alkaline vapors upon the constituents of the sides or roof of the furnace, particularly when chloride of sodium or sulphate of soda is used in the manufacture. The volatilization of the alkali, whether soda or potassa, produces over the pots a rapid vitrification of the bricks of the vault, and hence drops of *colored glass*, known by the name of *tears*, which occasionally fall into the pots. These are produced by the silicic acid of the bricks combining with the alkali, and forming with it, and with the iron and alumina of the clay, a green and very infusible glass, which sinks to the bottom of the pot from its greater density, leaving in its course a fibrous tail which remains in the glass. Imperfections of the same kind are produced, though less frequently, by the action of the glass upon the walls of the pot itself.

According to KIRN, the drops of aluminous glass may be prevented from falling into the pots by constructing the latter and the arch of the furnace in the manner represented in Fig. 144. In this case the portion of the wall of the furnace, which comprises the working hole, B, is made so large that drops, falling perpendicularly from any protuberance or irregularity, b, can only reach the

Fig. 144.



exterior of the inflected margin, a, of the pot, A; and the size of the working hole is reduced to the proper dimensions by a second less solid arch, D. Another plan, mentioned by KNAPP, is to make the working hole in the perpendicular wall of the furnace, and to spring the arch of such a form that the angle of the part over the pot may be sufficient to cause the *tears* to flow down the arch instead of dropping into the pot.

WORKING TOOLS AND APPARATUS.—The tools represented by BLANCOURT, in his work *On the Art of Glass*, which was printed at London in 1699, are almost precisely the same as those now in use; and the author's account of their mode of working might almost be taken as a description of the modern process. To those

curious on the subject, BLANCOURT's description is well worthy of perusal.

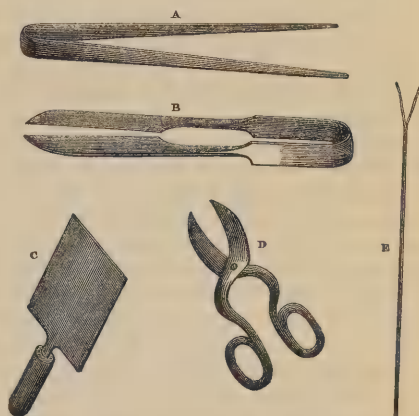
The most important of these instruments is the *pipe*, on the end of which the glass is taken up by the workman, and blown into spheres or bulbs, to be subsequently shaped into different forms, as will be afterwards described. A section of this indispensable instrument is shown in Fig. 145. It is simply a tube,

Fig. 145.



composed of wrought-iron, four to five feet long, one inch thick, and about one quarter to one inch in the bore. It is provided with a knob at each end, the one of which, a, serves as a mouth-piece, whilst to the other, b, the melted glass is attached. The upper portion is surrounded by a wooden cover, c, to protect the hands of the workman from the heat of the metal. A companion to this instrument is a solid iron rod, known as the *pontil* or *ponty*, which serves to receive the glass after it is blown on the pipe. The *spring-tool*, A—Fig. 146

Fig. 146.



—is a species of tongs for laying hold of half-formed handles, and for seizing the glass while making. The *pucellas*, B, have prongs resembling the cutting part of shears, but blunt, and are used for rubbing the outside of solid or hollow glass, and pressing it into smaller diameter, at the same time elongating the parts by rotation. The battledore, c, is made of wood, and is used for flattening the glass when necessary. The shears, D, are strong scissors for cutting and shaping the edges and handles of glass vessels while in a soft state. The fork, E, is employed for carrying the finished articles to the annealing oven.

An important part of the glass-blower's furniture is the *marver*, which consists of an iron plate or slab, resting on a stone or on wooden supports, and having a polished surface, on which the mass of glass that has been gathered at the end of the blowing tube is rolled, to give it a symmetrical form. The term *marver* is derived from the French *marbre*, a marble slab being formerly used. The *glass-maker's chair*—Fig. 147—is a flat seat of wood, about ten inches wide, each end of which is fixed to a frame connected with four legs and two

inclined arms, upon which is screwed an edging of wrought-iron for rolling the blowing tube with the hot

Fig. 147.



glass backwards and forwards with the left hand, while the required form is given to the glass with the pucellas held in the right.

Continual rotation of the melted mass is the principal point to be attended to in most of the glass-blower's operations; but these will be best described in connection with the special manufacture of the different varieties of glass.

SPECIAL MANUFACTURE.—A visit to the glass-house will convey a much more vivid idea of the beautiful art of the glass-blower, and the wonderful material with which he works, than the most elaborate written description or pictorial illustrations. There is, moreover, so much of the *mechanical* connected with the fabrication of glass, that great part of it does not properly fall within the scope of this work. In proceeding, therefore, to describe the details of the different departments of the manufacture, the Editor will dwell as briefly as possible on those operations which do not involve the application of chemical agencies.

The arrangement to be followed will be somewhat similar to that already indicated, as adopted by KNAPP, but with some important modifications—beginning with the coarser or commoner qualities, and rising by a natural gradation to the finer and rarer kinds of glass manufactured for optical lenses or ornamental purposes. On this principle, the following arrangement will embrace all that is necessary:—I. ORDINARY or GREEN BOTTLE-GLASS. II. WHITE BOTTLE-GLASS, including *refractory Bohemian and Foreign crown*. III. WINDOW-GLASS, embracing—1. *English crown*, and 2. *Sheet or cylinder glass*. IV. PLATE-GLASS, with the process of silvering mirrors. V. CRYSTAL or COMMON FLINT-GLASS, and OPTICAL FLINT-GLASS. VI. STRASS and COLORED or STAINED GLASS. VII. SOLUBLE GLASS.

I. GREEN BOTTLE-GLASS.—The materials for common glass bottles are coarser and cheaper than for any other kinds of glass; and, in consequence of this very coarseness or want of refining, the elements which enter its composition are more numerous, consisting, as already stated, of silica, lime, potassa or soda, oxides of iron and manganese. These last oxides communi-

cate a color to this glass, which owes, at the same time, a part of its characteristic hue to the charcoal. Indeed, as the color of bottle-glass may be considered as essential to it, or at least does not injure its sale or diminish its value for the purposes to which it is applied, no decoloring materials are used, and it is melted in open pots, even when coal is used as the fuel, which is always the case in this country. The omission of decoloring materials forms the distinguishing feature in the manufacture of ordinary bottle-glass.

Materials.—The English laws, till lately, prohibited the use of fine materials for making ordinary bottles. Nothing but the common river sand and soap-boilers' waste was allowed. About three parts of waste, consisting of the insoluble residuum of kelp, mixed with lime and a little saline substance, were used for one part of sand. This waste was first of all calcined in two of the fire arches or reverberatories reserved for that purpose, called the coarse arches, where it was kept at a red heat, with occasional stirring, from twenty-four to thirty hours, being the period of a journey or *journée*—a day—in which the materials could be melted and worked into bottles. The roasted soap-waste was then withdrawn, under the name of ashes, from its arch, coarsely ground, and mixed with its proper proportion of sand. This mixture was now put into the fine arch, and calcined during the working journey, which extended to ten or twelve hours. Whenever the pots were worked out, that frit was immediately transferred into them in its ignited state; and the founding process proceeded with such despatch, that this first charge was completely melted down in six hours, so that the pots might admit to be filled up again with the second charge of frit, which was founded in four hours more. The heat was briskly continued, and in the course of from twelve to eighteen hours, according to the size of the pots, the quality of the fuel, and the draught of the furnace, the vitrification was complete.

At the present time, in choosing ingredients for bottle-glass, economy is the chief object; color and appearance are here of no moment. Little soda or potassa is admitted into the composition of this description of glass; and, as the carbonates of these bases are costly, it is usual to employ in the bottle glass-works only recent ashes or wrack-soda to furnish the alkali. Moreover, the other materials are taken in a state of impurity fit only for bottles.

The primary materials of the manufacture of this kind of glass are yellow and ferruginous sands, residues proceeding from the lies of the soap and soda works, lixiviated ashes, common ashes, wrack sodas, and clay.

The colored sands are even preferable to white sands for bottle-glass, the oxide of iron, which colors them, performing the part of a flux. They do not require any washing or other preparation; nevertheless, any coarse foreign substances, such as pyrites, flints, *et cetera*, are separated from them. For this purpose they are dried, and passed through a sieve. The clay best adapted for bottle-glass is a yellow marly earth; it is furnace-clay, containing, therefore, alumina, silica, carbonate of lime, oxides of iron and manganese; it has not much of a binding quality, and is easily reduced to powder when dry, which facilitates the mixtures.

The ashes are generally obtained from common

domestic fires. Those are preferred on the Continent which proceed from the combustion of new wood or charcoal. They are sifted and dried before using. The wrack-soda is employed in a powdered state; it is even passed through a very close wire sieve.

The following is given by DUMAS as the usual proportion of these materials:—For

ORDINARY FRENCH BOTTLE-GLASS.

30-40 pounds.....	varec.
160-170 "	lixivated ashes.
30-40 "	fresh ashes.
80-100 "	clay containing iron.
100 "	broken glass.

The proportions in English bottle-glass are slightly different:—

ENGLISH BOTTLE-GLASS.

100 pounds.....	lixivated ashes.
40-90 "	kelp.
30-40 "	wood-ashes.
80-100 "	clay.
100 "	cullet.

The amount of cullet is not particular; it is increased for the first and second melting, when new pots are used. If a very argillaceous sand is employed, it is necessary to suppress the clay, and supply lime by a suitable addition of chalk. Natron or crude soda may be used to replace the potassa yielded by the varec; but in this case care is taken to add to the mixture a certain quantity of fresh ashes, that the glass may not be wanting in potassa.

The proportions given in the preceding recipes, as well as in those that follow, are calculated for one hundred pounds of sand:—

FOR CHAMPAGNE BOTTLES, ACCORDING TO JAHKEL.

200 pounds.....	felspar.
20 "	lime.
15 "	common salt.
125 "	iron slag.

ORDINARY GREEN BOTTLE-GLASS.

72 pounds.....	lime.
280-278 "	lixivated wood-ashes.

DARK GREEN BOTTLE-GLASS.

20 pounds.....	dry Glauber's salt.
18 "	soap-boilers' flux.
1 "	Scheffel—Pruss.—lixivated ash.
39 "	glass from the hearth.
179 "	green cullet or broken glass.
45 "	basalt.

Melting.—The melting-furnace for bottle-glass commonly contains only six pots. These are about three feet in height, and nearly the same in diameter. They are filled almost to the edges; and when the matter has sunk down, and is converted into a glass, more of the composition is put into the pots, and the fire is urged. The meltings are rapid; for as most of the bottle-glass compositions furnish but little glass-gall, no time is lost in fining. The process lasts from seven to eight hours, and, when it is concluded, the fire is slackened, that the glass may thicken to the point suitable for working it. For this purpose the fire-place is heaped up with small coal, draughts are intercepted as much as possible, and care is taken not to touch the fire during the working of the glass, lest the combustion should be re-excited.

Mechanical Operations.—The working or shaping of bottle-glass is very simple in principle, and yet the operations involved are somewhat complex in detail. These may be summarily stated as follows:—The assistant collects or *gathers* on the end of the pipe—Fig. 145—the requisite body of glass, and passes it to the blower. The latter, by blowing and constantly turning the pipe, gradually forms the body of the bottle, which is finished in a mould. While the bottle is in the mould, the workman continues to blow and to turn. He then raises the pipe, and, holding the bottle in a vertical and reversed position, he depresses or hollows the bottom. The bottle is then cut at the neck, and the iron rod termed the ponty fixed at the opposite end of it; the edge of the neck is rounded, and the ring or cord which encircles it is put on, as also the seal, if the bottle is intended to have one. The ponty then passes into the hands of the assistant, whose duty it is to carry it to the annealing furnace. He there detaches it from the rod by a slight blow.

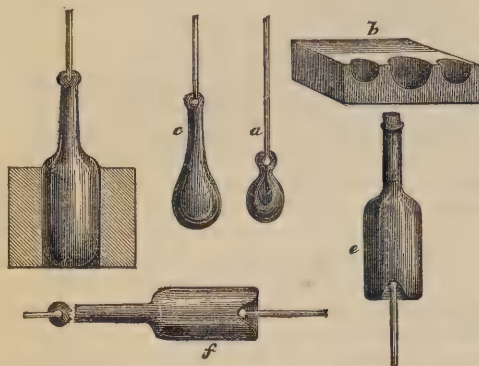
Such are the chief operations of the process of bottle-making, as described by DUMAS; but as this manufacture affords a good instance of the dexterous manipulations which are practised in blowing glass, a subject deeply interesting to the practical chemist, the following more detailed account, which is given by KNAPP as descriptive of the mode of working carried on in Spessart, will be not unacceptable to the reader:—

As soon as the working holes are opened, and the surface of the glass is cleared from sandiver or glass-gall, the workman attaches as much melted glass to the end of the pipe as he considers necessary for the production of a single bottle; his eye and hand are here unflinching guides as to the requisite quantity. By dipping the previously warmed pipe into the pot, a little glass remains attached to the end; after turning this in the air before the hole until it is cooled, and blowing slightly into it to render it hollow, a fresh layer of glass may be attached to it in the pot; to this, a third is added in the same manner, until the ball at the end of the pipe has accumulated to a sufficient size, *a*—Fig. 148. That this ball may become uniformly tractable in the subsequent forming, it is held by the workman in the flame of the furnace through the working hole; it is then brought into one of the round concavities of the *marver*, *b*, which is wetted or moistened when used. Here the ball gradually assumes the form of a thick hollow globe, or rather pear-shaped vessel. It acquires this shape by the constant rotary motion given by the workman to the pipe, whilst the cooling and stiffening of the mass is rendered uniform by the marver, and is prevented shrinking together by constantly blowing into the tube with very little force. The mass of *metal*, which, as already stated, is the technical term applied to glass during working, must be equally distributed round the axis of the instrument, and advanced in front of its mouth, being connected with it only by a short neck. Towards the front part, where the subsequent widening occurs, and the mass is blown out, it is thickest; the portion nearest the pipe is less massive.

Thus far advanced, the glass has again become cool, and is re-heated by insertion into the working hole, in such a manner that the front part receives the chief

portion of the heat, and becomes the softer. The pear-shaped vessel is now lengthened by the blower, and its form is made somewhat to resemble that of a bottle by a threefold operation: by blowing into the tube with greater force, *swinging* it backwards and forwards in the manner of a pendulum, and by a simultaneous constant rotary motion of the pipe round its axis. The globular form which the glass tends to assume under the influence of blowing, is converted into a long, thin egg-shape, *c*, by the swinging motion, and so much the more

Fig. 148.



as the lower temperature at the extremity is less favorable to the formation of a globe, than to the lengthening of the neck. The rotation round the axis of the pipe is an essential part of every operation in glass-blowing. The glowing mass of glass creates a powerful current of air in an upward direction, and the lower portion becomes cooled in consequence much more than the upper. This naturally creates an inequality in the resistance offered to the blowing, and the upper portion would be more expanded than the lower, if the cooling influence were not allowed to act upon all parts of the surface alike, by the revolving motion of the pipe, and this is particularly the case when the latter has to be held in a horizontal position. The mould, *d*, which is a simple cylindrical hollow block of wood or iron, is placed at the side of the workman who is blowing the pear-shaped vessel; into this he inserts the vessel as soon as it has acquired the proper thickness, in the manner represented in the figure, and by blowing forcibly into the tube, he presses the glass firmly against the sides of the mould, whilst, by a kind of jerking motion, the neck is drawn out to the proper length. The unfinished bottle, which as yet has no bottom or mouth, is again warmed in the working hole in such a manner, that the lower part only is heated, whilst the other part remains comparatively cool. In the meantime, another workman or a boy has attached a small quantity of glass to the ponty or pontil, which is also kept hot in the working hole. Both workmen now stand opposite to each other; and whilst the pipe and ponty are kept constantly turning, the latter is forcibly pressed against the middle of the lower part of the bottle, which is thus forced inwards, and an even edge is produced, upon which the bottle may stand steadily. The bottle remains for some moments between the two instruments, as shown at *f*, until, by the application of cold iron or a drop of water,

the neck can be separated from the pipe. This is an operation of constant recurrence in the glass-house, and is effected by a sudden change of temperature produced at the point of separation in the hardened glass, either by the cold application of a drop of water, or by the powerful heat of a red-hot iron, or thread of liquid glass from the pot. The point of separation must often be re-heated, to cause it to fly on the application of cold water. The bottle is now supported by the ponty, as shown at *e*, so that the neck can be warmed, and the sharp edges melted round without softening the other parts. A rotating motion is then given to the red-hot neck, the pipe being rolled backwards and forwards upon the knees of the workman. The bottle then revolves upon its axis, as if it were placed in a lathe, and it is only necessary to press the pucellas, *b*—Fig. 146—or an iron instrument like a turning chisel, against the mouth, to widen or reduce it to any required dimensions; the rim for strengthening the neck is formed from a drop of glass taken from the pot by the edge of the flask, and wrapped round the mouth in the form of a thick thread. The bottle, which is now finished, as shown in the last cut, is immediately carried on the ponty-rod to the annealing-oven by a boy, pushed into its proper place, and the ponty-rod is finally detached from the bottom of the bottle by a sudden sharp jerk. The place where the ponty was attached is perceptible in every bottle blown in this manner, by the sharp edges where the fracture occurred.

Large round bottles are blown without the use of a mould, and when of a very great size, like the carboys for sulphuric acid, the aid of steam is called in, by spirting about an ounce of water into the interior, and holding the mouth of the pipe with the thumb. Bottles in the shape of a flattened globe, are also made without any mould by simple blowing. The preparation of the mass of glass, the formation of the concave bottom and of the neck, is in this case effected in precisely the same manner as above; the swinging motion, however, must not be continued for such a length of time, as the bottles required are shorter. In blowing the belly of the bottle, the workman stands in front of a slanting board and presses the globe, as it is gradually formed by slow blowing, against the board at every half revolution of the pipe; the flat surfaces on opposite sides are thus produced.

As the greater number of bottles are necessarily sold with a legal stamp upon them, and as their capacity must be suited to the standard measures of the country, the fulfilment of these conditions presupposes an extraordinary degree of dexterity and correctness of eye in the blower. Attempts have consequently been made by many inventors to furnish the bottle-maker with a mould of such construction as would enable him to secure the formation of a bottle, perfect, both as regards form and capacity, at one single operation, without reliance upon his own correctness of sight. The use of moulds of this description, like that of RICKETS, which is easily managed, affords a great saving of time, and the repeated heating of the bottles is unnecessary. The mould consists of a body, which forms the belly of the bottle, and of four other parts, a fixed bottom-

piece with a movable piston for forming the concavity, and two movable pieces for the neck. Two treadles set these different parts in motion. As soon as the workman has introduced the hollow lengthened globe into the belly of the mould, by pressing with his foot upon the first treadle, he brings up the neck piece, then forces the glass into contact with all parts of the mould by a powerful blast, and finishes the bottle by working the second treadle, which forces the pestle against the bottom. On the removal of the pipe, the rim is all that remains to be perfected.—*Knapp*.

The circle of operations above described is continued with much quickness, four or five men being able to make a hundred wine bottles in an hour; and, with a few modifications, according to the size, shape, and purpose of the bottles, may be taken as a general exemplification of the mode of proceeding. The vicinity of the Tyne on the Wear is abundantly supplied with many of the requisites for bottle-making, and hence the manufacture is there largely carried on.

Champagne and Aerated Water Bottles.—The uses of bottle-glass do not require to be explained in detail, but it is necessary to say a few words with reference to bottles intended to resist a high pressure, such as those for holding champagne, and still more in this country for holding aerated waters, which are now manufactured in immense quantities. Bottles employed for such purposes undergo an internal pressure, which readily produces the fracture of weak vessels, and this occasions a loss which is always considerable, and often disastrous. It is evident that this might be diminished by testing all the bottles under a pressure the double of that to which they are intended to be subjected, and accordingly different machines have been invented for this purpose, by means of which water is forcibly pumped into the bottles, until the indication of the manometer shows them to have withstood a sufficient degree of force. DUMAS states that, from the experiments made by the *Société d'Encouragement*, champagne bottles were found to stand only when they were capable of supporting a pressure of twelve atmospheres. He adds that the mode of filling and annealing, as well as the form of the bottles, must exercise a great influence, which it would be necessary to find the means of estimating; also, that perhaps it would be desirable to leave a larger unfilled space in the bottles, and to use them only after a careful annealing in boiling water. KNAPP remarks, that although every bottle, when quite filled with water and containing no air, will burst in the belly from a slight blow on the cork, in consequence of the sudden force being communicated from the liquid to the sides, yet champagne bottles will often withstand a pressure of forty atmospheres and upwards, equal to six hundred pounds on the square inch.

II. WHITE BOTTLE OR CHEMICAL GLASS.—Under this head may be included white glass for medicinal bottles and chemical purposes, refractory Bohemian glass for tubing, *et cetera*, and foreign crown. The most beautiful material for bottles is furnished by flint-glass or crystal, but these are only intended for ornamental articles or vessels for the table, and will be alluded to under Flint-glass.

The general character of white bottle-glass consists

in this, that it is composed of purer materials than the green; decoloring matters are used, and the materials are selected as free from iron and alumina as possible. Moreover, in this case the glass is subjected to a thorough fining process. The following are given by KNAPP as general standards of composition for different varieties of glass of this description:—

FOR APOTHECARIES' PHIALS.

100	pounds	white sand.
30-35	"	potassa—impure.
17	"	lime.
110-120	"	ashes.
25-5	"	binoxide of manganese—cullet.

BOHEMIAN CRYSTAL FOR GRINDING.

100	pounds	white sand.
0-60	"	purified potassa.
8	"	chalk.
40	"	broken glass.
75	"	manganese.

SEMI-WHITE.

100	pounds	sand.
100	"	crude soda, containing lime.
100	"	cullet.
5-1	"	manganese.

100	pounds	sand.
30	"	potassa.
18	"	lime.

decoloring matters.

CLEAR WHITE.

100	pounds	sand.
65	"	calcined potassa.
6	"	fallen lime.
100	"	white cullet.
5	"	manganese.

WHITE GLASS FOR CHEMICAL PURPOSES.

100	pounds	white sand,
41.4	"	potassa,
17.5	"	lime.

Bohemian Glass.—The coarser qualities of this kind of glass are analogous in composition to bottle-glass, and are distinguished by comparative freedom from color, great lightness, and their very refractory nature, which renders them capable of resisting not only high heats, but sudden changes of temperature. Hence the value of this glass for chemical purposes, such as tubing, retorts, *et cetera*. Its lightness, and the almost total absence of coloration—when it is made with pure materials—cause it to be highly valued on the Continent for tableware, where it is also employed to make costly windows for fine buildings and carriages, for covering engravings, and in general for all those uses which require the glass to have a considerable thickness without coloration. In common with crown-glass, it is also peculiarly fit for optical instruments, in which it is employed to achromatize the flint-glass. These remarks apply to the finer qualities, for which DUMAS gives the following choice of proportions:—

Quartz in powder, or fine silicious sand,				
washed with hydrochloric acid,....	100.	110.	120	100
Purified carbonate of potassa,.....	60.	64	66	75
Very pure carbonate of lime,.....	20	24	25	50

In a Bohemian glass of old manufacture, DUMAS found

Silica,.....	69.4	=	36	oxygen.
Alumina,.....	9.6	=	4.48	} 9.04 oxygen of the bases.
Lime,.....	9.2	=	2.57	
Potassa,.....	11.8	=	1.99	

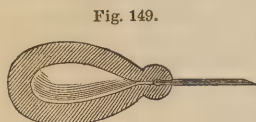
which would give exactly the proportion of 1 : 4 between the oxygen of the bases and that of the acid. On the whole, Bohemian glass may be described as a silicate of potassa and lime, with a small proportion of alumina, magnesia, and other ingredients. This will be obvious from the following analysis of a glass, taken by M. PERDONNET from a manufactory at Neuvelt, and analysed by M. GROS in the laboratory of the School of Mines at Paris:—

Silica,.....	71.6	=	37.1	Oxygen.
Lime,.....	10.0	=	2.81	
Potassa,.....	11.0	=	1.86	
Alumina,.....	2.2	=	1.02	
Magnesia,.....	2.3	=	0.89	
Oxide of iron,.....	3.9	=	1.20	
Oxide of manganese,.....	0.2	=	0.05	
			7.83	
			101.2	

Here it will be noted, that the silica contains about five times the aggregate oxygen of the bases. It will be observed also, that in Bohemian glass potassa takes the place of soda.

Tube-drawing.—Though tubes may be formed of any kind of glass, yet, for chemical purposes, and more especially for resisting a high temperature, the Bohemian or German tubes are the best. This may, therefore, be a fitting place to introduce some account of the curious operation of *tube-drawing*, which depends on the singular fact, that when a hollow lump of glass, for instance a globe, is drawn out whilst hot, the cavity in the interior is always preserved, even when the glass is drawn out to the tenuity of the finest thread. The operation is described by KNAPP in the following terms:—

Whilst one man collects the necessary quantity of glass on his pipe, and blows this out to a very massive globe, preserving a uniform thickness of the sides as much as possible—Fig. 149—the other attaches a drop of glass to a ponty-rod, and warms it on the fire by the side of the globe. Both instruments are then removed from the fire at once, and the ponty-rod is pushed forcibly against the globe in such a manner as to form exactly a straight line with the pipe, as represented in Fig. 150,



where A is the pipe, and B the ponty. This being accomplished, one of the workmen retires backwards as quickly as possible, to the distance of fifty, sixty, or one hundred feet. In this operation the globe at first shrinks, as is represented at *a*, in Fig. 151, and forms the commencement of the tube, which soon cools, and does not diminish in thickness, whilst the mass of glass is spun out by the constant drawing

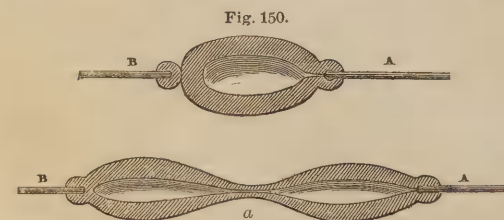


Fig. 151.

where A is the pipe, and B the ponty. This being accomplished, one of the workmen retires backwards as quickly as possible, to the distance of fifty, sixty, or one hundred feet. In this operation the globe at first shrinks, as is represented at *a*, in Fig. 151, and forms the commencement of the tube, which soon cools, and does not diminish in thickness, whilst the mass of glass is spun out by the constant drawing

from the warm end. Continual rotation of the pipe and ponty-rod is here as necessary as in all the other operations of glass-blowing, or the part of the tube nearest the ground would cool quickest, and the tube thus assume an irregular form. This, however, does not prevent the tube, in consequence of its great length, from sinking in the middle like a stretched rope, and it becomes, consequently, thicker at the two ends, as is represented in Fig. 152. The curve in the tube is, however, remedied by placing it on a ladder before it has become perfectly set; it then straightens, and is

Fig. 152.



cut into lengths of four or six feet each, by taking hold of it with a cold pair of tongs. Tubes cool very uniformly, in consequence of their small amount of metal, and they are, therefore, not placed in the annealing oven. Lastly, the bore of the tube is dependent upon the length to which a given mass of glass is stretched, or, the length being the same, upon the mass of glass; the stoutness of the tube is, however, determined by the thickness of the sides of the original globe, as the relation between the thickness of the sides and the bore is not altered by drawing. Wide, thin tubes—such as are used for spindles, *et cetera*—must therefore be drawn out of a large thin globe, and *vice versa*: it is necessary, however, whilst the tubes are drawing to blow into them, that the sides may not sink in. —Knapp.

Foreign Crown-Glass.—The name of crown-glass is limited in this country to that which is formed into circular tables by the process of blowing; but the crown-glass of the Bohemian glass-houses assumes the variety of forms which belong to articles of luxury and art, and is generally moulded into different shapes, with a view to grinding and polishing. Regarded in this light, the foreign crown, properly so called, is rather distinguished by its composition, than by the methods of manipulation adopted in its manufacture. Like the coarser Bohemian glass, it is a silicate of potassa and lime; whereas, in the English crown, soda is employed, either in the shape of sulphate or carbonate. DUMAS analysed a good crown-glass of German manufacture with the following result:—

	Centesimally.	Oxygen.
Silica,.....	62.8	= 32.6
Alumina, oxide of iron and of manganese, 2.6		= 1.2
Lime,.....	12.5	= 3.5
Potassa,.....	22.1	= 3.7
		38.4

So that in this case the silica contained about four times more oxygen than the bases, and the quantity of oxygen in the lime and potassa, the two principal bases, was nearly the same. As this glass is chiefly manufactured for the same uses as crystal, it is better prepared by means of suitable moulds than by simple

blowing, partly because the forms required are frequently so complex as scarcely to admit of their being made by hand, and partly because the various indentations and projections upon the surface can be roughly given by means of a mould, and time and trouble are thus saved in the subsequent laborious operations of grinding.

As the beauty and value of this glass depend upon its absolute limpidness, the most careful selection of materials, both for the mixture and the pots, and a protracted and assiduous process of fining are required. Speaking of foreign crown-glass, DUMAS remarks that it is not an easy matter to arrive at a certainty of success in its manufacture. It is evident, he adds, that to obtain it without color, one must use potassa, and not soda. Even if the soda yielded a colorless glass, it should still be put aside on account of the facility with which glass having a soda base devitrifies, which would render the thick masses that require a long cooling quite milky, and full of crystalline and opaque nodules. Crown-glass should therefore be formed with a potassa base, and without oxide of lead; but lime must also be added. By forming a glass with merely a potassa base, there would be no danger of devitrification; but the glass would be soluble in boiling water, and consequently hygrometrical. This would be a serious disadvantage; for spectacle-glasses or other lenses so formed would constantly tarnish by the deposit of a film of aqueous vapor, and in the space of a few years would altogether lose their polish. This inconvenience is avoided by adding to glass with a base of potassa a certain quantity of lime; but then arises a not less serious evil—a proneness to devitrification. Glass with a base of potassa and lime, submitted to the prolonged annealing which thick masses intended for large lenses require, is apt to assume the milky aspect which indicates a commencement of crystallization in the mass. Thus the manufacture of crown-glass, as well as that of flint-glass—the two glasses indispensable for the preparation of achromatic objectives—both present the most serious difficulties, although from very different causes.

III. WINDOW-GLASS.—The glass which has long been in common use for window-panes is that which is generally known as *English crown-glass*, in the manufacture of which a large globe is first blown at the end of the pipe, and this is converted by a rapid rotatory motion into a circular plate or disc thickened at the centre. Until a comparatively recent period this was the only method employed in the manufacture of window-glass in this country; but latterly the Continental method has been extensively introduced, which consists in forming the globe into a cylinder, and then, after cutting it up in a direction parallel to the axis, flattening it out into a broad sheet, from which it has received the designation of *British sheet-glass*. *Plate-glass*, or that which is cast into sheets by pouring the liquid metal on a flat surface, is now beginning to be much used for the same purpose, especially for the windows of shops and fine buildings; but as the chief demand for plate-glass is still for mirrors and other similar articles, this will be treated under a separate head, and in the meantime

the term window-glass will be considered as confined to *English crown* and *sheet-glass*, which are composed of precisely the same materials, and differ only in the mechanical operations by which they are brought into form. Chemically speaking, they are the same, except that the nature of the crown-glass manipulation requires a smaller quantity of lime. Plate-glass, on the other hand, is formed with a larger proportion of alkali.

Composition.—The materials employed for the manufacture of English crown and sheet-glass—in other words, of window-glass—are chiefly silica, soda, and lime. This glass differs, therefore, from the foreign crown and Bohemian glass in the circumstance, that soda, as the cheaper alkali, is generally substituted for potassa. Sometimes, however, though rarely, a mixture of the two is employed. Alumina, oxide of iron, and oxide of manganese are also found in window-glass, but only as accidental ingredients. It is true, indeed, that when iron is present, as is almost always the case, the binoxide of manganese is purposely introduced to neutralize its effects; and a little arsenic is generally added to promote the decomposition of the other ingredients.

Mr. HENRY CHANCE, one of the highest authorities on this subject, remarks, that to lay down any standard proportions for window-glass is almost impossible, as no two manufacturers use the same; and even in the same works the melting powers of the furnaces may so far differ as to render necessary, for the production of the same glass, variations in the proportions of its elements. RICHARDSON and RONALDS give the following as the mixtures used in some English manufactories:—

	Pounds.	Pounds.	Hundredweights.
Sand,.....	560	448	16
Chalk,.....	154	146	5
Carbonate of soda,..	119	168	5
Sulphate of soda,.....	63	17	1.25
Arsenic,.....	2	2	0
Cullet,.....	448	448	16

The introduction of carbonate of soda, prepared from salt, into the glass manufacture of England, dates from the year 1831. Previously to this, kelp was employed as the source of alkali. In the meantime, the French manufacturers—released, in 1825, through the exertions of M. CLEMENT DESORMES, from the absurd veto which the government had pronounced on the sale of sulphate of soda—were enabled to turn their attention to the employment of this salt instead of the carbonate. They proceeded with caution in the introduction of the new ingredient—first mixing a small quantity of sulphate with a large proportion of carbonate; then half of each; and, finally, excluding carbonate, they adopted the sole use of sulphate, to the injury, doubtless, of the color of their glass, but gainers by the employment of a cheaper and more manageable material. Where absence of color, however, is an object, as in the manufacture of plate-glass, the exclusive use of carbonate of soda is still retained.

Proceeding cautiously in the steps of their foreign brethren, says Mr. CHANCE, the English glass-makers, after they had established the use of carbonate, made trial of the effect of a small quantity of sulphate of soda in a large quantity of carbonate. The carbonate gradually decreased, until at length, in the preparation of

blown window-glass, sulphate generally stood alone. But here, as abroad, the manufacturers of plate-glass still adhere to the carbonate. The preceding table of three different proportions for crown-glass evidently refers to a period when the carbonate still preponderated in this manufacture also. As the use, whether of carbonate or sulphate of soda, involves their preparation from common salt and sulphuric acid, attempts have been made to accomplish the direct union of silica and salt in the manufacture of window-glass, but have hitherto failed of success. The black bottles of Newcastle are made from common rock salt and sand from the bed of the river, with the carbonate of lime of the soap-works, and the tank waste of the alkali-makers; but for all better kinds of glass the circuitous combination of silica and alkali is still found necessary.

The following is a French composition, which gives, according to DUMAS, a window-glass of fine quality:—

	Parts.
Sand,	100
Chalk,	35 to 40
Dry carbonate of soda,	28 to 35
Broken glass,	60 to 180
Binoxide of manganese,	0.25
Arsenic,	0.20

Sometimes in larger quantity.

The oxygen of the bases in this glass is generally to the oxygen of the acid as one to four.

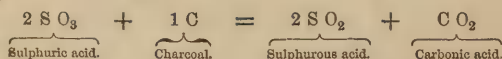
M. BASTENAIRE gives the three following compositions, which DUMAS considers too rich in alkali, and too poor in lime:—

	Parts.
I.	
White sand,	100
Good potassa,	65
Lime slaked in the air,	6
Fragments of white glass,	50
Arsenious acid,	1
Oxide of manganese,	0.30

	Parts.
II.	
Very white sand,	100
Good soda,	90
Red oxide of lead or minium,	5
Broken white glass,	100
Carbonate of lime,	5
Oxide of manganese,	0.40

	Parts.
III.	
White sand,	100
Good soda,	80
Carbonate of lime,	8
Broken glass,	110
Oxide of manganese,	0.20
Oxide of cobalt,	0.10

In none of these French receipts is the sulphate introduced, and therefore they may be referred to a period anterior to 1825, when, as already remarked, the sulphate began to be generally adopted in the French glass-works. DUMAS remarks that the object to be kept in view in employing this salt, is to render its decomposition by the silica as quick and easy as possible; and he adds, that this is managed by adding to the mixture a suitable quantity of charcoal, to transform the sulphuric acid into carbonic and sulphurous acids. Thus—



For each equivalent of dry sulphate of soda there

is required, therefore, one equivalent of charcoal, or else about six of charcoal for seventy-two of sulphate of soda. But to avoid coloring the glass yellow, only five equivalents of charcoal are employed. Thus, to produce a beautiful window-glass, continues the same writer, the following proportions are taken:—

	Parts.	Parts.
Sand,	100	100
Dry sulphate of soda,	44	58 to 75
Charcoal in powder,	4	4.5 to 5.5
Slaked lime,	6	13 to 15
Broken glass,	from 20 to 100	25 to 100

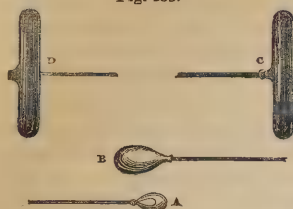
Mechanical Operations.—It has been stated that the difference between English crown and cylinder or sheet glass, is almost entirely in the manipulation. The above materials and proportions apply to both, inasmuch as the two are the same window-glass in the pot. The specific description of these two varieties, if they may be so distinguished, involves, therefore, only a series of mechanical operations, which do not strictly belong to the special object of this work. Yet, as the present article would be incomplete without such details, the Editor will here introduce a short account of both processes, beginning with crown-glass as the oldest; and, in doing so, he begs to acknowledge his obligations to Mr. HENRY CHANCE, by whose kindness he is permitted to present the reader with the following animated account of the mechanical part of the manufacture, from a paper which was read by that gentleman before the Society of Arts, in January, 1856.

1. *English Crown-Glass.*—Assuming one or other of the mixtures or compositions above given to be melted in the crown-glass pot, represented in Fig. 141, Mr. CHANCE begins by observing, that upon the surface of the melted glass is a ring of fire-clay, which, when the materials were thrown in, lay at the bottom of the pot, and after the completion of the melting, found its way upwards. This ring is of great service, for, floating in the centre of the pot, it prevents the exterior surface of the metal, or melted glass, which becomes stiff and stringy during the long period of working, from mingling with the interior or hotter surface, which thus remains throughout of a suitable consistency. The labor, also, of the skimmer, whose duty it is to clear the surface of the metal from any scum or dirt that may collect upon it, is considerably diminished by the ring, which, limiting the space from which the glass is drawn, limits also the space which it is necessary to cleanse, and any bubbles or impurities in the glass have a tendency to attach themselves to the ring.

The metal, or melted glass, having been brought, by the gradual cooling of the furnace, from a state of complete fluidity to a consistence capable of being worked, the *gatherer* dips the end of his pipe, or hollow rod of iron, into the pot inside the ring, and twirling it round its axis, to equalise the thickness of the gathering, collects upon the end, or nose, as it is technically called, a pear-shaped lump of glass, similar to that represented at A, Fig. 153. Resting his pipe upon a stand or horse, he turns it gently round, and allows the surface of the lump to cool, to fit it for a second gathering. So much glass is collected in this way, in successive layers, as will form a disc or table of about nine pounds weight,

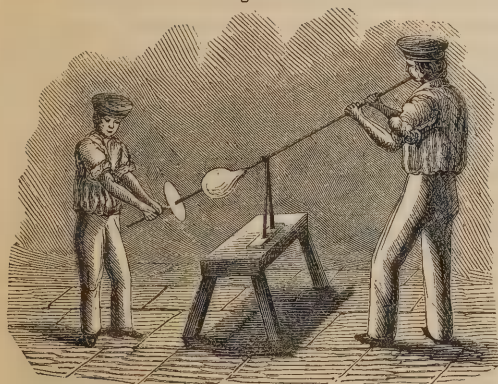
and an experienced workman seldom fails more than an ounce or two in the correct weight. The lump completed, the gatherer, having cooled his pipe under a

Fig. 153.



trough of water, that he may handle it at any point, proceeds to roll the glass upon the marver, or metallic bed, until it assumes a conical form, the apex of the cone forming what is termed the *bullion-point*. A boy now blows down the pipe while it is still being turned by the gatherer on the marver, and expands the glass into a small globe. Having been heated, it is blown again, and assumes the shape of a Florence flask, as shown at B, and the future rim of the developed plate or disc is prepared by rolling the *piece*, as the glass under operation is technically termed, near the pipe nose, upon the edge of a marver. Again heated, it is now expanded by the blower into a large globe. During this expansion, it is important to keep the *bullion-point* exactly in the position which it previously occupied, in a line with the axis of the pipe. To effect this, the blower rests his pipe upon an iron support, and while he blows down the pipe and turns it round at the same time, a boy holds against the *bullion-point* a piece of iron terminating in a small cup. This operation is represented in Fig. 154. Again presented to the fire, by the peculiar manipulation of the workman, and the peculiar direction of the flame upon it, the front of the globe is flattened, the possibility of the globe collapsing during this operation being prevented by its rapid revolution round its axis. The piece now resembles somewhat in shape an enormous decanter, with a very flat bottom and a very short neck, as at C, Fig. 153. The *bullion-point* is still to be seen in the centre of the flat bottom, and its use now

Fig. 154.



becomes manifest. The pipe is laid horizontally upon an iron rest, and a man approaches, having in his hand the large rod of iron called the *pontry*, tipped with a lump of molten glass. Pressing this lump upon an iron point, so as to give it the form of a little cup, he fits it, when thus shaped, on to the *bullion-point*, to which it soon becomes firmly attached. The lump thus formed is called the *bull's-eye*, or *bullion* of the

developed plate. The incision of a piece of cold iron in the glass round the nose of the pipe, and a smart blow, soon detaches the pipe, leaving a corresponding hole in the flattened sphere, at a point exactly opposite the attachment of the *pontry*, as shown at D in Fig. 153. The blowing pipe thus removed, and carrying with it a piece of glass, is allowed to lie idle a few minutes, till the glass adhering to it has cracked off; it is then warmed, and carried back to the pot to repeat its course in a similar operation.

The open projecting end of the piece, which was next the now detached pipe, is called the *nose*, and gives its name to the furnace or *nose-hole*, where this nose is, on account of its thickness, heated almost to melting, with a view to the next operation. It is now that the glass

Fig. 155.



undergoes its last and most dreadful torture in the hands of a man who, with a veil before his face, as shown in Fig. 155, stands in front of a huge circle of flame, termed the *flashing furnace*, into which he thrusts his piece, rapidly, meanwhile, revolving his *pontry*. The action of heat and centrifugal force combined is soon visible. The nose of the piece, or hole caused by the removal of the blowing pipe, enlarges, the parts around cannot resist the tendency, the opening grows larger and larger; for a moment is caught a glimpse of a circle with a double rim; the next moment, before the eyes of the astonished spectator, is whirling a thin transparent circular plate of glass, which, but a few minutes before, was lying in the glass-pot, an indistinguishable portion of the molten mass. The sound of the final opening of the piece has been compared to that produced by quickly expanding a wet umbrella. In this way a flat circular disc, nearly sixty inches in diameter, or sometimes more, is produced, of almost uniform thickness, except at the point of attachment to the *pontry*, where there is a swelling called, as already stated, the *bull's-eye*. The glass at the edge of the disc is also in some cases a little thickened. Still whirling, the *table*, as it is now called, is carried off, laid flat upon a support called a *whimsey*, detached by shears, or otherwise, from the *pontry*, lifted into the annealing kiln upon a fork, E—Fig. 146—and piled upon its edge against the preceding table. The weight of so many tables pressing one against another, would cause the hindmost to bend; but this is prevented by the intervention of iron frames, or dros-

sers, which divide the tables into sets, the first dresser leaning against the wall of the kiln, the second against the first, and so on; and thus rendering each set of tables independent of those behind it for support. As the bull's-eye, or centre lump, which the ponty has left behind it, keeps each table from close contact with its neighbors, the air passes freely between them, and the annealing is completed with tolerable rapidity, varying from twenty-four to forty-eight hours, according to the number of tables in the kiln. From the kiln the tables are conveyed to the warehouse, having passed, since their first exit from the pot, through the hands of ten distinct workmen.

Such, with a few slight additions and illustrations, is the description of this most interesting process given by Mr. HENRY CHANCE. He adds that the process may be regarded as twofold—first, the development of the lump into a sphere; and, secondly, the resolution of a sphere into a circular table. Constant rotation of the glass, while in a yielding state, is an essential element of this process; as, if allowed to remain motionless, its symmetry would be immediately destroyed.

A table of crown glass of to-day, would scarcely recognise as of kindred origin a table of the earlier part of the present century. The principle of the process in each case was the same; it is the improvement of minute details that produces so different a result. To Mr. HARTLEY and Mr. CHANCE, who, during the years 1832 to 1836, gave to the manufacture of this glass their constant attention, is owing, in a great measure, its present status.

When the tables of crown-glass are drawn from the kiln, they are covered with a whitish film or *hum*. The history of this hum, continues Mr. CHANCE, is curious. It arose, probably, in the first instance, from the deposition of sulphur from the fuel upon the surface of the glass. It thus became associated with the process of annealing, and buyers fancied that the more hum there was upon the glass, the better was the glass annealed. The manufacturers of crown-glass, ever ready to accommodate themselves to the fancies of their customers, have taken the trouble to produce an additional hum by the introduction of sulphur in the kiln. The members, however, of the Glass Jury of the Paris Exhibition, not being in the secret of this hum, stoutly maintained that glass thus clouded must be bad glass, and that the hum was owing to the exudation of the alkali.

In the warehouse, the tables are laid upon a *nest*, or cushion, and are divided by the diamond of the splitter into two unequal parts—the larger half containing the bull's-eye. The diameter of the table is measured on the nest, the usual size being now about fifty-four inches, and weighing thirteen pounds. Tables have been made as wide as seventy inches, but the difficulty of manipulation, and the uncertainty of the result, render such sizes too costly to be general.

The splitter carefully examines each table before splitting it, and turns it round till he has brought it into the position in which he may split it to the best advantage, announcing at the same time its quality. The first quality is called *best*—the next, seconds—then thirds—fourths—CC—CCC or Irish—and tables con-

taining any very glaring defects, come under the denomination of *coarse*.

These variations in quality depend on the presence or absence, number and extent, of those defects to which, even in the best regulated manufactories, glass is unavoidably liable. Perhaps the glass has been badly melted, and is seedy—that is, full of little vesicles, to which the rotary motion has given a circular shape. Or the gatherer may have enclosed air within his *metal*, and a gatherer's blister is the result; or a pipe blister, or pipe-scales, or dust from the pipe-nose, or dust from the marver, or dust from the bottoming-hole, or dust from the nose-hole, or dust from the flashing-furnace, or bad bullions, or scratches, or music lines, may disfigure the table, or the glass may be crizzled, or curved, or bent, or hard, or smoky, or small and light, defects to explain which would be a long and dreary task. No wonder that tables of the best quality are few and far between, in some manufactories a forlorn hope never to be realized.

The difficulty of obtaining glass free from defects will account for what may at first astonish—the fact that the value of a table of the highest quality is three times that of the lowest.

The defects enumerated, many as they are, are instantly detected, even through the obscuring hum, by the splitter, who not only can descry faults invisible to ordinary eyes, but can refer each fault to a particular stage of the process, and to a particular cause in that particular stage, and the faults are registered accordingly. The nomenclature of defects is much facilitated by the mapping out of the table into certain ideal divisions, derived from shapes assumed during various periods of the process. The centre lump is termed the bullion, round this lies the bottom; next the bulge; the shoulder; the top, and the rim, or the outermost edge of the circle.

Independently, however, of these defects, there are certain other disadvantages under which even a faultless table of crown-glass must unavoidably labor. The cutting of a circle into rectangular sheets, must necessarily be attended with waste, while the bull's-eye confines those sheets to comparatively small sizes. Uniformity of thickness, also, except by the most skilful manipulation, is difficult of attainment. Wavy lines, termed music lines, forming a series of concentric circles round the bull's-eye, and owing to the treatment of the glass upon the marver, were formerly a common defect; but improvements in the process have in a great measure removed them.

On the other hand, extreme brilliancy of surface is a distinguishing characteristic of this glass, ascribed by some to the influence of the marver, by others to the effect of the flashing-furnace.

It is this brilliancy of surface which has enabled crown-glass to maintain in England its position against that formidable rival which is now to be briefly described.

Cylinder, or Sheet-Glass.—The above method of making window-glass has long been abandoned on the Continent, where the glass is first formed into a sphe-roid, the ends of which are cut off, so as to form a cylinder open at both extremities; this is then cut

lengthwise with shears, or a straight line is traced with a drop of water in the direction of the length of the cylinder, and over the line so traced a red-hot iron is passed, which immediately produces a very uniform crack or fracture along the whole length. The cylinder, thus split up, is then taken to the furnace to be spread or flattened out into a sheet. The glass so manufactured, though formed of the same materials as crown-glass, is coarser in texture, more wavy and dull, but allows of larger sheets being formed, since crown-glass can only be cut up into comparatively small panes, in consequence of its circular form and the central bull's eye.

M. BONTEMPS remarks that there is no evidence by which to determine the relative antiquity of the crown and cylinder glass processes. There is reason to believe, however, that even in this country the latter was the more ancient, although at a comparatively early period it was abandoned in favor of the rotary method. The cylindrical process is the only one mentioned by THEOPHILUS in the thirteenth century; and this method was adopted by the Venetians, as the more uniform thickness which resulted from it insured, in their colored glasses, a greater uniformity of tint. But in France, England, and the North of Germany, the cylindrical process fell gradually into disuse, as the demand for colored glass diminished, and at length in these countries the rotary principle exclusively prevailed. Bohemia, however, still retained the cylindrical method, which she had learned from Venice, and this method was reintroduced into France by M. DROLENVAUX in 1730 with great success. Hence speedily resulted, not only in France, but also in Belgium and the North of Holland, where the style of building required panes of large size, the general abandonment of the rotary principle, and the adoption of the cylindrical, which continues, as already stated, to be practised universally on the Continent at the present day.

In England the manufacture of crown-glass maintained its position, notwithstanding its abandonment abroad, and attained to such superiority over the spread or broad glass manufactured on the German principle, that the former was used for all houses of the better class, while the latter was confined to poorer dwellings. The inferiority of this spread glass, manufactured indeed on the German principle, but by no means so good as the German glass, tended to prejudice the public against all glass made by the cylindrical method. This prejudice was, however, gradually overcome, by the establishment in England of the manufacture of cylindrical glass, according to a process introduced from France, and from which resulted a glass that has entirely displaced the manufacture of spread glass. The latter was so called from the circumstance that the cylinder, unskilfully blown, and then cut open with shears, as already stated, was spread out immediately upon a plate of iron covered with sand. Hence not only was the thickness of this glass very irregular, but its surface very coarse.

The introduction into this country of the manufacture of cylindrical glass by the French method, was due to the MESSRS. CHANCE of West Bromwich, near Birmingham, and Mr. HARTLEY, now of Sunderland, but then

in partnership with the Messrs. CHANCE, who, on visiting in 1830 the works of M. BONTEMPS, near Paris, were much struck with the advantages of the glass made on this principle, and having secured the co-operation of M. BONTEMPS, commenced the process at their own works in the autumn of 1832. So great, however, were the difficulties to be overcome, that it was not till 1838 that the fabrication of this glass was completely established. Since that time there has been great progress, and the sheet-glass now manufactured in this country, though inferior in color, is in other points generally superior to that of the foreign teachers. On this point Mr. BANNATYNE, in the new edition of the *Encyclopedia Britannica*, says:—The French, Belgians, and Germans, having pursued the cylindrical system for the last fifty years in making their window-glass, have much improved the old method of making it; and as the parties who are now manufacturing this article in England—namely, the Messrs. CHANCE and Mr. HARTLEY—are crown-glass makers, and have imported all the improvements adopted in the making of sheet-glass in France, Belgium, and Germany, and combined with these the improvements which their experience as crown-glass makers had taught them during the same period, they have surpassed the French, Belgians, and Germans in sheet-glass, and can now compete with them in all parts of the world.

After this testimony, the following account of the process for making British sheet-glass, as given by Mr. HENRY CHANCE, one of the partners of the eminent firm above-named, will be received by the reader as of very high authority:—

Imagine, as before, a lump of glass collected upon the end of the gatherer's pipe. For the metallic table or marver is now substituted a block of wood, so hollowed out as to allow the lump, when placed upon it, to be expanded by the blower to the diameter ultimately required. The block, during this operation, is sprinkled with water, to prevent the wood from being burnt, and from scratching the glass. In the meantime the lump is slightly distended by blowing, and, having received the shape represented in Fig. 156, it is carried from the block to the blowing furnace, which is accessible through a number of holes or openings, each hole being allotted to a single blower. In front of the furnace, corresponding to each opening, is a stage or frame of wood, erected over a large pit or well about ten feet deep—as represented in Fig. 157—and these parallel stages are sufficiently apart to enable each blower to swing his pipe to and fro in a vertical plane, that the glass may run freely out, as the phrase is, to the required length. When the glass has been sufficiently heated in the blowing furnace, it is brought out, and held over the head while blown, until it assumes by its own weight the flattened form represented in Fig. 158. It is then swung round in a vertical plane, as well as backwards and forwards, and the blower at the same time, by blowing down the pipe, constantly keeps the lengthening cylinder full of

Fig. 156.

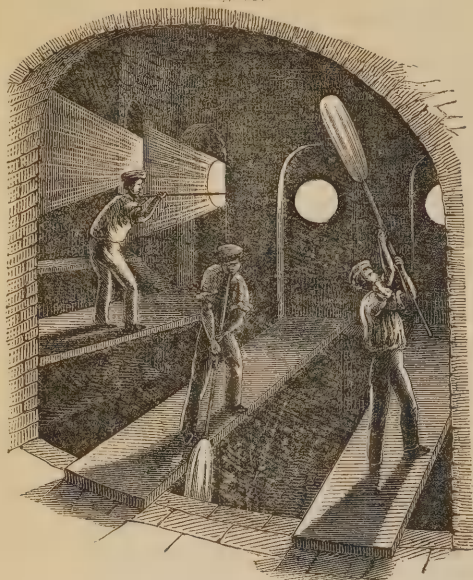


Fig. 158.



air. The first form which the glass assumes in consequence of the swinging motion is represented in Fig. 159. If the man were to blow without swinging, a

Fig. 157.



globe or sphere would be formed, as indicated by the dotted line. Uniformity of substance and of diameter is chiefly secured by the skill of the workman, who, when he finds the metal running out too freely, repeats the operation of holding the cylinder vertically above

Fig. 162.

Fig. 161.

Fig. 160.

Fig. 159.



Fig. 164.

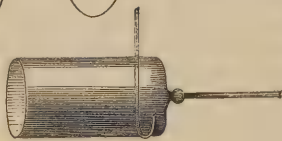


Fig. 163.

his head, still keeping it well filled with air. These operations are continued until the cylinder has reached the length required, as in Fig. 160.

The next stage of the process is opening the end of the cylinder. The thinner kinds of glass are all opened by submitting this part to the fire, and at the same time forcing in air through the pipe, and stopping up its aperture with the thumb. The air is expanded by the heat of the fire, and bursts open the cylinder at the end, this being the hottest and most yielding part. The thick and uneven margin of the aperture thus formed is trimmed with scissors, and

the cylinder now appears as in Fig. 161. The aperture is then widened out to the full diameter of the cylinder with the pucellas, and by turning the cylinder to and fro with the opening downwards, until by the centrifugal force, and its own gravity, the yielding glass assumes a uniform diameter with parallel sides, as shown in Fig. 162.

The ends of the thicker cylinders, if these were opened in the furnace in the manner above described, would be so thinned out that a considerable portion would be wasted. An extra mass of hot glass is therefore incorporated with such cylinders at the end, which thus becomes the hottest and weakest part, without applying them to the furnace, and the air forced in as before bursts them open. The opening is then enlarged by cutting round it with scissors.

The neck or cap is now removed by supporting the cylinder on a chevalet or wooden rest, and turning the upper part two or three times in the curve of a bent iron heated to redness, as shown in Fig. 163; a drop of water allowed to fall on the heated line produces fracture and separation of the cap. Or, the same may be done by wrapping round the end of the cylinder a thread of hot glass, removing the thread, and applying a piece of cold iron to any part which the thread covered.

The cylinder, as it now lies upon the chevalet, is little more in weight than two-thirds of the lump of glass which the gatherer collected on his pipe. The quantity left upon the pipe-nose, with that which formed the cap of the cylinder, are nearly equivalent in weight to one half the cylinder.

The next operation is to split it open along its length in the manner represented in Fig. 164. Till of late this was uniformly done by means of red-hot iron and water—a method which is still practised on the Continent; but in the English glass-works, it is now effected with greater certainty and regularity by a diamond, which, attached to a long handle, and guided by a wooden rule, is drawn along the inside length of the cylinder. In performing this operation, it is important to make the line pass through, or in the neighborhood of, some notable defect or group of defects, if such be present, for the line forms two edges of the future plate, and defects brought to the edges are of lessened injury to its value. An object to be avoided is the black mark which the cylinder sometimes receives from the charring of the wooden chevalet, on which, while hot, it rested in the glass-house. If the diamond passes, inside the cylinder, over the space occupied by this mark on the outside, the cylinder will fly to pieces. The reason of this, says Mr. CHANCE, is not difficult to understand. The chevalet prevented, by its non-conducting tendency, that portion of the glass with which it was in contact, from cooling equally with the rest, and the particles at that point remained in a state of tension. A careful blower will never place any large defect in his cylinder in contact with the chevalet, being aware of the probable result.

The use of the diamond in dividing plain surfaces of glass, dates from the sixteenth century; but its application to the splitting of cylinders which had not undergone the process of annealing, was introduced only about twenty years ago by M. CLAUDET, the distin-

guished photographer, then a glass manufacturer. Previously, all such cylinders were split by a red-hot iron, and, even now, all cylinders of flashed glass, that is, of ordinary sheet-glass covered inside with a skin of colored, are still split in the same fashion. On the Continent the diamond is gradually replacing the use of red-hot iron, though the latter is still the method more generally practised.

Having been split along its length, the cylinder is now ready for the flattener, who, having prepared it by a preliminary warming in the flue by which it is introduced into the *flattening-furnace*, passes it, by means of a croppie, or iron instrument bent at right angles, on to the *flattening-stone* or *spreading-plate*, which ought, of course, to be perfectly even and smooth, as the soft glass moulds itself to the surface upon which

it is flattened by heat. The sandstone of Godstone, in Surrey, has been found to answer well for this plate, which, however, is usually covered with a *lagre* or sheet of glass. Upon this lagre, *BB*—Fig. 165—the cylinder, lying with the split uppermost, is soon opened by the flame passing over it, and falls back into a wavy sheet.

The effect of the heat is assisted by spreading out the softened sheet, *A*, with an iron ruler, *c*, introduced through an aperture in the furnace. The flattener now applies another instrument, a *polissoir*, or rod of iron,

c, Fig. 166, furnished at the end with a block of wood, *D*, and rubs down the waviness into a flat surface, often, upon a refractory piece, using considerable force.

Some cylinders are so distorted in the blowing that no rubbing can flatten them; but all, good, bad, and indifferent, pass through the same treatment. The flattening stone is now moved on wheels to a cooler portion of the furnace, and by the aid of the flattening fork, delivers its sheet to another stone, called the cooling stone. From this, when sufficiently stiff, it is again lifted, and then piled generally on its edge, in order to be annealed.

In 1842 the Messrs. CHANCE patented certain improvements, whereby, instead of at once removing the glass from the flattening to the annealing furnace, and lifting it to the cooling-bed while soft and liable to distortion, they flat and cool it by passing it through a succession of decreasing temperatures, so that it is not lifted until it becomes quite stiff and rigid. By this arrangement the workman can flatten the glass while the annealing is in progress, which could not be effected by the old method, because the temperature of the flattening kiln must be reduced with that of the annealing kiln, to which it is contiguous, thus leading to the successive heating and cooling of the kiln, and waste both of time and fuel. At Messrs. CHANCE'S establishment the flattening and annealing kilns are two circular buildings communicating with each other, and shown in

Fig. 165.

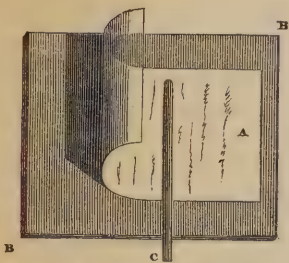


Fig. 166.

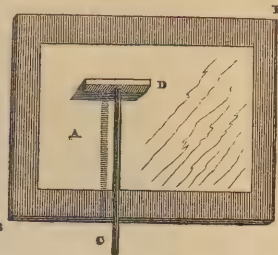
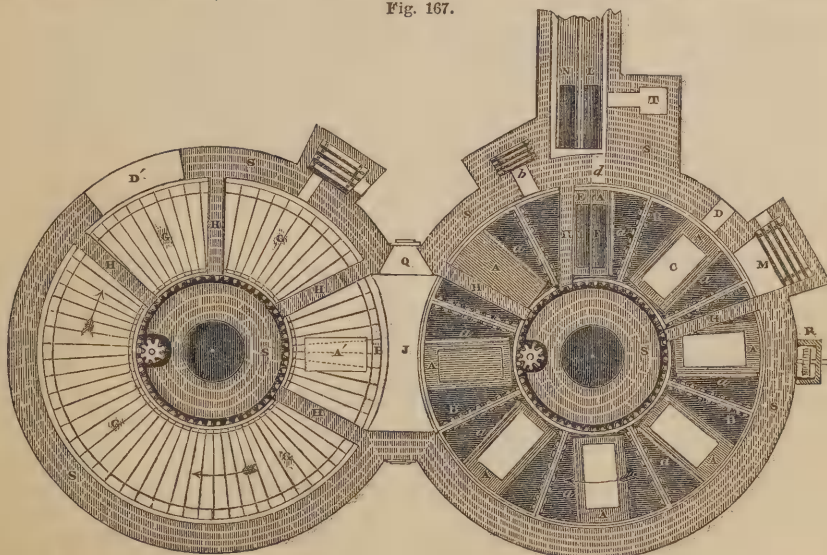


Fig. 167.



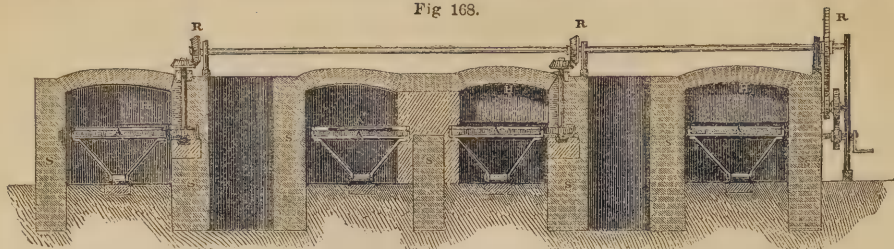
plan and elevation in Figs. 167 and 168. Each of the buildings consists of exterior and interior walls, *s*, the intervening space being a circular arched vault. In each vault is a cast-iron frame, moving on casters, and capable of being turned round by a winch on the outside, communicating with the shaft and bevil

wheels, *RR*—Fig. 168. The frame, *BB*, in the flattening kiln carries the flattening stones, *a*, and lagres, *A*, eight in number, and that in the annealing kiln a number of metallic wires, *G*, radiating towards the centre of the building, for supporting the sheets of glass. The flattening kiln is heated by the grate, *M*, and in order that the stones and

lagres, which will have cooled during the rotation, may be re-heated and arrive at the position, *R*, at a proper temperature, a second smaller grate is placed at *b*. If coke be used, a chimney at *T* will be required, but with

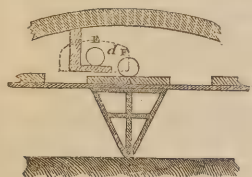
wood fuel it will not be needed. Partitions, *H*, are placed at certain intervals, to prevent the too rapid dissipation of the heat from those parts where it is most required, and to retard the entrance of cold air through

Fig 168.



the openings in the external wall. At the bottom of the partitions are spaces to allow the frame, with the stones and glass or the wires and glass to pass below. The space, *J*, on which the glass is shifted from the lagres to the wires, is lighted by gas. The kiln is worked in the following manner:—The cylinder of glass is first placed in the position, *N*; then in that of *L*; thirdly, it is introduced through the external wall, *d*, and placed on a stone, *E*, suspended over the lagres; it is lastly placed in the position *R*, on the lagre beneath. To prevent the cylinder rolling off, the stones are provided with a

Fig. 169.



ledge. This part of the kiln is shown separately in Fig. 169. The frame *B* is then turned round till the cylinder of glass occupies the position *C*, opposite the working hole, *D*, through which it is then flattened in the ordinary way. From *C* the glass passes round in the direction shown by the arrow, till it arrives opposite *J*, when it is shifted to the position *A'* on the wires, by the flattener using his instrument through the opening, *Q*; and after passing through the successive positions, arrives finally opposite *D'*, where it is drawn out fully annealed. Thus each sheet of glass, after having been flattened, remains on the stone during the time that other cylinders are being flattened, and before the sheet is lifted off the stone, it has passed through a gradually decreasing temperature, and has become rigid. The annealing is also carried on without lowering the temperature of the kilns by the movement of the frame, and the sheets, being isolated by the wires, become more quickly annealed.

Mr. HARTLEY, of Sunderland, introduced two improvements in this operation. One consists in making part of the floor of the flattening kiln to consist of a movable stone, about ten inches in diameter, on which the cylinder is placed, and by causing the stone to revolve on its axis, the cylinder is gradually exposed on all sides to the action of the fire, thereby avoiding the objection to the previous plan, where one side of each cylinder became so much hotter than the other. His other improvement consists in making holes, about the eighth of an inch in diameter, all over the flattening-stone. When the sheets of glass are to be polished, the absolute smoothness of the original surface is not

so much an object as to have them perfectly flat, and the air which lies between the common flattening-stone and the cylinder or spread sheet renders this difficult to accomplish; but by Mr. HARTLEY'S process the difficulty is overcome.

One of the most recent improvements is that of Mr. FARTHING, in which the kiln is heated by means of flues arranged under the floor, around the walls, and over the arch. By this means all deposit of dust or hard particles from the fuel on the surface of the glass is avoided, and any cheap kind of fuel may be employed.

To return to the flattened sheets: When annealed, they are drawn from the kiln, and carried to the warehouse, where they undergo examination. Being blown by a less complex process than crown, sheet-glass is liable, in the glass-house, to a less number of defects, but the subsequent process of flattening, notwithstanding the improvements above mentioned, often makes up the deficiency; and the manner in which a sheet, spared by one process, is disfigured by another, is described by Mr. CHANCE as sometimes curiously provoking. Standing upon the table of the *assorter*, he remarks, your eye lights upon a piece which, blown under an evil star, has imbibed in the glass-house every possible defect. The founder, skimmer, gatherer, and blower have all stamped their brand upon it. It is seedy—the vesicles, which were in the crown tables rounded by the rotary motion of the piece, are here elongated by the extension of the cylinder; it is stony, disfigured with stony droppings from the furnace; stringy, thin threads of glass meandering over its surface; *ambitty*, covered with stony speckles, symptoms of incipient devitrification; conspicuous with gatherers' blisters and blisters from the pipe—badly gathered; badly blown—thin here, thick there, and grooved with a row of scratches; and on this abortion the flattener chances to have exerted his most exquisite skill; it has passed through his hands unscathed, flat as a polished mirror, yet, from its previous defects, is entirely worthless. Next comes before you a piece whose beginning was miraculous—no seed, no blisters; it prospered under the hands of the gatherer and blower, and left the glass-house a perfect cylinder. But the croppie of the flattener marked it; the fire scalded it; dust fell upon the lagre and dirtied it; scraps from the edges of the preceding cylinder stayed upon the lagre, and stuck to it; the stone scratched it; and the heat of the annealing chamber

bent it. Such are the difficulties to which every cylinder is subject—those of the glass-house, and those of the flattening kiln. Not all, however, are such as these; there are good as well as bad, but the good are generally in the minority.

The qualities range thus—best, seconds, thirds, fourths, and H, the latter standing for horticultural, and including all coarse glass, such as may be applied to horticultural purposes. The difficulty of escape from defects renders the best quality, as in crown-glass, three times as costly as the common. The expense of production to the manufacturer is in each case the same; the materials, the labor, the fuel, the same for each. Success, therefore, clearly hinges on the proportion of good glass which a manufacturer can obtain. The six qualities of sheet-glass may each consist of six different thicknesses, forming thus, in all, thirty-six varieties.

When this manufacture was new in England, the size usually blown was thirty-six inches long, and twenty wide. The usual size now is forty-seven inches long by thirty-two wide, and cylinders are occasionally blown seventy-seven inches long; but large sizes and heavy weights are accomplished only by workmen of the first class. A sheet of this latter size, containing twenty-one ounces to the foot, would require for its formation a lump of glass upon the gatherer's pipe, of no less than thirty-eight pounds weight.

The size which sheet-glass can thus reach is obviously a great advantage, and adapts it to many purposes from which the limited dimensions of crown are excluded. It was this glass that covered the Great Exhibition in 1851. A cylinder was blown to cut, as the phrase is, forty-nine inches by thirty; this was subdivided into three panes of forty-nine inches by ten. About three hundred thousand of these, extending over a million square feet, and weighing upwards of four hundred tons, were the work of a few weeks, and this without absorbing or interrupting the ordinary produce of the manufacturer. The energy of the glaziers was equal to their task; eighteen thousand three hundred and ninety-two panes were fixed in the roof in one week by eighty men, one hundred and eight panes being accomplished by one man in a single day. It was the house of CHANCE and Company which executed the large order for the Exhibition, without materially affecting their power of executing their general orders, a feat almost unparalleled in the history of the manufactures of this country.

But sheet-glass has its faults as well as its virtues; it is devoid of that brilliancy of surface for which crown is so remarkable. It is subject, also, to undulations on the surface, the precise origin of which it is difficult to explain. Mr. SHAW, in his admirable lecture on the glass manufacture, as illustrated by the Great Exhibition, speaking of this defect, says—When the divided cylinder is softened by heat, and either allowed to flatten by its own weight, or flattened by the workman, the concave interior of the cylinder has to expand, and the convex exterior to contract, as the curved surface becomes plane. He adds, were this contraction and expansion to take place uniformly throughout the glass, the undulation in question would not occur, but since

one part invariably yields somewhat more readily than another, perfect flatness cannot be attained.

It is, however, more probable, in Mr. H. CHANCE's opinion, that this undulation is produced in the operation of blowing, and is due to the double movement of the particles of glass which accompanies the formation of every cylinder, the one movement being parallel to the axis of the cylinder, and the other in planes at right angles to that axis.

Grinding and Polishing Sheet-Glass.—A further development of the sheet-glass manufacture in England is the process of polishing and grinding this glass by machinery, whereby a new branch of manufacture has been established, which has furnished glass peculiarly applicable for purposes for which none previously existed. This improvement, which is the work of Mr. JAMES CHANCE, is characterized by M. CLAUDET as one of the greatest improvements which has ever been introduced in the manufacture of window-glass, as it has produced, at a cheap price, an article equal in effect to plate-glass, and by which houses can now be glazed with a glass that does not distort external objects, while, at the same time, when viewed from the outside, it has all the polish and fine appearance of plate-glass. To explain the merits of this invention, it must be recollected that the sheet-glass has the polish of its surface much injured by the mode of its production, and that a still greater defect arises from the inside and outside of the cylinder not being of the same length, so that when developed by the flattening operation either the one surface must contract or the other expand; and the result is a kind of undulating or wavy appearance called *cockles*. These cockles reflect and refract light in various directions, and the objects seen through the glass are necessarily distorted.

Several attempts, continues M. CLAUDET, were made in France and Germany to grind and polish this glass, in order to destroy these inequalities and imperfections. For this purpose sheet-glass had to be made considerably thicker, owing to its never being perfectly flat throughout its length and width, so that one corner or another, and even several points on the surface, were liable to be completely worn out before the end of the operation.

Mr. JAMES CHANCE conceived the ingenious idea of laying every sheet of glass intended to be ground and polished, upon a flat surface covered with a damp piece of soft leather. The sheet adhering completely to the leather after having been pressed against, produces, in fact, a vacuum, so that by the pressure of the atmosphere the whole sheet is maintained in a flat position. Two sheets having been placed in this manner, each on the retaining or sucking surface, they are turned one against the other in a horizontal position, sand and water being constantly supplied between them; and by means of the most ingenious machinery, the two surfaces rapidly rub one against the other in all directions, and are ground at the same time by the sand. When the grinding has been performed on one surface, the sheets are turned to have the other surface ground in the same manner.

The sheet being ground while it is kept perfectly flat, it is not necessary to wear out more than a thin

layer of the whole surface. Of course, after the operation, the sheet of its own elasticity resumes its former shape more or less curved, but the whole surface of both sides has a polish as perfect as plate-glass, and this is the desired condition for glazing purposes. Although the glass could not make perfect mirrors of a large size, on account of the slight curve arising from the flattening operation, still it may be usefully employed for small looking-glasses. M. CLAUDET states that this glass has all the perfection and qualities required for taking pictures by the collodion process, and for framing all photographic and other pictures, for which last purpose it is even preferable to cast plate-glass on account of its lightness.

Mr. JAMES CHANCE's invention is, therefore, one of the most important improvements in the manufacture of window-glass during the present century; and to him is due the cheap but beautiful glass now so generally used in glazing ordinary dwelling-houses—an article quite equal in effect to the expensive plate-glass which was formerly seen only in the windows of palaces and aristocratic mansions.

IV. PLATE-GLASS.—DODD justly remarks that a better name than *plate-glass* would be *cast-glass*, since the former is vague in its acceptation, and might be applied to any kind of glass in sheets, whereas the latter expresses the mode of manufacture of this beautiful article, which is formed by being *cast* or *founded* upon a smooth table while in a liquid state, and is totally independent of the process of blowing. It is not generally known, however, that originally all plate-glass was made by blowing; and that in this country it was not till 1773 that the British Plate-Glass Company first began to make plate-glass by casting, although this process had been in use in France for nearly a century. The method of blowing plate-glass was very similar in principle to that of sheet-glass, differing only in some mechanical contrivances to assist the workmen in handling so much heavier a piece. The plates formed by this method, however, were much smaller than can be executed by the casting process, which sometimes exceed ten feet in length, and are about half an inch thick. Plates have been cast as much as fourteen feet long by eight or ten feet in width, and some of enormous dimensions were shown at the Great Exhibition.

The principal consumption of plate-glass is for mirrors, the manufacture of which dates from the earliest introduction of glass-works into Europe. Mirror-glasses were for many years the object of an important commerce to Venice, the only city which could produce them. The manufactory, which was situated on the island of Murano, produced, however, only sheets prepared by blowing, and this was the process imported into France in 1665, along with the art of covering plates of glass with tinfoil, which had long been exclusively possessed by the Venetians. The largest mirror-glasses which could be made in this manner were about three feet in the side, and they were liable to the air-bubbles, knots, and striæ so frequent in common window-glass. All these disadvantages disappeared with the invention of the casting process which is now in use. ABRAHAM THEVART devised this bold me-

thod, as DUMAS terms it, and put it in practice at Paris in 1685. It was the same artist who founded in 1691 the celebrated manufactory of Saint Gobain in Picardy, which remained so long without a rival, and where perhaps the best plate-glasses are still made, though two or three other manufactories have been established on a very large scale, which renders the mirror-glass manufacture a very important object for France. In this country, as in France, the business is confined to a very few large establishments.

Composition of Plate-Glass.—This beautiful variety of glass is similar in composition to crown and sheet glass, the only essential bases being lime and soda; but in plate-glass the soda is introduced in somewhat larger proportion. So far as regards the purity of the tint, it would be attended with advantage to substitute potassa for the soda; plate-glasses would thus be freed from the greenish or bluish shade which they sometimes present, and, in this case, one might increase the proportion of lime, which is kept comparatively low in plate-glass to avoid devitrification. But soda is preferred to potassa for this description of glass, because it imparts a higher degree of fluidity, and because the impurities which it contains are more readily dissipated by the heat; so that the use of soda, though objectionable as tending to color the glass, facilitates both the fining and casting—two most important advantages in the manufacture. Subjoined is the analysis of a plate-glass by DUMAS:—

	Centesimally.	Oxygen.	
Silica,	75.9	=	39.4
Alumina,	2.8	=	1.3
Lime,	3.8	=	1.0
Soda,	17.5	=	4.4
	100.0		6.7

From this analysis it appears that the quantity of oxygen of the silica is about six times that of the aggregate oxygen of the bases. It will be seen, also, that this glass differs considerably from window-glass in the proportions; in the latter, for each equivalent of soda, there is always at least half an equivalent of lime, whereas, in plate-glass, for one equivalent of soda, there is only one-fourth of an equivalent of lime. In window-glass, putting the alumina and lime together, the oxygen of these earthy bases always exceeds the oxygen of the soda; in plate-glass the oxygen of the lime and the alumina constitutes scarcely the half of that of the soda. All these circumstances have the effect of rendering the plate-glass more fusible, more readily altered, and less hard than window-glass; but it is also less brittle, and less liable to be devitrified.

The preceding analysis is elementary and theoretical; the subjoined practical recipes are given in KNAPP'S *Technology*:—

Composition used at St. Gobain.	Composition according to Bastenaire.
100 pounds pure sand from Senlis.	100 pounds white sand.
35 pounds pure salts of soda.	60 pounds salts of soda.
5 pounds lime, crumbled.	13 pounds carbonate of lime.
100 pounds broken glass.	100 pounds broken glass.
Decoloring matters,	1 pound peroxide manganese.
	0.5 pounds smalt.

The following proportions, which have been used in England, are said to produce a superior quality of plate-glass:—

	Parts.
Lynn sand, well washed and dried,.....	720
Alkaline salt, containing forty per cent. of soda,.....	450
Lime, slaked and sifted,.....	80
Nitre,.....	25
Broken plate-glass,.....	425

These quantities produce one pot of *metal*, which yields one thousand two hundred pounds of glass.

The object for which plate-glass is chiefly manufactured requires in the materials the highest degree of purification, and the utmost care in the fabrication. A good mirror should reflect an image in its true and natural shape, and no distortion must occur, which invariably happens if lumps or waves in the glass unequally refract the light or produce irregular reflection. Moreover, the light must pass through the thickness of the glass before it is reflected from the metallic surface at the back; and as the thickness of the plates must correspond with their lateral dimensions, which are often considerable, it is evident that transparency and absence of color are points of great importance. It is true that in the last century this was a disputed question. MONTANEY advanced that the black color was preferable to all others for mirrors, and his theory appeared so plausible as to require a formal refutation on the part of ALLUT. It is evident that, unless the light were assumed to be reflected at the first surface, this theory is quite untenable; and even assuming the reflection to take place at the first surface, it would be necessary to give the glass, not only a black color, but a complete opacity, similar to that of the metals themselves, of which mirrors were anciently made; but this absolute opacity, in the case of glass, would be very difficult, if not impossible, to attain.

In the present day the object aimed at, by universal agreement, is to give the most perfect transparency to mirrors, and to destroy the slightest traces of coloration. With this view, not only must the metal or melted glass be thoroughly fused, but the original materials must be selected with very great care. The sands which enter into the composition should be very white and fine. In default of suitable sand, soft sandstone, white and well pulverized, is used. Flint and quartz, calcined and reduced to powder, are excellent materials for the purpose. Particular care must be taken in the choice and treatment of the soda, to avoid, as far as possible, the green tint which is peculiar to glass formed with this alkali, and which the thickness of the plate-glass betrays. It might be possible to counteract this evil to a certain extent by a perfect fining or purification of the soda, and by replacing part of it with potassa, to the amount of about one-fifth. If plate-glass were formed with potassa alone, instead of soda, it is to be feared that a glass necessarily so rich in alkali, would be hygrometrical, and would partake too much of the nature of soluble glass. Even the small proportion of potassa which, in the shape of nitre, usually enters into the composition of French plate-glass is found to give it a dampness, so that when two of these are kept together for any length of time, they can scarcely be separated. Mr. VARLEY stated at a meeting of the Society of Arts, that he was once shown some very large glasses by a London manufacturer, which were beautifully clear, but appeared

to be covered with steam, and this, when wiped off, appeared again. The manufacturer had applied to Professor FARADAY in hopes of learning how to cure this imperfection. On examining these glasses with a magnifier, the apparent steam was found to consist of very minute but long crystals, which shape indicated nitre, showing that so much potassa was used in the manufacture of the glass that it exuded. Now, repeated washings, which, with eight or ten feet glasses, is a serious labor, might much lessen the exudable matter; but the glass would thus become porous all over, and its power of transmitting or reflecting light would be diminished. What was still worse was, that such glass could never be wiped so as to remain clean, for the wiping filled up the pores with what should have been quite removed. This began again to exude in minute gummy dots, which continued to enlarge, and on again wiping, smeared the surface, rendering it difficult to clean. Soda is prone to dry and lose its water of crystallization; potassa, on the contrary, attracts moisture, and becomes liquid. Hence it would seem that soda must make the more durable glass, besides fulfilling the important conditions of rendering the vitreous composition more fusible and more easy to fine. The latter advantage arises from the fact, that the gall or sandiver of the soda-glass, consisting of sulphate of soda and chloride of sodium, is more volatile than potassa-gall, and is hence more readily got rid of from the open pots in which the glass is fused.

Melting and Fining.—Two sizes of pots are used in the manufacture of plate-glass—the larger for melting the vitreous mixture, and for keeping it long in a state of fusion—the smaller for receiving a portion of the glass to be fined and cast. The latter are termed cisterns, or in France *cuvettes*. The English pots and cisterns are of the same form as the pots used in the manufacture of crown-glass; and this is also the form of the French pot—Fig. 141; but in France the cistern or *cuvette* is formed square or rectangular—as shown in Fig. 170—and three pots contain the material for six small *cuvettes*, or for three large ones. These last are employed for mirrors of large dimensions—for example, of one hundred inches and upward. Lately, furnaces have been constructed for six pots and twelve *cuvettes*, eight small and four large ones. The small ones have the form of a perfect square, the large ones of an oblong rectangle. About the middle of the depth of the *cuvette*, A A, a groove or indentation, B, is formed, whereby the vessel is grasped with the tongs.

The ingredients for plate-glass were formerly fritted before melting; but this preliminary process is now dispensed with, the mixture being composed of such pure materials that it can be placed cold in the pot in three successive charges. The time necessary for the fusion and the fining is in France divided equally between the pots and the *cuvettes*. The material is left sixteen hours in each, and, at the end of these thirty-two hours, it is fit to be cast. During the melting of the mixture in the pots, the *cuvettes*

Fig. 170.



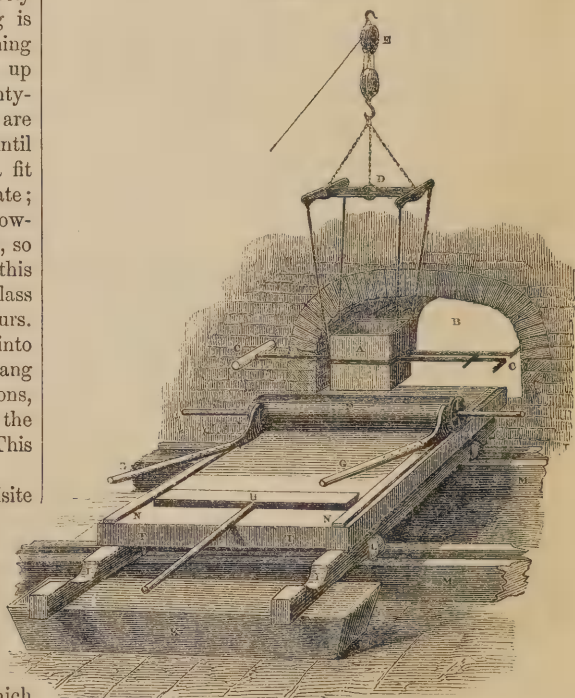
are placed empty in the furnace; but as soon as the whole charge is in a state of fusion, the cuvettes are removed by means of tongs, and cleansed from all impurity, and from the residual glass of the last operation by a scraper. They are then replaced in the furnace, and after a few moments' heating, the ladling or transferring operation commences. The surface of the metal in the pots is skimmed, and the liquid glass is transferred into the adjacent cuvette with a copper ladle, care being taken not to disturb any grains of sand or lumps that may have settled down at the bottom of the pot. Thus, as KNAPP remarks, at the very commencement a kind of double purification is effected—the infusible portion is left untouched, and the glass is well mixed by the agitation of ladling. This transferring process, which is termed in France *tréjetage*, requires two workmen, one after the other; each draws out the glass three times—whence the word *tréjeter*, to throw or cast thrice—and then plunges his ladle into cold water. The furnace is then shut, and the cuvettes are left to themselves, for the glass to fuse—that is to say, that the bubbles excited in the mass by the *tréjetage* may be disengaged, and the excess of soda be entirely volatilized. It has been stated that the melting is generally accomplished in sixteen hours; but the fining which succeeds the ladling process must be kept up quite as long, and extends indeed sometimes to twenty-four or even forty-eight hours before the bubbles are dispersed and no more alkali is volatilized, or until specimens of the glass exhibit in every respect a fit state for casting. This is not exactly a liquid state; but after the perfect melting has taken place, the glowing mass is allowed to lower its temperature a little, so as to acquire a slight degree of viscosity. With this view the fire is allowed to decline, and the glass acquires the proper consistency in three or four hours. To make sure of this, the end of a rod is dipped into the cuvette; the portion taken up is allowed to hang down, and by the form it assumes and other indications, the workman readily judges whether it has acquired the necessary consistence and is free from bubbles. This is termed *drawing the glass*.

Casting.—While the glass is acquiring the requisite consistence, attention must be given to heat the annealing furnaces, as well as the casting-slab or metal plate which is to receive the liquid glass. This table was formerly made of bronze; but the liability of this metal to crack induced the British Plate Company to try a plate of cast-iron, which was found to be quite successful, and even the large bronze slab at St. Gobain, which weighed fifty thousand pounds, and cost one hundred thousand francs, or £4000, has been discarded, and replaced by one of iron. The table, *TT*—Fig. 171—must be of longer dimensions than the largest plate; it varies from ten to twenty feet in length, with corresponding breadth, and is six to seven inches in thickness; it rests on a strong wooden frame or truck, *MM*, movable on casters, and sometimes running on a railway, along which it is wheeled from one annealing oven to another, since it is necessary that the table should be placed close to the oven or arch, *B*, into which the plate is to be removed for annealing after being cast.

With this view the height of the slab or table is made exactly on a level with the floor of the arch. Its upper surface is flat and polished, to mould the lower surface of the mirror; and, before the casting, it is heated by hot coals spread over it, and then wiped perfectly clean.

The annealing-ovens being heated to a brown-red, the casting-slab brought to a suitable temperature, and the metal or melted glass thickened to the requisite point for flowing readily and equably, the aperture into the cuvettes which are to be taken out is then opened; two workmen introduce tongs into the furnace, and grasp the cuvette by the groove shown in Fig. 170, while a third slides a large pincer under it. When this instrument is pushed well under the bottom of the cuvette, the workman draws it towards him, aided by the others with their tongs, which are supported on rollers. In this manner the cuvette is drawn to the mouth of the opening, where it is raised by a crane, placed upon a truck or low carriage, and removed to the casting-table. The melted glass being skimmed, the cuvette, *A*—Fig. 171—is then drawn up to a sufficient height

Fig. 171.



by the tackle, *DE*, and suspended above the upper end of the casting-table, where it is tilted over by means of the tongs, *CC*, and the metal is poured out on the table. The appearance presented by the molten sheet is now exceedingly splendid. The building being very dark within, the glowing liquid throws a strong light on the faces and persons of the workmen. In the meantime, the glass is prevented from running over the sides by ribs or rims of copper, *NN*, which are exactly equal in height to the intended thickness of the plate of glass; and when the cuvette has been emptied of its contents, a

massive hollow copper cylinder, *r*, three feet in diameter, and resting at each end on the side ribs, is set in motion. This cylinder, which weighs several hundred-weights, is moved by means of the handles which form a prolongation of the axis, and spreads the glass out into a sheet of uniform breadth and thickness. It would, however, overflow the sides, if this were not prevented by the workmen applying the iron pieces, *g g*, which form a dam at the sides, and precede the course of the rollers. Lastly, to prevent any impurity from contaminating the glass, a workman draws the washer, *h*, covered with cloth, immediately in front of the advancing sheet of fluid glass; the excess of glass pours over the front edge of the slab into a trough, *k*, filled with water, and finally the roller passes off and is received in the grooves, *l l*. A beautiful play of brilliant colors, comprising every imaginable tint, is exhibited by the glass immediately after the roller has passed over it; caused, probably, by a temporary oxidation of the surface.

Whilst the cuvette is carried back to the furnace to receive a fresh charge of glass, the two ribs are removed, and any blisters or seams or redundancy which may exist at the two sides of the plate are broken off; a thick flange of the still soft glass is then turned up at the end, *t t*, and a rake-shaped iron is applied to it, by means of which the plate is thrust forward into the annealing oven, *b*, where it rests upon sand. As the plate is not perfectly rigid when this is done, the force which must be exerted to push it over the floor of the kiln often produces considerable undulations on the upper surface, which subsequently disappear under the polishing.

While the introduction of the plate into the annealing arch is being proceeded with, other workmen are engaged in taking from the fining furnace another cuvette, which arrives at the casting-table at the moment when the preceding plate has just been introduced into the annealing oven. After filling the oven, all the openings are carefully stopped up with iron plates and clay mixed with sand. At the end of twenty hours, some of the pieces of iron are taken away; an hour or two afterwards more are removed; as the oven cools, more and more are taken away, and at last the whole of the clay and plates of iron which stopped the apertures are removed. When the hand can be placed on the glass plates without feeling much heat, they may be taken out of the oven. Such, at least, is DUMAS' account of the French method. But in this country the plates are allowed to remain in the oven, resting in a horizontal position, from five to ten days.

It has been stated that the temperature of the annealing kiln, when the plates are introduced, should be a dull red. If the kiln were too hot the plates would enter into a state of semi-fusion, and would get out of shape, or at least would adhere to the floor of the kiln, so that they could not be detached without breaking. On the other hand, if the kiln were too cold, the plates would be badly annealed, and might fly to pieces in the act of being taken out of the oven, or afterwards. The slightest change of temperature is sufficient to split into pieces plates which have been badly annealed. They break also when one proceeds to cut off the jagged

edge with a diamond. It almost always happens that, in plate-glasses badly annealed, the separation does not occur at the place where the incision has been made.

The annealing ovens, termed in France *carquaises*, are very large, and have several fire-places. The bed or floor is made of bricks, presenting in its whole extent a perfectly level surface. Sand must be sprinkled over the bed, that the plates may slide freely upon it, and encounter no impediment in shrinking or contracting.

Squaring, Grinding, and Polishing.—After being withdrawn from the annealing oven, the plates have to undergo the operations of squaring, grinding, and polishing. As taken from the oven, they are about half an inch thick, and present an irregular mottled appearance, roughened on the lower surface by the sand on which they have rested, and smoother, but not flat on the upper surface. The first process is that of squaring, or cutting them into their useful dimensions; for which purpose they are carefully examined, and the workmen endeavour, notwithstanding the imperfect transparency of the glass, to select those which appear to be free from defects, to be reserved for large plates, while such as show imperfections that cannot be removed by grinding, are picked out to be cut into smaller plates, transposing the faulty parts to the sides. The squaring is performed by passing a rough diamond along the surface of the glass, guided by a square rule; the diamond cuts to a certain depth into the substance, when, by gently striking the glass with a small hammer, underneath the part which is cut, the piece comes away; and the roughnesses of the edge then left are removed by pincers.

The plates having been squared, next undergo the processes of grinding and polishing. In these operations two plates are employed, one of larger dimensions, and one three or four times smaller, which are made to rub against each other. This was formerly done by hand, but is now almost entirely performed by machinery. The lower and larger plate is embedded in plaster of Paris, in a perfectly horizontal position, upon a table about two feet high, which is termed the *grinding bench*; the smaller plate is cemented upon the lower face of a swing table, made heavy by weights, and caused to traverse over the lower plate in such a way, that by a combination of a rotatory and oscillating motion, the relative position of the two plates is constantly changed. In adjusting the plates, a rough or rolled surface of the one is opposed to the comparatively smooth or casting-plate surface of the other, and the material employed to grind the surfaces is thrown upon the lower plate from time to time. River sand and water were formerly used for this purpose, but ground flint of different sizes is now substituted, as answering the purpose better. The machinery is set in motion by a steam-engine, and this process is continued until the ground plates exhibit a perfectly horizontal and even, though still unpolished surface. When one side of each plate has been sufficiently ground, it is loosened from the frame and turned over, so as to present the other surface to be ground in the same manner. Some degree of pressure is employed by loading the upper plate with weights, as the grinding of each side approaches to completion. The

process thus described used formerly to last three days, but the time is now much abridged. The greatest attention is required to complete the operation, with the surfaces perfectly level and parallel, for which end a rule and plumb-line are employed.

By means of this grinding, the plates are made level, but are still too rough to receive a polish. To fit them for this, they are now ground with emery powder of increasing degrees of fineness. When the plates become sufficiently smooth for this operation, there is a tendency to cohesion between the surfaces, which produces so much friction that when the work is done by machinery one surface will frequently tear the glass from the other. Hence hand labor has been generally employed in this part of the process. The lower plate is placed upon a stone bench covered with wet canvas, which holds it firmly in its place; the surface is sprinkled with emery and water, and a small plate, moved by the hand, is used as a runner or grinder. Women are generally employed in this operation, and are said to perform the work better than men, on account of their superior delicacy of touch, which enables them to use precisely the degree of force required, and readily to detect and remove gritty particles among the emery. Young girls are employed on small plates. About three sizes of emery are used, the different qualities being previously separated and assorted by suspension in water; and between every size the plates, canvas, bench, and hands are thoroughly washed. After the application of the last or finest emery, the plate has become quite smooth and partly polished. To dispense with the necessity of manual labor in this operation, Mr. BLAKE, of the Thames Plate-Glass Works, has recently introduced a machine which imitates the motions of the arms of the persons employed in smoothing, and works admirably.

The glass, although now perfectly even, appears opaque and deadened on the surface, and still requires the final polishing. To effect this, a piece of wood is covered with numerous folds of woollen cloth, having carded wool interposed between each two layers, so that the whole forms a tolerably hard but elastic cushion, which is fitted with a handle. The plate is embedded in plaster, as already described, and the cushion, being wetted, is covered with Venetian pink, which contains a small portion of oxide of iron, mixed with earthy matter, and is moved backwards and forwards on the surface of the plate, with considerable pressure. This rubbing is now generally performed by machinery, as hand-polishing is tedious, and is apt to produce a wavy appearance; hence machine-polished glass is to be preferred.

In 1856, a patent—communicated by ALBERT BROUGHTON, ALEXANDER LINDSAY, and JOHN RUTHVEN PLATT, all of New York—was taken by WILLIAM EDWARD NEWTON, of the Patent Office, Chancery Lane, London, for an improved method of polishing the surface of glass, stone, metal, or other materials capable of being polished by friction. The distinguishing principle of this method consists in grinding and polishing the flat surfaces by means of a rotating plane of glass, metal, stone, or other suitable material, the substances of which the surfaces are to be ground or polished being held in a frame in such a man-

ner, that the friction, exerted by the rotating plane upon the surfaces of the substances under operation, will cause them to rotate with a slower motion upon their own centres. The form adopted as most convenient for the grinding and polishing surface is circular; it therefore generally consists of the upper surface of a circular table or wheel, which may be of cast-iron, and is secured firmly at the upper end of a vertical shaft, which is supported in suitable bearings in a strong framing of timber or iron. The upper end of the shaft is not allowed to stand above the table, and therefore the article to be polished will be allowed to pass over its centre. Rotary motion is communicated to this circular table by means of suitable gearing. The apparatus for holding the plate of glass to be ground and polished consists of a plate or frame of metal or wood, having a rim all round the lower side, within which the glass is received in a bed of plaster of Paris. This plate or frame is connected with a perpendicular spindle which is capable of being moved nearer to or further from the centre of the rotating circular table. The grinding and polishing operation is effected with the aid of sand, or any common polishing material. To commence the operation, the plate of glass, having been secured in its bed or frame, is placed on the rotating circular table, and the holding plate or frame is connected with the long lever by means of its spindle. Rotary motion is now given to the circular table, and when the sand or grinding material is properly distributed, the friction produced on that part of the plate of glass which is at any time on that side of the spindle of the holding frame which is furthest from the centre of the table, being greater than that on the part which is at the same time on that side of the spindle nearest the centre of the table, causes the plate to rotate in the same direction as the latter. The sand or grinding material, when a fresh supply is applied, will always distribute itself evenly after a very few revolutions. The grinding may be regulated by a screw and nuts on the spindle of the holding frame, so as to produce a pressure on the plate, additional to what is produced by its own weight, and the weight of the plate or frame and other parts of the holding apparatus, or to take off some of that pressure. The patentee alleges that, by producing the rotary motion of the glass to be ground and polished, by means of the friction of the grinding or polishing surface, an evenness and smoothness and freedom from scratches are obtained, that cannot be produced when the rotary motion is positive, or produced by gearing, as in other polishing machines. The reasons assigned for this are as follow:—In the former case, the grinding or polishing surface and the surface to be ground or polished undergo an infinite transposition, while in the latter, they are frequently in precisely the same relative positions; again, when the motion is produced by friction, it is found to be steady and free from the tremor which is produced when an independent and positive motion is given.

The Editor is informed by Mr. FINCHAM, the active and intelligent manager of the British Plate-Glass Works, that the preceding process acts admirably, and is sure to supersede all those hitherto in vogue. It is daily working under Mr. FINCHAM's superintendence.

Mr. BESSEMER some years ago proposed a new method applicable to the whole process of casting, grinding, and polishing plate-glass. Dispensing with the use of cuvettes, he pours the melted glass directly from the pots between two rollers, placed at a certain distance apart, and kept cool by a current of water passing through them. This insures a uniform thickness in the glass. The furnace employed by Mr. BESSEMER is a reverberatory with a low arch, and the pot, which is of very large dimensions, is set upon a movable siege composed of masses of firestone firmly cemented together. The pot and siege run upon four wheels, by means of which they are readily moved out of the furnace, to empty the contents of the pot between the two *forming* rollers already alluded to, and, after passing between these, the glass is received between two *finishing* rollers placed closer together, and moving with accelerated speed, so that, on emerging from the latter, the glass appears smooth and flat, though wanting in polish. The plate now slides down a curved surface upon a flat table, and, when sufficiently cooled to become rigid, it is transferred to the annealing kiln, which is heated by a current of hot air obtained from a chamber situated between the furnace where the glass is melted and the chimney. A saving of fuel is thus effected, the heat is more easily regulated, and the articles to be annealed are not subject to injury from the dust and products of combustion of the fuel. The polishing, according to BESSEMER'S method, is performed by laying the plate of glass upon a slab of slate placed perfectly horizontal upon a bed of brick-work, and causing an endless belt of gutta percha, covered with felt and polishing material, to pass rapidly over the surface of the glass in contact therewith, and to traverse at the same time slowly across the plate by a lateral motion at right angles to the line in which the belt moves over its drums. The belt is of the same length as the sheet to be polished, and is pressed upon the entire surface of the glass by a number of small rollers. The continuous action of the strap in one direction renders it unnecessary to cement the glass to the table, which is effectually prevented from shifting its position by a raised rib or stop let into one end of the table.

By the grinding and polishing, the plates are reduced in thickness as much as one-third, and in some cases one-half. If any radical defects exist in the glass, these are only heightened by the polishing, and hence a second and more careful examination and selection of the plates is now made. In fact, in every stage of the manufacture, the experience of the workman is called for, to determine whether any and what imperfections appear, and how they are to be removed; and as, on the one hand, no manufactured article would betray the existence of defects more readily than a large sheet of plate-glass, so, on the other hand, the most sedulous attention is paid to the detection of such defects when they appear in the course of the manufacture. Those which are still found defective after the polishing, are cut up into smaller plates, and polished again, while the perfect ones, when destined for mirrors, are subjected to the final process now to be described.

Silvering of Mirrors.—This designation is a misnomer, there being no silver used in the common method of performing the operation; but a compound of tinfoil and mercury, or quicksilver, whence probably the mis-appellation. The operation is commenced by spreading a sheet of tinfoil, which must be of somewhat larger dimensions than the plate to be covered, upon a flat stone or slate slab, termed the *silvering table*, and brushing mercury over it. When the surface of the tinfoil is uniformly covered, more mercury is added till it covers the metallic sheet to the depth of one-sixth or one-fourth of an inch. A brilliant surface is then produced upon the fluid metal, by skimming aside the grey coating of oxide with a wooden rod. The plate of glass is now introduced by pushing it forward horizontally from one side of the table, with the longest edge foremost, and so that this edge always dips below the surface of the mercury. By this means dust and air are totally excluded; whereas, if the plate were let down perpendicularly upon the mercury, more or less of both would certainly be enclosed between the glass and the amalgam. On the contrary, by sliding it forward in the manner described under the surface of the mercury, the pure metal alone is brought into contact with the glass. To get rid of the excess of quicksilver, the plate or mirror is loaded with weights, and the table is inclined at an angle of ten or twelve degrees, when most of the uncombined mercury flows away. The last portions are removed by placing the plate in an upright position, and in the course of three or four weeks a dry permanent coating of tin amalgam is left on the glass.

A great disadvantage attending this operation is the serious detriment to the health of the workmen from the vapor of the mercury; another objection is the very considerable time required to complete the work; and, lastly, the process is subject to frequent failure from different causes: the plates often break under the pressure of the weights, and, when set on edge, drops of mercury sometimes trickle down, and carry the amalgam with them, producing curved streaks, technically termed *worms*, so that it becomes necessary to re-silver the whole mirror. The amalgam, also, is liable to spoil by crystallization, and is easily injured by carriage. A process proposed by DRAYTON, and tested by FARADAY and WARINGTON, is free from these defects. It consists in employing a *silvering fluid*, obtained by mixing ammonia with nitrate of silver, filtering the mixture, and adding to it an alcoholic solution of oil of cassia. The proportions are one ounce of nitrate of silver, three ounces of alcohol, of the strength of 87 per cent., and twenty to thirty drops of cassia. This fluid has the property of depositing *bright metallic silver* on the addition of what is termed the *reducing liquid*, consisting of a solution of one part oil of cloves in three parts alcohol. The term *silvering* is, therefore, strictly applicable to this process, which is performed by surrounding the plate of glass, after being perfectly cleaned, with a rim of putty, and pouring upon it a layer of silvering fluid to the depth of one or two lines. The oil of cloves solution is then added, and, more or less rapidly, in proportion to the quantity of this solution

employed, a film of brilliant metallic silver is deposited, and attaches itself firmly to the glass. The coating succeeds best when a very small portion of the reducing liquid is used, so as to cause the reduction to proceed slowly. To cause the precipitation of four and a half ounces of the solution of silver, from six to twelve drops of the reducing liquid are sufficient; and so thin is the film of metal thus deposited, that a square foot of it only weighs from twelve to eighteen grains. The principle of the process consists in deoxidizing the oxide of silver, by means of the volatile oil, which is effected without any evolution of gas, that might destroy the continuity of the metallic coating, while the nitric acid disengaged from the oxide of silver enters into combination with the ammonia.

Great as may appear the advantages of this process, it has not been applied extensively by the manufacturers of mirrors, partly on account of the difficulty of obtaining, by this means, a perfectly clear unspotted surface, and partly on account of the darker color of the silver coating, which gives a black effect to the mirror. This black appearance is probably due to the shade of the silver, although it has been also ascribed to the very perfection of the coating, and the precision with which it reflects the rays of light, whereas the ordinary coating of tin amalgam is crystalline, and reflects the light to the eye in almost any position.

The mixture now employed by Mr. DRAYTON is somewhat different from that above given, and consists of one part of ammonia, two parts nitrate of silver, three parts water, and three alcohol; this solution, being filtered, is mixed with one-fourth part of grape sugar dissolved in weak spirit. This method, or one very similar, is stated by PELOUZE and FREMY to be now successfully practised at Paris. The exact proportions given by them are as follow:—Six hundred grains of pure neutral nitrate of silver are dissolved in one thousand two hundred grains of water. To this solution are added:—First, seventy-five grains of a liquor prepared from twenty-five parts of distilled water, ten of sesquicarbonate of ammonia, and ten of ammonia, of specific gravity 0.980; second, thirty grains of ammonia, specific gravity 0.980; and, third, one thousand eight hundred grains of alcohol, specific gravity 0.850. The mixture is left at rest to become clear. The liquid is decanted or filtered, and a mixture of equal parts of alcohol—specific gravity 0.850—and of oil of cassia is added in the proportion of one part of this *essence of cassia* to fifteen parts of the argentiferous solution; the mixture is agitated and left to settle for several hours, after which it is filtered. Just before pouring it upon the glass to be silvered, it is mixed with one-seventy-eighth of its bulk of *essence of cloves*—composed of one part of oil of cloves, and three of alcohol, specific gravity 0.850. The glass having been thoroughly cleansed, is covered with the silvering liquid, and warmed to about 100°, at which temperature it is maintained for two or three hours; the liquid is then decanted, and may be employed for silvering other glasses. The deposit of silver upon the glass is washed, dried, and then varnished.

VOHL proposed to form the silver coating for the

interior of glass balls, *et cetera*, by dissolving gun-cotton in caustic potassa, with the aid of heat, adding to the brown solution a few drops of nitrate of silver, and the ammonia, until the precipitated oxide of silver is re-dissolved. This mixture is introduced into the glass ball, or other article to be loricated, and heated in a water-bath, when, after a certain time, the mixture becomes blackish-brown, froths up, and deposits all the silver upon the glass, forming a mirror which is said to reflect the light with surpassing brilliancy.

V. FLINT-GLASS.—This compound, which is commonly termed *crystal*, from its great resemblance to the natural production known as rock-crystal, is chiefly manufactured into articles of domestic use and ornament, such as tumblers, decanters, wine-glasses, vases, drops for chandeliers, *et cetera*. In consequence of its great transparency and high refractive power, it is also formed into lenses for optical instruments. On the Continent the term flint-glass is almost exclusively applied to glass which is expressly manufactured for the latter purpose, and *crystal* is employed as the more comprehensive designation for glass containing lead, of which flint or optical glass is regarded as a variety. In this country, flint-glass and crystal are used as synonymous terms, and that particular variety of this description of glass which is manufactured for optical purposes is termed *optical-glass*.

Flint-glass is so called from the circumstance that, formerly, flints calcined and ground were employed in the manufacture as the source of the silica; but for many years past, Isle of Wight, Lynn, or Reigate sands have been substituted. These sands are not only more free from iron, but less expensive in the preparation than flints, when washed and calcined. Not only in this respect is the name inapplicable. To convey a correct idea of its composition, it ought to be termed lead or metallic glass, as the presence of a new element, *lead*, is that which distinguishes flint-glass or crystal from the different varieties of glass already mentioned. It is also distinguished from English crown and plate-glass by the use of potassa, instead of soda, in the manufacture.

DUMAS remarks that, by all the old writers, colorless glass, whatever be its nature or composition, is designated indifferently under the name of *crystal*. Thus, under this common designation, were confounded glass with a simple base of potassa, glass with a base of potassa and lime, and lastly, glass with a base of potassa and lead. It is necessary to be aware of this confusion, if one wishes to read with profit the old works on glass-making. At the present day, the term crystal or flint-glass is reserved to denote the double silicate of potassa and lead employed for the purposes already mentioned.

This beautiful variety of glass is admitted on all hands to be of English origin. Its invention was a natural and almost necessary consequence of the use of coal in the English manufactories—a usage which goes back to a very remote epoch. To prepare white glass in an open pot, with coal as fuel, is a problem which admits of being solved at the present day, but which could not be so at an early period. To protect the glass from the contact of the smoke which blackened

it, it was necessary to convert the common pot into a retort with a short neck, which presented its mouth outside the furnace. But under this condition, the vitrification became too difficult for ordinary glasses; it would have been necessary to increase beyond measure the proportion of alkali. It was essential, therefore, to find the means of increasing the fusibility of the glass, without rendering it deliquescent; and this was accomplished by means of a suitable addition of protoxide of lead. The beauty of the product soon assigned it a high rank among the different varieties of glass, and the manufacture of it was not long in extending even into countries where coal is not used. But in these localities the manufacture could be conducted in common pots, taking care to manage the wood fire, so as to avoid all production of smoke, and modifying slightly the proportion of the substances employed.

Flint-glass, however, is not entirely a modern invention, or, at least, if it was necessary to re-invent it, it is certain that it was known at a very remote epoch. This is demonstrated by the analysis of the ancient glass known as *Virgil's mirror*, an operation performed in 1787 by M. FOUGEROUX DE BONDAROY. This mirror, weighing thirty pounds, polished on both faces, transparent, but colored a yellowish green, contained at least half its weight of oxide of lead, and exhibited, moreover, all the characters of crystal. It had been preserved in the treasury of Saint Denis in France from the time of its fabrication, which assigns to its manufacture an epoch long anterior to the discovery of modern crystal. It is evident, indeed, that the name applied to the mirror is not correct, and proves nothing—that it did not belong to VIRGIL, and that it could not claim an antiquity so remote. This article only proves that the method of making lead-glass had been long known, and that the processes of the manufacture must have been well understood, since at that time a mirror could be formed of a size which would be deemed remarkable even at this day, and that the secret had been lost during a long succession of years. It may be affirmed, indeed, that the *colorless* crystal or lead glass of the present day, or, in other words, a crystal possessing that quality which constitutes its chief beauty and value, is entirely of modern invention. It is very natural to suppose that the method of making a colored crystal like Virgil's mirror might be known to many mediæval chemists, without assuming that they equally knew how to prepare a pure and colorless crystal like that now manufactured under the name of flint-glass.

Composition and Properties of Flint-Glass.—Five elementary analyses of crystal or common flint-glass have been given at page 192. The table in the same page, in which flint-glass is associated with strass and enamel, refers to that variety of flint-glass known as optical glass. From the former analyses it will be seen, that the composition of common flint-glass, after deducting the extraneous constituents, may be expressed by the following formulæ:—

- I. $\text{K}_2\text{O}, 2 \text{SiO}_3 + 3 (\text{PbO}, 3 \text{SiO}_3).$
- II. $3 (\text{K}_2\text{O}, 3 \text{SiO}_3) + 4 (\text{PbO}, 3 \text{SiO}_3).$
- III. $2 (\text{K}_2\text{O}, 2 \text{SiO}_3) + 3 (\text{PbO}, 2 \text{SiO}_3).$
- IV. $3 (\text{K}_2\text{O}, 2 \text{SiO}_3) + 3 (\text{PbO}, 2 \text{SiO}_3).$
- V. $\text{K}_2\text{O}, 2 \text{SiO}_3 + \text{PbO}, 2 \text{SiO}_3.$

In one case, therefore, triple silicates are the proximate constituents of the glass; in the others, double silicates. In fact, the proportions of the three essential constituents, namely, silica, potassa, and oxide of lead, vary according as the melting furnace is heated with wood or coal. In the latter case, the proportion of oxide of lead is increased. The following analysis by DUMAS has been already given at page 192, but is here repeated, to show the proportion of oxygen in the bases, as compared with that of the silica or silicic acid.—

	Centesimally.	Oxygen.
Silica,	56	29
Limé,	2.6	0.72
Oxide of lead,	32.5	2.25
Potassa,	8.9	1.50
	100.0	

Here the oxygen of the bases is to that of the acid as 1 : 7. In the following analysis by M. BERTHIER, of a Vonêche crystal made with coal as fuel, the proportion is nearly 1 : 9 :—

	Centesimally.	Oxygen.
Silica,	61.0	31.7
Oxide of lead,	33.0	2.3
Potassa,	6.0	1.0

These two analyses show, beyond all doubt, that the law of saturation of crystal or lead-glass varies within wide limits.

Many metallic oxides are capable of combining with silicic acid, and thus furnishing silicates which readily mix with alkaline silicates; but almost all these are colored. Till lately, the protoxide of lead and the oxide of bismuth were regarded as the only oxides capable of yielding silicates with little color, and, consequently, colorless glasses, by their mixture with the silicate of potassa in a proper proportion; but a *glass of zinc*, which had a very pleasing and white appearance, and was specially suited to achromatic purposes, was the subject of a reward at the Great Exhibition of 1851. This glass had the remarkable property of being of greater specific gravity, and much more pure and pellucid than lead-glass. It is to be expected, therefore, that the former may come into general use. On the contrary, the oxide of bismuth is much dearer than that of lead, and hitherto the latter has been alone employed in the manufacture of common crystal.

Crystal or flint-glass well prepared is almost without color. It is more transparent, more brilliant, and heavier than plate or window-glass. It excels the fine Bohemian crown-glass in refractive power and easy fusibility, although the latter is harder and more completely colorless. Flint-glass, of not less than the usual density of 3.200, well polished by the lapidary, is considered the nearest approach to the diamond. It owes its brilliancy and high density to the silicate of lead; but as the latter is itself yellow, it communicates a yellowish tint to the crystal when it preponderates over the alkaline silicate beyond a certain limit. There is also another reason for avoiding to use too much of it. The silicate of lead is much softer than the alkaline silicates. In too large quantity, therefore, it renders the glass so easy to scratch by the slightest friction, that it could not be employed for most of the articles

of domestic use or luxury into which it is fashioned. Moreover, this addition rendering it both heavier and more costly in the manufacture, would be at least useless, even if it were not absolutely prejudicial, for the reasons already mentioned. It is a common mistake to suppose that great density or *weight* is an advantage in crystal for articles of common use. It is, on the contrary, as DUMAS justly remarks, a real inconvenience, and, in the most favorable view, can only be considered as a ready means of showing that the crystal or flint-glass contains enough of silicate of lead to impart to it all the other qualities which give it its peculiar value, and render it preferable to other glasses for certain purposes.

As lead affords the only metallic oxide which is usually employed in the manufacture of flint-glass, so potassa is the only alkali which can be successfully associated with that ingredient to yield a colorless crystal. The silicate of soda always communicates a blue or green tinge, which would become more perceptible and disagreeable in the thick articles usually manufactured of crystal. If this thickness were much reduced, the silicate of soda might, so far as color is concerned, be used in the manufacture; but as crystal vessels are generally intended to receive mouldings or cut ornaments, they do not admit of being made thin in the sides. The annealing, also, would become a difficult operation in vessels of considerable size without a proportionate thickness. Crystal is so fusible that it is not easy to prevent such articles from sinking in, or collapsing, during the annealing. This kind of glass is, therefore, almost exclusively confined to the manufacture of thick articles; and hence it is only the colorless silicates that can be used—that is to say, those of lead, or zinc, and potassa. It is stated, indeed, that M. BONTEMPS uses soda instead of potassa, or a mixture of the two, in his recipe for optical glass; but this is an exception to the general rule, and requires explanation. The following practical recipes are given by M. BASTENAIRE for a good common flint-glass, the one with coal, and the other with wood as fuel:—

	With coal as fuel.	With wood as fuel.
	Pounds.	Pounds.
Sand—washed and calcined, . . .	100	100
Minium,	70	45
Purified potassa,	30	35

In addition to these, cullet or broken glass is added at discretion, and saltpetre or arsenic is used as a decoloring material. It will be seen that, when coal is used, the sand, red lead, and potassa are nearly in the proportions of 3 : 2 : 1; but that, when the composition is fused in open pots, with wood fuel, the proportion of the red lead is much diminished. The following composition, in which the above-mentioned proportions of the principal ingredients are exactly adhered to, is given by Mr. APSLEY PELLAT, as yielding a highly pellucid and transparent flint-glass:—

Carbonate of potassa, one hundredweight.
Red lead, or litharge, two hundredweight.
Sand—washed and burnt, . . . three hundredweight.
Saltpetre, fourteen to twenty-eight pounds.
Oxide of manganese, four to twelve ounces.
Cullet, or broken glass, *ad libitum*.

Such is the most common proportion; but DUMAS affirms that a finer and more durable product is obtained by reducing the amount of alkali; thus, for three hundred parts of sand and two hundred of minium, ninety to ninety-five parts of purified carbonate of potassa, instead of one hundred, will yield a better result when the furnace draws well—in winter, for example. But in summer, the preceding proportions must be used, or the following French recipe:—

	Parts.
Pure sand,	300
Minium,	215
Purified carbonate of potassa,	110
Nitrate of potassa,	10
Borax,	12

It has been stated, that when open pots are used, as on the Continent, with wood fuel, the proportion of minium may be reduced. This arises from the circumstance, that the oxide of lead, being an active flux, is less necessary for the fusion in uncovered pots, which admit of the direct action of the heat on the contained mixture or metal. However, the use of the three essential ingredients in the ordinary proportion of three, two, and one, is, in all cases, a safe one. It is chiefly for economy that the minium is reduced in amount, when the heating power of the furnace is sufficient to permit the reduction. On the other hand, if the minium be too much reduced, the beauty of the product will suffer. The lowest proportion of this ingredient which can be used with safety is shown in the following composition, which yields a good crystal:—

	Parts.
Sand,	300
Minium,	180
Purified carbonate of potassa,	120
Cullet,	300
Arsenious acid,	0.45
Oxide of manganese,	0.60

The mere due proportioning of the materials for flint-glass is not sufficient—the utmost attention must be given to have them in a state of purity. The silica or sand should be very white, and absolutely free from coloring oxides, as those of iron or manganese. Some manufacturers cleanse the sand by hand-washing, and others have machines. To render the Isle of Wight sand fit for making flint and other compound glasses—that is to say, to cleanse it from chalk and other impurities, by which it loses about one-fifth of its original bulk, requires about eight waters; it is afterwards passed through a heated arch, called a *calker*, and thoroughly dried, or burnt, at the discretion of the operator; and then sifted through a lawn-sieve, to separate the larger grains and pieces of coal or coke. DUMAS recommends that the sands be washed with dilute hydrochloric acid, to remove from them any traces of oxide of iron or of manganese.

The carbonate of potassa also requires a preliminary purification, which is easily effected by dissolving it in water, decanting the quite clear solution, and evaporating the liquor. All the coloring oxides are deposited, and by the evaporation carbonate of potassa is obtained, mixed with other salts, but at least quite free from oxides of iron or of manganese. If the nitrate of potassa were low in price, one might employ it to replace the carbonate.

The protoxide of lead, or litharge of commerce, is almost never pure. It contains oxides of copper, of iron, or of manganese, in too great quantity, in most cases, to admit of its making a colorless flint-glass. Moreover, an oxide of lead is expressly manufactured for the making of crystal. In general, there is selected for this purpose a very pure lead, which is carefully oxidized, to avoid introducing into it foreign and injurious matters. It is the practice to carry the oxidation of the lead to the state of *minium* Pb_3O_4 . Not that the crystal contains red lead; the latter loses by the action of the heat a portion of its oxygen, and passes again to the state of protoxide which alone forms part of the glass. But it is advantageous, and probably even indispensable, to furnish to the mixture which is to produce the flint-glass a body capable of yielding oxygen at the beginning of the fusion.

It has been supposed that this disengagement of oxygen was necessary to produce in the glass the agitation which prevents this product from separating itself in layers of different densities. But DUMAS observes that the decomposition of the minium must be concluded long before the fusion is effected. The oxygen which the minium disengages has very probably, for its object, to burn an organic matter analogous to ulmin,

which is found in large quantity in the crude salt; a matter which is decomposed in part, calcining this last to make potassa of it, but which is still found in the potassas of commerce in notable quantity. This matter, put in contact with the protoxide, would reduce it to the metallic state, and would color the crystal; whereas, being burned by the oxygen of the minium, it disappears, without leaving a trace of its existence.

It is evident that the same result would be arrived at by using nitrate of potassa instead of the carbonate, and that the minium might be replaced by pure litharge, or protoxide of lead. In point of fact, the small quantity of saltpetre which is usually added, exerts a beneficial effect, by increasing the proportion of oxygen, and assisting to drive off the globules of air in the liquid glass. This salt, when the price admits of its application, is at once a pure and a purifying material. A few ounces of manganese are employed to neutralize the greenish tint produced by the presence of iron or other impurities; and, with this view, the peroxide must be used in the purest crystallized state.

Melting and Fining of Flint-Glass.—The plan and sectional elevations of a melting furnace, figured at pages 199 and 200, are equally applicable to flint-glass, and other descriptions of glass, except that for bottle

Fig. 172.



and crown-glass the furnaces are usually oblong, and are only constructed to contain from four to six pots; whereas, for flint-glass works, round furnaces, containing from eight to twelve pots, are almost exclusively used. Mr. APSLEY PELLATT remarks, that ten pots

of thirty-six inches diameter are the medium number for a well-proportioned furnace, and are found the most economical for fuel. When the furnace has too large dimensions, too great an area is left unoccupied by the pots or fuel, and too small a furnace exposes the backs

of the pots to hang over the fire-place in the centre, which in time enlarges by burning away, and causes the pots to crack at the bottom, or back, by cold draughts through the fire-bars. According to the same authority, a furnace of twelve pots, exposing a much larger unoccupied area than a ten-pot furnace, will consume nearly double the quantity of fuel in uselessly heating the interior, whereas twelve pots of melted metal will hold only in the proportion of one-fifth increase. On the other hand, furnaces of less dimensions than eight pots are objectionable, through the great loss of pots, in consequence of the comparatively small size of the siege. In the Falcon glass-house, belonging to Mr. PELLATT—and from which have emanated many important improvements—there are two furnaces, instead of one, both opening into the same flue, as represented in Fig. 172, which shows also an interior view of the glass-house and working operations. By this arrangement, while one of the furnaces is in full operation the other may be undergoing repair, or the working of one may be entirely suspended without injury to the other, during a dullness of trade.

But the principal and only essential difference in the conditions for the melting and fining of flint-glass, consists in the shape of the pots, which, as represented in Fig. 142, page 201, are distinguished from those employed for other descriptions of glass, by being covered with a hood-shaped top, the mouth of which fits the working holes of the furnace, so that the smoke and heat cannot escape in the same way as in the usual glass furnaces. Open pots are used in some parts of France for flint-glass, with dried beech or oak-wood for fuel, and so little carbon is produced by the smoke as not to affect materially the metal, although the flames play upon its surface; but when coal or coke is used, as in this country, the fumes and smoke emitted would carbonize or deoxidize the lead, and precipitate it to the bottom in the original metallic state, if the pots were not covered; besides that the solid particles of soot would blacken the glass, by attaching themselves firmly to its surface.

The ingredients previously mentioned, having been carefully mixed together and sifted, are brought to the furnace in wooden vessels, like hand-barrows, and thrown into the pots in successive charges with an iron shovel. In this state the batch or frit, as the composition is called, is of a salmon color, the red tinge being derived from the oxide of lead. English melting-pots, which are usually much larger than the French, hold about eighteen hundredweight each, and the batch is introduced in quantities of about four hundredweight at a time, allowing a sufficient interval between each filling for melting down the various charges, until the pot is entirely filled with fused glass. By this method, says Mr. PELLATT, every pit in the furnace is fully charged with liquid metal in about twelve to fifteen hours; air-bubbles and striæ then abound, and they are not expelled until thirty to forty hours more have elapsed, during which period—namely, from fifty to sixty hours—the gas and air-bubbles are driven off, and the mass becomes homogeneous. During the founding, the mouths are securely stoppered and clayed up, and the furnace is urged to its utmost intensity. The shorter

the time of fusion and refining, the better; for this purpose the heat can scarcely be too great. With the best possible recipe, and the purest materials, good results depend upon an intense and continuous fusion: too little caloric will fail to refine the metal and drive off air-bubbles, and the coloring matter of the manganese; and too long continuance of intense heat will destroy the manganese, cause the glass to attack the pot, and become striated, gelatinous, and greenish. If the glass do not get fine by the usual time allotted, but becomes coddled or gelatinous, it never will recover, however urged by subsequent fusion. Such glass must be ladled into water, and considered only as cullet for re-fusion, with a proportion of new materials. The moment the metal is fully fused, and refined by continuous rapid fusion, the high temperature of the furnace should be reduced from its maximum heat to a working temperature; this period being considered *the crisis*. When flint-glass is kept in fusion beyond the crisis, it not only assumes a greenish tint by acting upon the iron of the Stourbridge clay-pot, but takes up a small portion of its alumina, which, by its inferior density, rises to the surface, frequently with detached portions of the pot, causing striæ and other impurities, which injure its quality for common uses, and render it entirely unfit for optical purposes. Formerly, scum or sandiver was allowed to run off, or was skimmed from the surface of the pots when opened for working, but the modern relative proportions and purity of the chemical materials are so good, as seldom to render this skimming necessary.—*Pellatt*.

Mechanical Operations.—The mechanical operations connected with common bottle-glass, crown, sheet, and plate-glass, are uniform in their character; the description of the making of one bottle, or of one table, sheet, or plate of glass, applies to all. On the contrary, the infinite variety of shapes into which common flint-glass or crystal is manufactured, would render a complete account of the manipulations tedious, even if it were not in some degree foreign to the plan of this work. Only a few examples will, therefore, be selected, to illustrate the general character of these ingenious processes.

Flint-glass is either formed by simple blowing with the pipe, and then shaping by hand; or, secondly, by blowing in moulds; or, thirdly, by moulds alone, in which the glass is subjected to pressure. In each of these cases, the form and appearance of the article are very generally improved by grinding, cutting, *et cetera*.

By way of illustration, the common tumbler may be mentioned as one of the simplest articles to make by hand.

In this case the workman collects on the end of the pipe a small quantity of glass—Fig. 173; this is rounded on the marver, expanded by blowing, and somewhat elongated by swinging, when it assumes the form—Fig. 174. The pipe is then suspended vertically, and the glass is allowed to drop by its own weight upon the marver, which flattens it at the extremity; and, being at the same time further

Fig. 173.



Fig. 174.

blown, it now resembles—Fig. 175. The pipe, with a

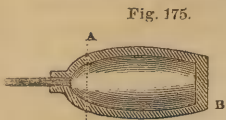


Fig. 175.



Fig. 176.



Fig. 177.

Fig. 176—so as to make it perfectly even, as at D—Fig. 177—and fit it for the flashing and finishing. Finally, it is knocked off from the ponty by a sharp blow, and taken to the annealing arch.

Part of the above process is omitted for common light cheap tumblers; these are not sheared, but simply flashed, and no pains is taken in subsequently polishing out the marver marks. Hence they are often ringy or wavy.

Wine-glasses are usually made in three pieces. The process is the same as for the tumbler, till the gathering assumes the shape represented in Fig. 175. A solid ball of glass is then attached to the flat end, as in Fig. 178, this being a separate gathering, out of

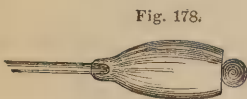


Fig. 178.



Fig. 179.



Fig. 180.



Fig. 181.

which the stem is shaped by the pucellas, while it is rotated on the inclined planes of the glass-maker's chair. It then assumes the form represented in Fig. 179. To form the foot, a small hollow globe is now attached to the stem, which is afterwards opened by the pucellas, as in Fig. 180; and when the pipe, with a portion of the glass, is separated from the other end, and the mouth expanded, sheared, and flashed, the glass finally assumes the form represented in Fig. 181.

To make a ringed decanter, the glass, by the process already described, is brought to the form represented in Fig. 182. The ponty is then attached to the flat end,

and the mouth is warmed up, and shaped with the pucellas, as in Fig. 183. Another workman then gathers upon a ponty a small piece of glass, which is dropped on near the mouth, as shown in the same figure, and, by rotating the decanter, the entire circle or ring is welded by contact, and its surplus tapered and torn suddenly off. By re-heating the

Fig. 182.

Fig. 183.

decanter, a second, third, and fourth ring may be added, as shown in Fig. 184.

The process of blowing and moulding common green glass bottles has been briefly described at page 210. Bottles and other articles of flint-glass are blown and moulded in much the same manner, but the finer descriptions are afterwards cut and ground. Moulded glass never exhibits a full lustre, nor even the sharpness of the metallic mould. The glass, not being perfectly liquid, does not penetrate into the sharp corners, nor does it even accommodate itself perfectly to the flat sides of the mould. Hence the edges are blunt, and the surface is never perfectly even, but more or less curved and wavy. Moulded articles can, therefore, never be compared with cut-glass, but some are now produced of remarkable beauty; and even as a preparatory step to grinding, the use of moulds is of great advantage, as the vessel acquires a regular form, and presents, although in a crude state, all the prominent and receding features, to be perfected at the lathe.

The moulds for flint-glass are carefully constructed of brass or iron, and, when of simple construction, are somewhat wider at the upper part, that the pieces may be easily removed, or are composed of more than one piece when projecting parts are to be moulded. A common *open and shut mould*, such as is used for apothecaries' phials, as well as for common wine-bottles, is shown in Fig. 185. It is constructed in two exact

Fig. 185.



halves, connected with a bottom hinge. The glass to be moulded is gathered on the pipe, rolled on the marver into a cylindrical form, and then pinched with

the pucellas at the end attached to the pipe, to form the neck of the bottle. The cylindrical mass, still adhering to the pipe, is then inserted into the mould lying on the ground; its two halves are shut; and the workman blows through the tube, which renders the mass of glass hollow, while it receives from the mould the external form required. With this form of mould two seams or lines are produced, by the two sides of the mould not shutting quite closely. In round bottles these seams are unsightly, but they are scarcely perceptible in square bottles, as the joinings of the mould are placed at two of the corners.

This imperfection, though not entirely removed, is much diminished by the use of an improved mould, invented by Mr. PELLATT, and represented in Fig. 186. It consists of one piece, D, for the body, and two pieces, B B, for the neck. By this construction the seam down the body, so objectionable in round bottles,

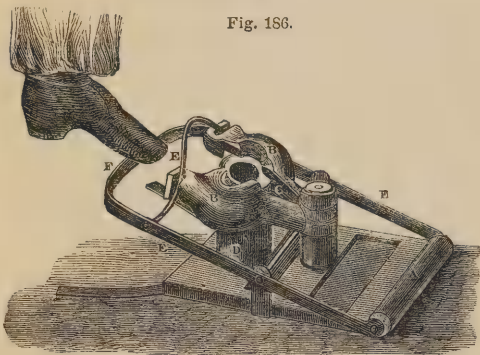


Fig. 186.

is avoided, although the neck is still marked by two slight seams. The neck-pieces, which are kept open by a spring, C, are brought together, after the insertion of the globe or spheroid of metal, by the guide, E, on pressing down the treadle, F, with the foot. The workman then blows through the pipes, and, on raising his foot, the counterweight, A, falls, and the bottle is readily taken out.

Moulded Roman Pillars.—With reference to this species of moulding, recently introduced by the English manufacturers, Mr. PELLATT remarks that it owes its refractive and cut-like effect to its inequalities of substance, the interior having no indentations to correspond with its exterior projections. In this case the mould is only about one-third the size of the object to be manufactured. The metal is first gathered upon a pipe in the ordinary manner, except that the first gathering is allowed to cool more than

Fig. 187.

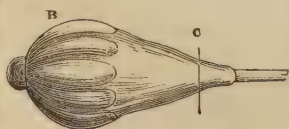


Fig. 188.

usual, and the second coating is pressed into the mould, A—Fig. 187—as hot as possible, so that only the exterior portion may be acted on by the mould, while the

interior preserves its smooth circular section. When about half-formed, the projecting parts, B—Fig. 188—have a centrifugal enlargement given to them by a sharp trundling of the iron at, or immediately after the blowing. During the re-heating process, the piece is separated at the dotted line, C, has a foot welded to it, and is rewarmed as D—Fig. 189. It is then sheared, as E—Fig. 190; and when finished by flashing, shaping,

Fig. 189.



Fig. 190.



et cetera, so as to appear as in Fig. 191, it is known as patent pillar moulding. A little cutting or scolloping makes this refractive moulding still more ornamental; but though it much resembles cutting, as to its round pillars, it is inferior where sharp angles are required. Pillar moulding is, however, one of the greatest modern improvements, and is used advantageously for lamp-pedestals, chandelier work, toilet-bottles, salt-cellar, *et cetera*, at very moderate cost.—*Pellatt*.



Fig. 191.

It may here be remarked that all bottle-moulds require, while working, to be kept nearly at a red heat, either by a small furnace, or by a piece of hot glass held inside by a boy on the end of a ponty-rod during the intervals of the moulding. This precaution is essential to the polish, but the heat of the moulds must be kept below redness, otherwise the glass would adhere to them.

Pressing.—The third method of manipulation with flint-glass, is moulding by pressure—an American invention, which consists in dropping the soft metal into a prepared die, and then pressing down the matrix or plunger upon it by means of a lever. The chief conditions of success in this operation are, to take care that sufficient glass is introduced to fill the mould, and that the latter is kept at a steady temperature, a little short of red heat, to produce a polished surface. When the die or mould is once formed, articles are produced in this way with great rapidity; but much practice and dexterity are required to gather the exact quantity of metal. Under this head may be mentioned

Fig. 192.



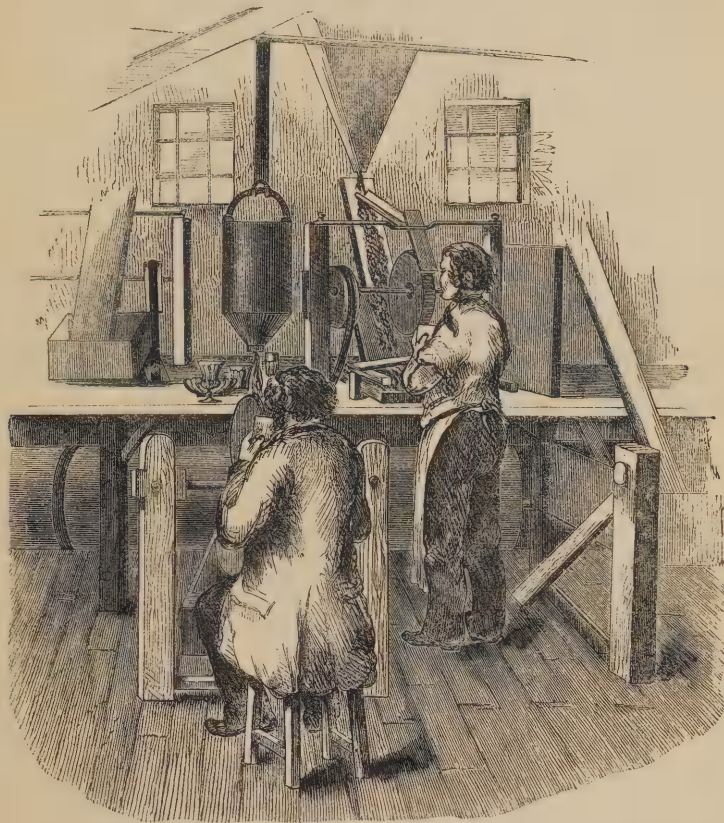
drop-pinching, or the moulding of drops for chandeliers, girandoles, and candlesticks. In this case, lumps of glass made expressly for the purpose, are first softened by a blast-furnace, and then shaped in twin-dies, A B—Fig. 192. Arms of chandeliers are formed

on the same principle, but using a powerful leverage press. Both arms and drops are afterwards cut and polished, to produce the required brilliancy.

Cutting and Polishing.—The finishing process which gives to the finer articles manufactured of flint-glass their distinguishing beauty, is technically termed *cutting*, but is actually performed by grinding. The inferior hardness of flint-glass renders it fitter for this purpose than any other glass. The operation, as represented in Fig. 193, is performed by discs of iron, sandstone, or copper, revolving in a lathe which is

usually propelled by steam power. The edges of the discs, which are sharp, angular, or rounded, according to the work to be performed, are supplied with sand and water dropping from a hopper for *rough grinding*, and with emery for *fine grinding*. A stone-wheel with water is employed to smooth out the rough sand-marks, and prepares the glass for the *polishing*, which is effected by means of a willow-wood disc, first with a mixture of pumice and rotten-stone, and finishing with a preparation of tin and lead, termed putty-powder. All table-glass ware and hollow articles are thus cut.

Fig. 193.



Chandelier drops are cut or ground with iron and stone-wheels in the same manner, but are finished with a lead-wheel supplied with a little very fine rotten-stone and water.

For many years the practice has been introduced of roughing lamp-lustres by means of sand. It is easy to conceive how the exterior roughing may be performed, but the rubbing of the interior surface appears a more difficult operation. It is, in fact, performed on a somewhat different principle. In this case, sand of a uniform grain is put into the globe or lustre; a certain number of these globes are arranged in a drum or cylinder, and a rapid rotatory movement is given to the latter, by means of which the interior surfaces of all the globes are quickly worn and roughed in a very equal manner.

Glass-Engraving.—Small copper discs of the size of

a halfpenny, and finely pulverized emery mixed with oil, are used to execute the outline and ground of the glass-engraver's work; and for polishing, lead-wheels and very finely pulverized emery are employed. Coarse patterns for hall-lamps are engraved by the glass-cutter's smoothing wheel; and Mr. PELLATT remarks that the contrast of the polish of a wood-wheel upon a ground roughed by sand is often effective, though the range of pattern is somewhat curtailed by the large size of the cutter's ordinary wheels rendering it difficult to execute curvilinear designs. For inscribing initials, coats of arms, and minute designs, very small discs must be employed. The finest incisions are made with copper pencils, either pointed, or ending in a button-like disc.

Etching on Glass.—It has been stated at page 199, that hydrofluoric acid, either in the gaseous or liquid

state, exerts a peculiar action on glass, which has been turned to account as a substitute for cutting or engraving designs; and though not confined in its application to flint-glass, the process may be appropriately described in this place.

For etching on glass by means of the gaseous acid, the glass is cleaned, well dried, heated, and melted varnish poured upon it, which is spread in a homogeneous coating. This varnish is formed of wax and turpentine; it ought to be soft enough to admit of being removed by the burin without scaling it off; it is generally formed of one part of turpentine to four parts of wax. When the glass is cold, the varnish acquires a little opacity, but not so much as to prevent tracing through it. The burin is then passed over the varnish, following the lines of the figure, and cutting through the varnish to the glass. When the figure is traced, the glass so prepared is exposed to the action of hydrofluoric acid. For this purpose a leaden tray or earthen vessel is used; in this is put fluoride of calcium pulverized with concentrated sulphuric acid; it is mixed well, and the vessel is then placed on a very gentle fire, and the glass to be etched is laid over it. At the end of some minutes from the time when the vapor begins to rise, the operation is terminated; the glass is then taken off, and the varnish is removed by melting it, and wiping with a soft linen rag.

If, instead of exposing the glass to the action of the acid vapors, it is plunged into the weak liquid acid, the same effect is produced in a few moments.

But when it is desired to produce a very pure and correct figure, with half-tints and strong shades, recourse must be had to a longer and more delicate process; a particular varnish, too, must be used.

The best is drying linseed oil, or, better still, fat varnish of copal blackened with lamp black, perfectly pulverized, and sprinkled with oil of turpentine. The coatings laid on must be very thin, and each should be quite dry before putting on a new one. The glass is sufficiently covered with varnish when the light can scarcely be seen to pass through it. The design is then copied through, and the varnish is removed from the lines with the points of gravers, or simple needles of different forms and sizes. For greater convenience, the design is lighted from below by inclining it at an angle of about 45° on a desk pierced for a window. The position of the glass enables one to perceive the most delicate lines.

After having formed the figure, it must be corroded out with liquid hydrofluoric acid; but before commencing this operation, it is necessary to test the glass as well as the acid. This preliminary trial is made on a small piece of the same glass, covered with the same varnish. This piece is divided into five or six parts; on each of these parts some traces are drawn with the needle, and the operator covers them successively by means of a pencil with liquid hydrofluoric acid. A minute is allowed to intervene between each operation, so that when the acid has acted during one minute on the last portion, it has then been in contact with the glass for two minutes on the preceding one, and for six minutes on the first. This being done, the slip of glass is washed with plenty of water, and the varnish is re-

moved by means of a knife and spirits of turpentine. It is then easy to determine the proper time for allowing the acid to act upon the design to be etched.

BEDFORD patented a peculiar process for etching glass, which consists in grinding five parts of peroxide of lead and one part of flux, composed of seventeen parts glass of borax, and thirteen parts of red lead, fused together. The peroxide of lead employed is puce-colored, and with the above composition the artist paints the devices or designs upon the surface of the glass. When the etching is to be done on colored glass, acetate of lead is substituted for the oxide. The article is then dried, and fixed in the same manner as in gilding glass. When cold, it is dipped in a weak solution of nitric acid, and as soon as the painted designs are acted on, it is placed in water, and the preparation removed from its surface.

On the whole, it must be admitted that etching by fluoric acid, though practised to some extent, and in some particular cases with marked success, has not been found effective for general purposes. It is usefully applied, however, to form the scales on thermometer tubes, and written or printed inscriptions on glass vessels. The attempt to make it subservient to topographical purposes has been a failure.

OPTICAL GLASS.—There are two kinds of optical glass—flint and crown—which, having different refractive and dispersive powers, may be so combined in the object-glass of a telescope that, while the rays are brought to a focus, the greater dispersion of the flint lens may be corrected by the less dispersive power of the crown—the one being negative, the other positive. Hence, by their combination, the lenses achromatize each other, or transmit colorless light. The celebrated DOLLOND, in 1753, aided by the co-operation of EULER, and of KLINGENSTIERNA the Swedish mathematician, succeeded, after many experiments, in discovering the due proportions of the curvatures of the two lenses; but still two important problems remained to be solved—the best chemical constitution of the glasses, and how to obtain them sufficiently free from the defects of ordinary glass to be adapted for optical instruments. It is this last question which presents the greatest difficulty. Purity, unchangeableness of color, transparency, and a certain degree of refractive power, may be obtained; but perfect uniformity in the structure of the glass, so as to render its composition absolutely homogeneous throughout, is much more difficult to be accomplished; and this is precisely the quality which is admitted to be the most indispensable for good optical glass. The difficulty arises chiefly from the difference in specific gravity of the different constituents of the metal. Some melt at a lower temperature than others; some evaporate or are decomposed in a heat required for the fusion of others; and different substances cool at different temperatures. Hence arise discoloration, threads, striæ, irregular crystallization, causing irregular refraction, and all the usual faults observable, more or less, in every description of glass.

It seems to be now generally admitted that there are more impediments in fabricating crown-glass lenses of large size, than in making good ones of crystal or flint-glass. The former requires a higher temperature, and

by adding alkali to increase the facility of fusion, it becomes more liable to attract humidity, or, as it is technically termed, to sweat. On the other hand, by rendering it too hard, one incurs the risk of crystallization and imperfect vitrification in cooling.

For a long period, however, the principal attention of opticians and glass-makers was devoted to the manufacture of a suitable flint-glass, which was considered to present the greater difficulty of the two. Occasionally, the flint-glass manufacturers found in their pots a portion of glass suitable for opticians; but this was an accidental product. The problem of the constant and regular manufacture of good optical flint-glass still remained to be solved, when M. GUINAND, a workman in the clock and watch trade, near Neufchatel, who had been accustomed to the fusing of metals in the prosecution of his business, devoted his attention to the subject, and succeeded in producing masses of flint-glass capable of furnishing objectives of nine inches—a size previously unknown. Even the celebrated chemists, MACQUER ROUX of St. Gobain, and AUUT of Langres, had never been able to obtain them of larger diameter than three to three and a half inches. M. DARTIGUES also, one of the first manufacturers of flint-glass in France, and who to his high reputation for practical skill added that of scientific knowledge, equally failed of success. GUINAND's discovery was therefore hailed with much satisfaction; but he kept the process a secret, except from M. UTZSCHNEIDER and the celebrated M. FRAUENHOFER, who proposed to him to join them in their establishment at Munich. This offer GUINAND accepted, and the process was successfully worked by them for several years without any one being able to discover it. After their deaths, one of GUINAND's sons being in possession of his father's method, continued the manufacture of optical glass in the environs of Neufchatel. The other son formed an association with M. BONTEMPS, one of the directors of the glass-work of Choisy-le-Roi, but the experiments which were made by them conjointly at that establishment did not succeed. The treaty was therefore broken; but M. BONTEMPS and his co-director, M. THIBEAUDAU, satisfied of the correctness of the principle, if properly applied, continued their experiments without excluding GUINAND; and ultimately, in 1828, they succeeded in producing good optical glass in discs of from twelve to fourteen inches, and a large quantity of smaller sizes. From that time the manufacture has been established on a regular system. In 1848, M. BONTEMPS was induced, in consequence of difficulties arising from the political state of the country, to retire from his position at Choisy-le-Roi, and to accept the invitation of Messrs. CHANCE, Brothers, and Company, to unite with them in attempting to improve the quality of this important branch of manufacture. How far they have succeeded may be judged of from the fact, that they have produced discs of flint-glass twenty-nine inches in diameter, weighing two hundredweight, and of crown-glass up to twenty inches. These discs are pure in color, good in structure, and exempt from those defects which tend to polarization of light. BONTEMPS' proportions for optical glass are as follow:—

FOR FLINT-GLASS.

Sand,	43.5
Red lead,	43.5
Carbonate of potassa,	10.0
Nitrate of potassa,	3.0
	<hr/>
	100.0

FOR CROWN-GLASS.

Sand,	60
Carbonate of soda,	25
Carbonate of lime,	14
Arsenic,	1
	<hr/>
	100

It will be observed that optical flint-glass is chiefly distinguished by the large proportion of lead which enters into its composition. According to DUMAS, who approached very near to the truth in assigning its probable composition, its density should not be lower than 3.6 at least. The essential point in the manufacture, however, consists in the constant stirring of the metal during the melting and fusing. The superiority of GUINAND's plan is considered not to have been in the novelty of the materials or proportions, but in carefully agitating the liquid glass while at the highest point of fusion, then cooling down the entire contents of the pot in a mass, and, when annealed and cool, separating unstriated portions by cleavage. It is worthy of remark, that some time before GUINAND's death, a commission of the Astronomical Society of London, composed of Messrs. HERSCHEL, FARADAY, DOLLOND, and ROGET, having been instructed to conduct an inquiry into the manufacture of flint-glass for optical purposes, arrived at the result that the necessary improvement was chiefly mechanical, not chemical, and that freedom from striæ could only be obtained by a constant agitation of the mixture. FARADAY, who took the lead in the inquiry, both in his own laboratory and at the glass-works of Messrs. PELLATT, changed, however, the composition, as well as the principle of fabrication, and produced a borate of lead of remarkable purity. This substance, known as FARADAY's heavy glass, which has proved so important in experiments connected with the polarization of light by magnetic action, is composed of the following ingredients:—

Protoxide of lead,	104
Silicate of lead,	24
Dry boracic acid,	25

This glass required but a red heat for fusion, thereby, as Mr. PELLATT remarks, offering facilities for minute agitating operations. It was found, however, not to be durable, and therefore not calculated for application to optical purposes or general use. The common process for making optical glass is described by Mr. PELLATT as follows:—A ladle, in the form of a sugar-loaf, about five inches in diameter and seven inches deep, is dipped carefully into the metal, which has been previously skimmed; when filled, it is taken out of the pot, and suffered to get partially cool. To the large end of the sugar-loaf-shaped piece of glass thus produced, a glass-blowing iron with a hollow disc is welded, and placed to the opening or mouth of the pot for reheating; when sufficiently soft, it is blown into a muff; the end furthest from the blowing-iron is cut off, the cylinder is flattened into pieces or plates of fourteen inches long, ten inches wide, and about half an inch thick, and annealed; in

which state the plates are sold to the optician for cutting and grinding into discs.

Zinc Optical Glass.—Allusion has already been made to a new kind of glass which was sent to the Great Exhibition of 1851 by M. MAËS of France, and was honored with a Council medal, as an instance of novelty of chemical application in the manufacture of optical and other descriptions of glass. The basis of this vitreous compound was oxide of zinc—a certain quantity of borax or boracic acid being added, to give the glossy character for which the boracic compounds, no less than the silica, are so eminently remarkable, combined with an easier fusibility. Its extreme limpidity, and total freedom from color, veins, and striæ, appeared to the council jury eminently to fit it for telescopes, prisms, and other optical apparatus—as a substitute, however, not for the flint-glass, but for the crown, in achromatic telescopes. The low dispersive power of the zinc compounds points to the use of glass of zinc for this purpose. Its refractive index is 3.285, and its dispersive ratio, as compared with a flint-glass of specific gravity 3.55, is as 0.6502 to unity. With reference to this peculiar glass, the following passage occurs in the Report of the Council Jury on Optical Glasses:—Suppose it should be found practicable—and the experiment is recommended to the attention of artists, as one in which, when tried on a very small scale, some success has actually been obtained—to form colorless and uniform glasses, in which fluorine enters as a distinguishing ingredient, in combination with silica, alumina, or other materials; the combination of such glass, as a convex lens, with this new material of M. MAËS, or with ordinary crown-glass as a concave, might be expected to produce achromatic object-glasses of a very perfect description. The colored dispersion to be removed being much less than that of crown-glass, owing to the peculiarity of the fluoric compounds which beset the manufacture of flint-glass, arising from the intense solvent power of the oxide of lead on the crucibles, and give rise to striæ and veins, would be evaded. M. MAËS, besides two prisms of his new glass, of the most limpid purity, and perfect freedom from veins or striæ, exhibited two discs of four and a half and seven inches in diameter, prepared for optical use. In an examination, through faces cut on their edges, no veins or striæ were detected, and, consequently, should there arise no objection to this material, either in point of durability or facility of working, it will probably prove very valuable for the use of the optician.

VI. STRASS AND COLORED GLASS.—The manufacture of glasses tinged, colored, or stained, by different processes, has now become a business of great and growing importance. The taste for stained-glass windows, which formed so distinguished a feature in the history of a former period, has revived, and is now displayed in the decoration, not only of splendid palatial and ecclesiastical structures, but even of many private dwellings; the skill of the Venetians of a former day, in producing colored vases and other ornamental articles of glass of every variety of hue, is equalled if not surpassed in modern times; and artificial gems, or pastes, which are true glasses, are now formed, that emulate,

if they do not eclipse, in sparkling lustre and pure transparency, the rarest and most beautiful natural productions of the mineral kingdom.

Although all the varieties of glass can be colored at pleasure by virtue of the property possessed by the greater number of the heavy metallic oxides of producing colored compounds with silica, yet in individual cases it depends upon the object in view, and even on the nature of the color, whether a glass void of lead, or a lead-glass with its higher refractive power, is employed as the basis for the coloring material. In general, however, the basis of the color, or that with which the coloring matter is actually mixed, is a lead-glass, and this, when real *glass-painting* is the object, is applied either as a pigment or in a melted state on common glass or some other finished article; in other cases, the colored lead-glass is itself formed, cut, or moulded into the finished article. When the latter is an artificial gem or paste, a peculiar glass is employed, termed *strass*, which it may be proper to describe in this place, before proceeding to give a short account of the different coloring materials, and the different methods of their application in particular cases.

Strass, so called from the name of its inventor, constitutes the only true glass not yet described, and forms, as above stated, the basis of artificial imitations of precious stones. For this purpose a glass is required, possessing the highest degree of purity and transparency, combined with the greatest possible lustre. These requirements are found in a composition analogous to that of flint-glass, but containing a much larger proportion of oxide of lead and a little boracic acid. DONAULT-WIELAND recommended, by way of example, either of the three following mixtures:—

	No. 1.	No. 2.	No. 3.
Ground rock-crystal,.....	100	—	100
Sand,.....	—	100	—
Pure minium,.....	156	—	154
White-lead,.....	—	171	—
Purified caustic potassa,.....	54	32	56
Boracic acid,.....	7	9	6
Arsenious acid,.....	.3	.3	.16

From these proportions, and from the analysis of a strass manufactured by DONAULT-WIELAND, which was given at page 192, it will be seen, that not only does the oxide of lead greatly exceed in amount that which is contained in crystal or common flint-glass, but that it is present in larger proportion than even in optical flint-glass. This will be observed by glancing at the same table in the page above-referred to, where flint-glass from GUINAND, or, in other words, optical glass, is placed in juxtaposition with strass and enamel. The very large proportion of oxide constitutes, in fact, the distinguishing peculiarity of the former, while the latter is further distinguished by containing oxide of tin, or is in reality a strass with a mixture of oxide of tin or stannic acid.

Strass, when well prepared, possesses as nearly as possible the high refractive power and all the other properties of the diamond, except its hardness. When cut into shape, therefore, without the addition of any coloring matter to its composition, it answers for imitating the diamond. On the contrary, when tinged by

silicates with metallic bases, it furnishes imitations of all the colored stones. For this purpose its perfect purity and high lustre are essential requisites. It is necessary, therefore, to exercise great care in the choice of the materials. The rock-crystal, quartz, or sand employed, must be of the purest description. The last two always contain a little iron, which colors the glass yellow, and should therefore be washed with hydrochloric acid after being carefully pulverized. The potassa must not be mixed with any other salts. DONAULT-WIELAND preferred the finest caustic potassa; but DUMAS remarks that the use of the nitrate might be preferable on account of the constant purity of that salt. The borax of commerce—that of Holland, for example—would produce a brown glass; crystallized boracic acid is therefore preferred. The oxide of lead employed is very pure minium.

DUMAS remarks that the choice of the crucibles is very important, and that the Hessian ones are better than those of porcelain. The crucibles sometimes color the metal yellow or brown, when particles of iron are detached from the internal surface. This inconvenience is not to be apprehended with crucibles of hard porcelain, but these often break or run out, and are too permeable. A pottery or porcelain furnace is used to melt the material, and the crucibles remain in the fire about twenty-four hours. The more tranquil and prolonged the fusion, the greater hardness and beauty does the strass acquire. If the crucibles are of excellent quality, a porcelain furnace may be used; but when the loss occurring is too great, one must be contented with a common potter's furnace.

COLORING MATERIALS.—It has been stated that colorless strass is the basis of artificial gems, most of which are formed by mixing with the strass certain coloring materials. In the article ENAMELS, many of the substances employed for this purpose have been enumerated; but further details may now be given in connection with the general subject of *colored glass*, before proceeding to the special proportions employed for imitating certain precious stones.

Yellow is produced either by charcoal, antimony, silver, or oxide of uranium. The charcoal, incorporated with the glass in a very fine state of division, produces a dirty yellow, which, as the quantity increases, passes into a dark brown without lustre; it is, therefore, little used as a pigment. A much superior yellow is obtained by roasting sulphide of antimony to the state of antimonious acid, and melting it with from 3 to 5 per cent. of undecomposed sulphide of antimony. An *orange yellow* is prepared with glass of antimony, minium, and a little oxide of iron. In these cases, the substances so prepared are mixed with the materials of the glass. When silver is employed, the process is quite different; in this case a mixture of powdered clay and chloride of silver is applied to the surface of the ready-made articles, and on reheating these in a muffle, the silver penetrates to a certain depth into the glass even before the latter softens; the article is then allowed to cool, and the coating which was applied is scraped off, when a yellow color of great purity and brilliancy appears on the glass. It is remarkable that this effect can only be produced on glass containing alumina, which shows

that the action is chemical, and not purely mechanical. Oxide of uranium produces a beautifully delicate yellow of a slightly greenish hue, which is attributed to the traces of iron usually found in the commercial oxide; but this pigment is too costly for common use.

Red, of different shades, is communicated by oxide of iron, suboxide of copper, or different preparations of gold, mixed with other materials. The oxide of iron— Fe_2O_3 —is employed either as pure oxide, prepared by heating the nitrate, or in the state of bloodstone or ochre. This substance, added to the glass mixture, produces a cheap and very common brownish red. The peculiar action of suboxide of copper has already been explained under ENAMELS, vol. i. page 821. This substance was much employed by the artists of the fifteenth and sixteenth centuries, for producing the brilliant red colors of window panes, and in later times the glass so colored was supposed to be indebted to gold for its beautiful rich hue. So intense is the coloring power of this oxide, that even a very small quantity reddens the glass so much as to render it opaque, and hence it is almost impossible to command any desired tint in applying it. Even a common window pane is scarcely permeable to the light when coloured with a small portion of this substance; and hence in crystal vessels, which are necessarily of much greater thickness, especially when intended for grinding, the effect becomes excessive—the glass is rendered quite opaque. To obviate this difficulty, recourse is had to the process of *flashing* or coating white with colored glass, as will be explained afterwards—a process so successful that it was subsequently extended to other colors.

The application of gold to produce a brilliant red color, which, according to circumstances, can be made to assume a scarlet, carmine, rose, or ruby tint, was first introduced by KUNKEL, who used for the purpose the brownish-red precipitate produced in a solution of chloride of gold by a salt of the sesquioxide of tin. This substance, known as the purple of CASSIUS, was long believed to be the only preparation of gold which could be employed for this purpose, till FUSSE demonstrated that ruby-colored glass may be obtained when the powdered ingredients for the glass are mixed, previous to fusion, with oxide of tin and the solution of gold; the mixture then appears like moist grey sand. Experience has further shown that the simple addition of a solution of gold to the flux, without any oxide of tin, is capable of producing rose and carmine-colored glass.

Blue is produced by oxide of cobalt, a pigment which is equally applicable to lead-glass and to glass containing no lead, but in the latter the color is more intense. The coloring power of the oxide of cobalt is so intense, that pure white glass is rendered sensibly blue by the addition of one-thousandth part of the oxide. Ample information as to the methods of preparing blue cobalt glass, which is produced in a pulverized state as a pigment, under the name of *smalt* or *zaffre*, has been given in the article COBALT.

Green may be produced either by protoxide of iron, protoxide of copper— CuO —or oxide of chromium— Cr_2O_3 . The tint produced by the first of these substances has little brilliancy. The oxide of copper yields

a beautiful emerald. For this purpose the glass is mixed with the product obtained by heating copper to redness with access of air, or with powdered verdigris, which is then decomposed in the fire, and converted into oxide by oxidizing agents. Care must be taken to prevent the protoxide of iron from being converted into sesquioxide, and the oxide of copper from being reduced to suboxide. The oxide of chromium, which occurs as a pigment in commerce, yields the purest and most brilliant grass-green hue, but is too costly for common use.

ARTIFICIAL GEMS.—The preceding cases may be sufficient to illustrate the general character of the substances employed to tinge glass, whether in the fabrication of artificial gems, or in the more important art of enriching with color articles of common use or ornament. Before proceeding to this latter subject, which embraces different methods of applying the coloring material, the following may be given as the most approved recipes for imitating those precious stones that are deemed of highest value:—

Diamond.—Colorless strass, without any addition.

Topaz.—DONALD recommends the following mixture:—

Very white strass,	1000
Clear yellowish orange-red glass of antimony, ..	40
Purple of Cassius,	1

A very good imitation of topaz is obtained from—

Strass,	1000
Oxide of iron,	10

Topaz, when obtained by the first of these two compositions is very subject to vary in tint during the fusion, according to the temperature and the time it is exposed to the fire. It passes from the colorless strass-white to a sulphur-yellow, violet, and reddish purple, according to circumstances, which are not well understood. This substance may be compared to the *rubin-glass* of the Germans and Italians. The glass of antimony must be selected of the greatest transparency, and of a clear orange-red yellow.

Ruby.—This is the rarest and most highly prized of artificial stones. The preparation of topaz furnishes a means of obtaining constantly and at pleasure very fine rubies. The mixture for topaz often gives an opaque mass translucent at the edges, and presenting in its thin plates a color red by transparency. One part of this opaque topaz-matter, and eight parts of strass melted in a Hessian crucible, when left thirty hours in the fire of a potter's furnace, give a fine yellowish crystal similar to strass. Remelted with the blowpipe, this produces rubies of the finest water.

A ruby not so fine, and of a different tint, may be made by employing the following proportions:—

Colorless strass,	1000
Oxide of manganese,	25

Emerald.—The emerald is very easy to imitate. That which succeeds best results from the mixture of the oxide of copper with colorless strass. If oxide of cobalt be added, the green obtained presents blue reflexions. The composition which gives the best imitation of natural emerald is as follows:—

Colorless strass,	1000
Pure oxide of copper,	8
Oxide of chromium,	0.2

By increasing the proportion of chromium or oxide of copper, and adding oxide of iron to the mixture, one may vary the green shade, and imitate peridot or dark emerald.

Sapphire.—To produce a fine oriental blue color, one must employ very white strass, and very pure oxide of cobalt. This composition, put into a luted Hessian crucible, should remain thirty hours in the fire. The proportions are as follow:—

Colorless strass,	1000
Oxide of cobalt,	15

Amethyst.—The color of this stone must be fine and velvety, to be of any value. The formula which succeeds best is the following:—

Colorless strass,	1000
Oxide of manganese,	8
Oxide of cobalt,	5
Purple of cassius,	0.2

Aqua-marina is a gem in little request—even the real stone. As generally met with, it is of a pale emerald tint, but the most valuable kind is colorless like the diamond. The colored kind is obtained by mixing—

Colorless strass,	1000
Glass of antimony,	7
Oxide of cobalt,	0.4

Syrian Garnet.—This stone, which was anciently termed *carbuncle*, has a lively color, for which it is much esteemed. It is especially employed for small jewels. The artificial garnet is a kind of dark ruby, and is made after the following formula:—

Colorless strass,	1000
Glass of antimony,	500
Purple of cassius,	4
Oxide of manganese,	4

In the fabrication of artificial stones, there are many precautions to be taken, many points to be observed, which can only be acquired by experience. The materials must be pulverized with great care. The mixtures can only be well made by repeated sifting. The same sieve must not be used for sifting different compositions, whatever care be taken to clean it after each operation. Lastly, to obtain masses well melted, quite homogeneous, without striæ or bubbles, it is necessary to employ substances very pure, and mixed in a state of extreme division; to obtain the best crucibles, to melt with a graduated heat, in a furnace which is quite equal in its maximum temperature; to leave the metal in the furnace during twenty-four to thirty hours, and to cool the crucibles very slowly, that their contents may undergo a kind of annealing.

COLORED FLINT-GLASS.—Assuming as the composition of the glass to be colored the common ingredients and proportions quoted at page 230, and remembering that these materials, when mixed together, are technically termed *batch*, and, when fused with the usual precautions, produce a highly pellucid flint-glass, this may be regarded as the basis of the following colored glasses, given on Mr. PELLATT's authority:—

Soft White Enamel.—To six hundredweight of batch

add twenty-four pounds of arsenic, six pounds of antimony.

Hard White Enamel.—To six hundredweight of batch add two hundred pounds of putty prepared from tin and lead.

Blue Transparent Glass.—Six hundredweight of batch colored with two pounds of oxide of cobalt.

Azure Blue.—Six hundredweight of batch with about six pounds of oxide of copper.

Ruby Red.—Six hundredweight of batch with about four ounces of oxide of gold.

Amethyst or Purple.—Six hundredweight of batch with about twenty pounds of oxide of manganese.

Common Orange.—To six hundredweight of batch add twelve pounds of iron ore and four pounds of manganese.

Emerald Green.—To six hundredweight of batch add twelve pounds of copper scales and twelve pounds of iron ore.

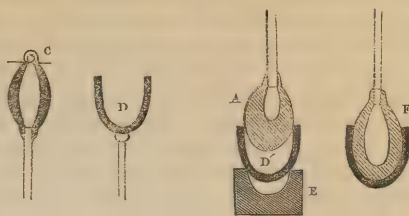
Gold Topaz Color.—Six hundredweight of batch with three pounds of oxide of uranium.

FLASHING AND CASING.—In speaking of the sub-oxide of copper, it has been stated that the coloring power of this substance is so intense that even a very small quantity of it renders the glass opaque; and allusion was made on that occasion to the process of *flashing*, by which the difficulty is overcome, and which, on account of the facilities it affords for regulating the intensity of the tint, has been extended to the manufacture of articles of every variety of hue. This process consists in coating a layer of colorless, with one of colored glass, which can then be reduced, by grinding, to the proper tint. For this purpose the glass-blower collects the proper quantity of colorless glass on the end of his pipe, rolls it upon the marver, and then dips it for a moment into a pot of melted colored glass, and blows out the two together into a cylinder or globe, which is flatted or *flashed* out in the usual way. In this manner panes for the glass-painter are formed, which consist of two layers of glass, one colored, the other colorless; and the former can be ground down to any required tint or degree of transparency. An ingenious application of this process is made to vessels of flint-glass, which are tinged on the outside in a similar manner, and colorless edges or facets are then produced by cutting through the outer layer of colored glass, into the substratum of pure white glass.

Flint-crystal glass is usually colored by a somewhat similar process termed *casing*, and thus described by Mr. PELLATT. Presuming that any two or more glasses intended for casing have been mixed of the same specific gravity, to give them the capability of harmonizing—that is, of contracting and expanding equally—the blower has to gather a ball of solid glass, intended for the interior layer, in the usual manner, as A, Fig. 194, which, in this instance, may be considered to be of white crystal glass. About the same time his assistant prepares a casing of colored glass, B, knocking off the knob at c, to open and shape it, as D, somewhat like the bowl of a wine-glass, or the broad end of a large egg-shell; this is set into a metal stand, E, on the floor, merely to steady the case or shell, D'; while the blower takes the lump of flint or white glass, A, and

gently blows it into the colored case or shell, D', to which it immediately adheres; and when submitted to

Fig. 194.



the flame of a pot-hole, it is found to weld perfectly, as F. If various coverings are needed, as many colored shells must be prepared as required, and each time melted in by fresh warming, until the entire number are obtained and cased. The whole are afterwards rewarmed, expanded, and shaped into vases, tazzas, or such other articles as the manufacturer requires, by blowing, and the usual appliances of moulds, tools, rotatory motion, *et cetera*. When cut through to the crystal in various figures, the edges of the different colors on enamel are seen.

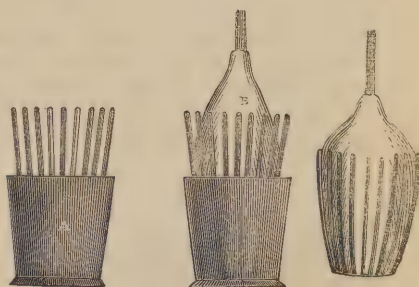
In connection with *flashing* and *casing*, may be mentioned a variety of methods of producing colored or variegated or ornamental glass, some of which are very ingenious, and are chiefly derived from the Venetians.

Venetian filigree work is produced in the following manner:—Pieces of *cane*, or solid rods of glass, of different colors, having been drawn out in the same manner as tubes, and whetted off to the required lengths, are arranged in the flutes or internal grooves of a cylindrical mould, A, Fig. 195. The blower then inserts a solid ball of transparent flint-glass, B, Fig. 196, and the whole is exposed to a welding heat, till the

Fig. 195.

Fig. 196.

Fig. 197.



canes adhere to the ball. Both are then withdrawn with it from the mould, when the piece presents the appearance represented in Fig. 197. When again heated, drawn, and twisted, the streaks of color produced by the adhering canes become spiral, and ornament the surface. If well softened and marvered before the drawing and twisting, the streaks spread till they meet; or if, before being drawn, the mass be redipped into the pot of crystal glass, and then twisted, the spiral lines of color or enamel become internal. By the repetition of this process, spirals can be formed

within spirals; and by placing the filigree canes side by side, and welding them together, very curious and intricate patterns are obtained.

The *Venetian ball* is simply a number of pieces of waste filigree glass collected together without regular design; they are then introduced into a globe of transparent glass, which is made to collapse upon the filigree fragments within by suction; that is to say, by the blower drawing in his breath. The round heavy paperweights, which generally contain regular devices, are formed in the same manner, and the lens-like shape of the crystal enhances the effect by magnifying the incrustated ornament.

The *mille-fiore* or *star-work* of the Venetians is formed by placing lozenges of glass, cut from the ends of colored filigree canes in the interval between two transparent cones, as shown in Fig. 198, and then, after reheating the whole, exhausting or sucking out

Fig. 198.

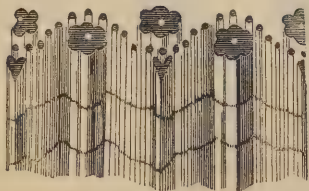


the air by means of a blowing-iron attached to the neck, A. The piece being then rewarmed becomes one homogeneous mass, which can be shaped into any required form, for *tazzas*, paperweights, *et cetera*. In forming such incrustations, it often happens that, from the unequal contraction between the object and the crystal by which it is surrounded, there is much difficulty in the annealing, and, to avoid the

risk of fracture, the contained object must be made of materials expanding and contracting like the glass or crystal itself.

Glass-mosaic, which is often confounded with *mille-fiore*, is produced by threads or small canes of variously colored opaque or transparent glass, of uniform lengths, ranged vertically side by side, in single threads or masses, so that the ends shall form grounds agreeably to some prefigured design. When submitted to heat sufficient to fuse the whole, the four sides at the same time being pressed together so as to exclude the air from the intervals between the threads, the result will be a thick slab of variegated glass—Fig. 199—exhibiting, for all parallel sections, the same figure or pattern.

Fig. 199.

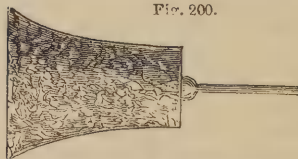


Hence, when cut into veneers, either in the direction shown by the dotted lines, or obliquely or longitudinally, it will yield a number of slabs or layers of the same uniform design. The thin rods of glass employed for this purpose are composed of very easily fusible glass of all possible colors and shades, and are prepared in manufactories erected expressly for this purpose.

In these manufactories, masses of colored glass are prepared, from which a kind of cake is formed, and this is converted, with the aid of a sharp hammer and an anvil, first into slabs, and then into the thin rods above-mentioned. In this form the material is supplied to the artist, who softens it in the flame of a lamp, draws out each rod into a thick thread, and breaks off a piece of the thickness of the intended picture. These pieces are then arranged one after the other, according to the design, on a slab of copper covered with a layer of cement, which serves to fix the picture. When the whole slab is covered, the surface, which is necessarily uneven and irregular on account of the unequal lengths of the rods or threads, is ground and polished. It is unnecessary to observe, that a large mosaic painting formed in this manner is often a work of years.

Venetian frosted glass is obtained by immersing the gathering of hot metal in cold water, quickly withdrawing it, reheating and expanding it by blowing, before it becomes so hot as to melt and weld together the numerous superficial cracks produced by the momentary immersion in cold water. These cracks only penetrate so far as the metal has been cooled by the water, and remain as depressions until the article is finished, when it presents the appearance represented in Fig. 200.

Fig. 200.



The art of making this glass was kept secret by the Venetians, but was rediscovered by Mr. PELLATT a few years ago.

Mr. PELLATT has also invented a method of ornamenting glass with delicate white argentine incrustations of dry porcelain clay, cemented into the solid glass. For this purpose the hot prepared cameo, which may be a small bas-relief or cast, is placed upon the red-hot manufactured vessel or other article; a small piece of liquid glass is then dropped on it, and becomes welded; and if rubbed while hot, the upper coat of fused glass will be spread as thinly as possible upon and around the cameo, behind which are driven any air-bubbles that may be entrapped; thus completely isolating the device between the two glasses. The polishing of the exterior layer gives the white figure a silvery appearance; but, of course, the incrustation may be colored before being applied to the glass. These incrustations require very careful annealing.

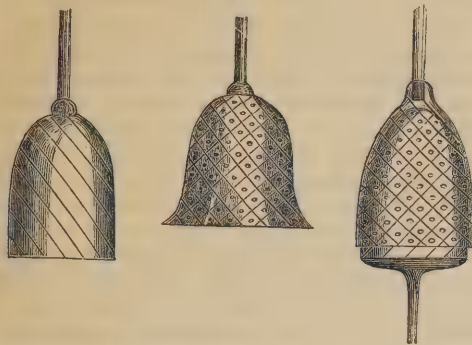
Venetian vitro-di-trino is a sort of lace-work, formed by intersecting lines of white enamel, or transparent lines of white or colored enamel or transparent glass, the centre of each mesh or diamond inclosing an air-bubble. It is formed by blowing a gathering in the mould with suitable canes arranged in the interior fluting, as shown in Fig. 195, page 241. It is then reheated, further blown and twisted, as for spiral filigree, the canes being left projecting from the outside, like ribs. By the usual manipulation, a cup or conical

vessel is formed, marked by oblique lines or spiral projections, as shown in Fig. 201. Another similar piece is then made and turned inside out; the projecting canes on this piece are inside, and the spiral lines reversed. The one piece is then placed under the other, as shown in Fig. 202, and the two are welded

Fig. 201.

Fig. 203.

Fig. 202.



together. The ribs or flutes projecting from the two surfaces in contact inclose, during the welding, a portion of air in each diamond, which air gradually assumes the bubble-shape. The vessel is then finished in the ordinary manner, and the lines exhibit the most beautiful regularity, as shown in Fig. 203.

Aventurine Glass is an easily fusible brown, or, in thin layers, yellow glass, interspersed with numerous fine yellow laminae or spangles with a metallic lustre, which give it a peculiar shining appearance. The method of manufacture was long kept secret by the Venetians. It was commonly supposed that aventurine glass was produced by melting scales of metal or mica with the glass; but this opinion was thought to be overthrown when GAHN observed that, under the microscope, these scales appeared as regular three or six-sided tables, perfectly crystalline in structure. He discovered, in fact, that the spangles consisted of metallic copper, crystallized in the form of flat segments of a regular octahedron. FREMY and CLEMANDOT succeeded, however, in preparing this glass by fusing together, for twelve hours, the following mixture:—

Pounded glass,	300 parts,
Copper scales,	40 "
Iron scales,	80 "

and afterwards cooling slowly. The glass obtained was somewhat deficient in lustre, but, like the true aventurine, it contained copper diffused through it in octahedral crystals.

GLASS-PAINTING.—Painting on glass is performed by means of a vitreous mixture termed the flux, combined with a pigment prepared from some metallic oxide. The flux and oxide are simply that combination of ingredients which is necessary to produce a highly fusible colored glass of the required hue; this mixture is reduced to a state of fine powder, rubbed up in oil of turpentine, boiled oil, or sometimes simply with water, and laid upon the glass to be painted, by means of a brush. The glass thus painted or stained with the intended design is then exposed to a heat

sufficient to vitrify the mixture of color and flux, without melting the glass; in other words, the painting is said to be burnt in; the ingredients of which it is composed are converted into a colored glass or transparent picture, while the pane or other article on which it is laid, is only sufficiently softened to cause the complete adherence of the colored glass to its surface.

It is evident, therefore, that the fusing-point of the pigment must be much lower than that of the glass to be painted. Indeed, it is necessary that the former should vitrify at a temperature at which the latter does not sensibly soften; for any considerable softening or yielding of the glass would distort the design. Hence the manifest inapplicability of crystal or lead-glass for painted articles, on account of its great fusibility. On the other hand, common window-glass, or even plate-glass, may be successfully used, and, best of all, the hard Bohemian glass, which contains potassa for a base.

When the coloring oxides employed are such that they are not injuriously affected by the oxides of lead and of bismuth, the flux is usually composed of the following ingredients:—

	Parts.
Quartz in powder,	100
Oxide of lead,	125
Oxide of bismuth,	50

But if these oxides exert an injurious action on the coloring matter, and tend to change its shade, the subjoined composition is used:—

	Parts.
Quartz in powder,	100
Fused borax,	75
Nitrate of potassa,	12·5
Carbonate of lime, free from iron,	12·5

To either of these mixtures or fluxes the proper coloring matter is added, and the composition so formed is introduced into a crucible, and melted into a colored glass. The latter is then reduced to a fine powder, mixed, as has been stated, with oil of turpentine, and used as a common pigment for painting on the less fusible glass. In this operation, a cartoon, or drawing upon paper, is placed below the glass, and the colors are applied on the corresponding lines. In preparing painted sheets or panes of glass, brown or black outlines are generally traced on the one side of the sheet, whilst the colors are laid on the other side; but in painting vessels or other articles, this is not the practice.

One great difficulty of the glass-painter consists in this, that the colors which he lays on have not the same appearance as they are intended to assume in the finished work. The difficulties of the artist on glass, says Mr. TOMLINSON, are of a much more formidable character than those of the artist on canvas; he must be as good an artist as the latter, but he must also have the faculty of seeing his effects as they will appear after the firing, and not as he lays them on; for the coloring oxides which he employs, especially when mixed up in their fluid vehicles, are dark, dusty, and disagreeable in color, and have nothing in common with the bright and beautiful effects we admire in a stained-glass window. When the same figure or pattern is to be repeated many times, it is, in some cases,

printed on the glass with a gentle pressure from an engraved metallic plate, or wooden block, boiled oil being used as the vehicle for the coloring oxide. The pane, having been prepared either by painting or printing, is exposed in an oven or muffle to a temperature sufficient to fuse the vitreous flux and dissolve the coloring material. The glass selected for the purpose of the stainer should be clear and colorless, in order to bring out the colors well; and difficult of fusion, so that the flux and metallic oxide may form a colored glass upon its surface before it shows any tendency itself to fuse. A glass containing a small proportion of alkali, such as crown-glass, is fit for the purpose.

SPUN GLASS.—There is no one who has not heard statements relative to the discovery of a malleable glass, one memorable instance of which is mentioned in the Historical Notice, page 186. If, by malleable glass, be understood a glass capable of being spread out into thin plates under the action of the hammer at the ordinary temperature, everything leads to the belief that this marvel never was, and will not for a long time be realised. If, on the contrary, it means only the ductility of incandescent glass, there remains in this respect little to be accomplished. It is, in fact, on this property that the whole art of the glass-maker depends. But whilst, in the ordinary operations of glass-making, the ductility of the glass is never pushed to its utmost limits, these limits are almost reached in the curious art of spinning glass into thread.

The art of spinning glass consists in drawing it out into threads when softened, by means of a wheel on which the thread is wound. By this means the art has been attained of spinning glass with astonishing rapidity. The drawn out end of a glass rod has only to be attached to a revolving drum, whilst the rod whence the thread proceeds is held in the glass-blower's lamp, in order to obtain in a few minutes several ells of spun glass. The thread possesses, of course, the color of the glass; but its tenuity is so great that the color is scarcely perceptible, unless very deep shades have been employed.

It has already been stated that when a piece of hollow glass is drawn out, the hole is always preserved, however fine be the thread. M. DEUCHAR took a piece of thermometer tube, the interior diameter of which was very small, and drew it out into threads. The drum which he used was three feet in circumference, and as it made five hundred turns per minute, he obtained thirty-two thousand ells of thread per hour; so that the thread was of extreme fineness, and its interior diameter was scarcely calculable. This thread was, however, hollow; for being cut into pieces of an inch and a half in length, and placed on the receiver of an air-pump, one end inside and the other out, it allowed the mercury to pass through in small shining filaments when a vacuum was made in the receiver.

The thread obtained from a small piece of window-glass, cut with a diamond, presents a very brilliant lustre; seen with the microscope, it exhibits a flattened form, with four very distinct right angles. It is very probable that it owes to this particular form the superiority of its lustre, for the threads obtained from round pieces of glass had always a dull appearance.

When glass of different colors is fused or welded together in one tube, the thread obtained from it preserves all the original colors without any mixture taking place, or any interruption being observable; but most of the colors become tarnished by the operation, particularly the yellow, which disappears; the black even sometimes passes to brown; the purple and green are a little altered, but the blue stands well.

The samples of spun glass are as pliable as silk, and may easily be wound in the manner of common thread, and employed as ornaments. To the touch they feel like hair, and like it may be curled in a permanent manner by rolling them on a hot iron. Threads from black glass have so much resemblance to black hair, that they are often confounded. It is well known that in the last century perukes were manufactured of glass thread, which is sometimes still used to make very brilliant head-dresses. Its glossy appearance, its great durability when not exposed to rough usage, as well as the low price of glass, naturally suggested to manufacturers the advantage of making it a material for spun fabrics. It has even been woven into stuffs, but hitherto this curious manufacture does not appear to have been attended with much success. It has been alleged, indeed, not without reason, that articles of clothing made of glass might be attended with some danger from the filaments becoming detached, and being drawn into the lungs by respiration. KNAPP states, however, that this branch of manufacture has lately been revived with success by OLIVI, DUBUS-BONNEL, and BOUILLON; and that DUBUS, in particular, is said to have succeeded in producing glass thread that can be knotted, and woven on JACQUARD'S loom into fabrics which are equal in every respect to the most beautiful gold and silver brocade. He adds that the particulars of this manufacture have not yet been made public, and the Editor cannot help thinking that its success has been greatly exaggerated.

VII. SOLUBLE GLASS.—Soluble glass is a compound, the knowledge of which would have spared the glass-makers many faults. It is, as has been stated, a simple silicate of potassa or soda, or a double silicate of these two bases. What is remarkable, this body is soluble in boiling water without a residue, though scarcely affected by contact with cold water. Nevertheless, it is very evident that such a glass must be strongly hygrometrical, and, among the numerous examples which might be cited, the Editor limits himself to the following, to show the inconveniences which arise from this. In 1780, Bohemian glasses, the process for which was then a recent importation, were made simultaneously in France by the two following receipts:—

	At Bayel in Champagne.	At Elmbac in les Vosges.
Silica,.....	100	100
Potassa,.....	100	100
Lime,.....	none	100

Now, while the Vosges glass was unalterable by the air, that of Champagne was wanting in clearness, brilliancy, and solidity, and attracted the moisture of the atmosphere to such an extent, that the hollow feet of drinking-glasses became filled in the warehouses with

a saturated solution of carbonate of potassa. To this fact, one might add many others which would prove the indispensable necessity of lime or of oxide of lead, for the making of glasses to be capable of resisting the action of water or of moist air.

Soluble silicated alkali or water-glass may be prepared by various processes. If sand be used, fifteen parts of fine sand, thoroughly incorporated with eight parts of carbonate of soda, or with ten of carbonate of potassa, and one of charcoal, fused in a furnace, will produce a silicated alkali which is soluble in boiling water. Messrs. RANSOME obtained this silicated alkali by dissolving broken flints in a solution of caustic alkali at a temperature of 300°.

This water-glass has been applied to several important purposes, three of which are especially noticed.

To protect Building-stones from decay.—The stone surfaces of buildings, by being exposed to the action of the atmosphere, become liable to disintegration from various causes. Moisture is absorbed into their pores. The tendency of their particles to separate in consequence of expansion and contraction, produced by alternation of temperature, is thus increased. Sulphurous acid is always present in the atmosphere of coal-burning cities, and cannot but corrode the calcareous and magnesian ingredients of oolites and dolomites. It is true that good stone resists these sources of injury for an indefinite time, but such a material is rarely obtained. As a preventive of destruction, whether arising from physical or chemical causes, it has been proposed to saturate the surface of the stones with a solution of water-glass.

It is well known that the affinity of silica for alkali is so feeble, that it may be separated from this base by the weakest acids, even by carbonic acid. According to the expectation of those who recommend the silification of stone, the carbonic acid of the atmosphere will set the silica free from the water-glass, and the silica thus separated will be deposited within the pores and around the particles of the stone. The points of contact of these particles will thus be enlarged, and a sort of glazing of insoluble silica will be formed, sufficient to protect the stone from the effects of moisture, *et cetera*. This cause of protection applies chiefly to sandstones. But wherever carbonate of lime or carbonate of magnesia enters notably into the composition of the building stone, then an additional chemical action, also sheltering the stone, is expected to take place between these carbonates and the water-glass. An insoluble salt of lime may be looked for, whenever a solution of water-glass is made to act on the carbonates of lime or magnesia existing in oolitic or dolomitic building stones.

This expectation, however, has not been altogether realized by experiment. Mr. CHARLES A. SMITH, a gentleman eminently conversant with building materials, immersed a piece of Caen-stone in a solution of silicate of potassa in the month of January, 1849. This fragment, together with a portion of the block from which it had been detached, was placed on the roof of a building in order that it might be fully exposed to the action of atmosphere and climate. After five years the silicated and the unsilicated specimens were found to be both in the same condition, the two being equally

corroded. But whatever ultimate results may ensue from this process, the immediate effects on the stone are remarkable. Two portions of Caen-stone were exhibited, one of which had been soaked in a solution of water-glass two months before. The surface of the unsilicated specimen was soft, readily abraded when brushed with water, and its calcareous ingredients dissolved in a weak solution of sulphurous acid. The silicated surface, on the other hand, was perceptibly hard, and resisted the action of water and of dilute acid when similarly applied.

Another proposed use of the water-glass is that of *hardening cements, mortar, et cetera*, so as to render them impermeable by water.

Fourteen years since, ANTHON of Prague proposed several applications of the water-glass. Amongst others he suggested the rendering mortars waterproof. He also suggests that this substance might be beneficially employed as a substitute for size in whitewashing and staining walls. It was demonstrated by several experiments that carbonate of lime, mixed up with a weak solution of water-glass, and applied as a whitewash to surfaces, was not washed off by sponging with water, and that common whitewash, laid on in the usual manner with size, was rendered equally adhesive when washed over with water-glass.

The Stereochrome of FUCHS.—The formation of an insoluble cement by means of the water-glass, whenever the carbonic acid of the atmosphere acts on this substance, or whenever it is brought in contact with a lime-salt, has been applied by FUCHS to a most important purpose. The stereochrome is essentially the process of fresco-sicco invested with the capability of receiving and perpetuating works of the highest artistic character, and which may be executed on a vast scale. This chemist's method is as follows:—

Clean and washed quartz-sand is mixed with the smallest quantity of lime, which will enable the plasterer to place it on the wall. The surface is then taken off with an iron scraper, in order to remove the layer formed in contact with the atmosphere; the wall being still moist during this operation. The wall is then allowed to dry; after drying it is just in the state in which it could be rubbed off by the finger. The wall has now to be fixed, *id est* moistened with water-glass composed as follows:—

	Centesimally.
Silicic acid,	23·21
Soda,	8·90
Potassa,	2·52
Water,	65·37
	100·00

The specific gravity of the solution is to be 3·81. This operation is usually performed with a brush. The wall must be left in such a condition as to be capable of receiving colors when afterwards painted on. If, as frequently happens, the wall has been too strongly fixed, the surface has to be removed with pumice, and to be fixed again. Repaired in this manner, the wall is suffered to dry. Before the painter begins, he moistens the part on which he purposes to work with distilled water, squirted on by a syringe. He then limns: if he wishes to repaint any part, he moistens again.

As soon as the picture is finished, it is aspersed over with water-glass. After the wall is dry, the syringing is continued as long as a wet sponge can remove any of the tint. An efflorescence of soda sometimes appears on the picture soon after its completion. This may either be removed by syringing with water, or may be left to the action of the atmosphere. Not to dwell on the obvious advantages possessed by the stereochrome over the real fresco—such as its admitting of being retouched and its dispensing with joinings—it appears that damp and atmospheric influences, notoriously destructive of real fresco, do not injure pictures executed by this process.

The following crucial experiment was made on one of the pictures. It was suspended for twelve months in the open air, under the principal chimney of the New Museum at Berlin; during that time it was exposed to sunshine, mist, snow, and rain, and nevertheless retained its full brilliancy of color.

The stereochrome has been adopted on a grand scale by KAULBACH, in adorning the interior of the great national edifice at Berlin, already alluded to. These decorations consist of historical pictures—the dimensions of which are twenty-one feet in height, and twenty-four and three-quarters in width—single colossal figures, friezes, arabesques, *et cetera*. On the effect of the three finished pictures, it has been remarked by one whose opinion is entitled to respect, that they have all the brilliancy and vigor of oil paintings, while there is the absence of that dazzling confusion which new oil paintings are apt to present, unless they are viewed in one direction, which the spectator has to seek for.

MR. A. CHURCH has suggested that, if the surface of oolitic stones—such as Caen-stone—is found to be protected by the process already described, it might be used, as a natural *intonaco*, to receive colored designs, *et cetera*, for exterior embellishings; the painting would then be cemented to the stone by the action of the water-glass.

MR. CHURCH has also executed designs of leaves on a sort of terra-cotta, prepared from a variety of WAX's silica rock, consisting of seventy-five parts clay, and twenty-five of soluble silica. This surface, after being hardened by heat, is very well adapted for receiving colors in the first instance, and retaining them after silication.—*Timbs*.

KUHLMANN remarks that the contact of lime with silicate of potassa, always determines the decomposition of this salt and its transformation into silicate of lime, which retains the coloring matter, and even carbonic acid, as lately supposed by M. FUCHS; but when the colors are applied on bodies which do not react on the soluble silicate—such as wood, iron, glass, *et cetera*—it becomes necessary to seek for conditions of insolubility in the reaction of the coloring matter on this silicate. On wood the difficulty may be removed by the application, before the silicious painting, of a sufficiently thick covering of chalk, which may be applied with zinc, or fixed with a very little silicate.

Even when the decompositions of the alkaline salt are determined by the coloring matter itself, there still remains one serious inconvenience: this is the exudation, during damp weather, of carbonate of potassa to

the complete expulsion of the salt. This chemist for a long time sought for a remedy for this serious injury to silicious paintings; he often conferred on this subject with those members of the Academy best acquainted with vitrification, and having been aided by their advice, KUHLMANN sought in various chemical changes for a remedy, and ascertained that washing the painting with a weak solution of chloride of ammonium, enables one to attain absolute insolubility of the color, but chloride of potassium remains, which spoils its brilliancy until its complete expulsion by repeated affusion with water. As the number is but small of chemical reagents, which have the property of consolidating potassa by forming with it insoluble compounds in the color itself, but without eliminating it, perchloric acid and hydrofluosilic acid are the chemical agents which first offer themselves to the mind.

In a theoretic point of view, there only remained to choose between them; but, in an industrial sense, hydrofluosilic acid was the only one on which his mind fixed itself. He ascertained so frequently that careful washing with hydrofluosilic acid much augmented the stability of these colors, and determined their complete insolubility, that he did not hesitate to point out the utility of this agent in every kind of silicious limning, but especially in painting on glass, provided that it is used in very weak solution; for in the concentrated state it has the remarkable property of dissolving most of the oxides, which property will be very valuable for industrial purposes, when this acid can be sold at a moderate price.

The silicious colors on glass have a certain semi-transparency which it is important to preserve, but which gradually diminishes by the action of water. Glass painted with silicates has been subjected to boiling in water without the colors being detached; these tints have even appeared brighter when seen by reflected light; but if, after this apparent improvement, the effect is examined by transparency, the hues are found to have become duller, which is to be attributed to the opacity which they had acquired, resulting from the solution of a portion of silicious cement, which acts on these colors as oil does on paper. The careful employment of hydrofluosilic acid gives a complete insolubility to paintings on glass; but, like chloride of ammonium, it slightly diminishes the transparency. One might perhaps apply, at long intervals, a slight varnish of pure silicate of potassa to paintings on glass which are exposed to rain. Long experience can alone determine this point. This varnish would advantageously replace the essences now used in the application of certain colors on glass and porcelain; it would not, like the essences, be subject to the drawback of spoiling certain colors by the reduction of the oxides or of the coloring salts.

STATISTICS.—Considering the vast importance of glass, and the peculiar facilities possessed by Great Britain in her ample stores of coal, and the possession of nearly all the materials for the manufacture, it might have been imagined that this country would not only have fully supplied her own wants, but would long ago have furnished a large portion of the world with glass, as with many other exports. It might be sup-

posed, also, that the various necessary, convenient, and ornamental purposes to which glass is applied, would have been held as a sufficient reason for exempting it from taxation, or at least for reducing the duties to the lowest possible limit. But so far was this from being the case, that the most exorbitant duties were imposed, and were exacted in the most oppressive manner; which not only limited the demand for glass, by directly increasing the price, but operated indirectly with most injurious effect, by fettering the operations of the manufacturers, and preventing them from making experiments, and introducing new processes and improvements.

As illustrative of the amount of the duties, which are exhibited more at large in the appended tables, it will be seen that in 1813 they were raised to not less than four pounds eighteen shillings a hundredweight on plate and flint glass, and three pounds thirteen shillings and sixpence on crown. With such enormous duties on one of the modern necessities of life, the result of ignorant legislation, it was impossible for this country to enter into fair competition with other nations, or even to keep pace with a rapidly increasing population. On the contrary, despite the increase in population, and the still greater increase in wealth in the interim, the consumption of flint and plate glass in 1813, and many subsequent years, was less than it had been in 1794, when the duty on these glasses was only one pound two shillings and twopence farthing a hundredweight. Again, it is stated by the late Mr. PORTER, that in 1801, with a population of only sixteen millions, the quantity of glass used was three hundred and twenty-five thousand five hundred and twenty-nine hundredweight; and in 1833, with a population of twenty-five millions, the quantity was no more than three hundred and sixty-three thousand four hundred and sixty-eight hundredweight—an increase of one-eighth, while the population had increased in the proportion of one-half.

By the imposition of the income-tax, the late Sir ROBERT PEEL was enabled to abolish, along with many other injurious indirect taxes, the excise duties on glass, which were repealed from the 5th April, 1845; and MACCULLOCH justly remarks, that the beneficial influence of this liberal and most judicious measure is obvious in the improved quality, the increased cheapness, and greater variety of descriptions of glass in the market. At the meeting of the Society of Arts, in 1856, to which reference has already been made in the course of this article, Mr. W. A. SWINBURNE, of the celebrated glass-making house of that name, alluded to the different price of glass in former times, as compared with the present; speaking of three shillings and sixpence or four shillings a foot as having been paid to glaziers now living for glazing ordinary-sized crown glass in sashes, for which now, perhaps, only as many pence could be obtained. In the case of plate-glass, he held in his hand a tariff used by their house, dated 1771, two years before the establishment of the British Plate-Glass Company, wherein the price of a chimney mirror fifty inches long by forty inches wide, a very usual size, and now in common demand, was quoted at sixty-one pounds three shillings! The price of this plate before

the repeal of the duty in 1845, was nine pounds nine shillings to ten pounds; after the repeal of the duty, about eight pounds; in 1854, four pounds ten shillings; and in 1855-6, about four pounds four shillings. So much had the public benefited by the reduction of the price of glass.

But, as may be supposed, this reduction in price, as well as the great improvement in quality, did not solely arise from the mere repeal of the duties. It arose also, in great measure, from the removal of those intolerable fetters which were previously imposed on the manufacturer by the excise regulations. During the excise reign, says Mr. PELLATT, in his *Curiosities of Glass-making*, no pot could be moved from the spot where it was dried, to be placed in the annealing arch, without a notice in writing to the supervisor; a second notice was required for gauging; a third for setting it in the furnace; again, for filling the pot; and another for lading it out; whilst the maker was forced to comply strictly with the act of parliament, by giving the officer six hours' notice for each of these intricate and vexatious requirements.

Again, with reference to the subject of annealing, the same able writer remarks:—When the excise upon glass existed, the lear was secured by fastenings and locks—supplied by the Government officer at the expense of the trader, and safely secured every Friday or Saturday, and not re-opened till the Monday following. During the whole of the week, the officer had the surveillance of the lear, but especially of the sorting-room, at the delivery end of the lear, which was only entered at the stipulated act of parliament periods. If a link forming part of the endless chain running under the lear, connected with the machinery drawing down the pans, accidentally broke in the night, and the officer should happen to be absent—which was rather the rule than the exception—either the whole works must be stopped, or some mode adopted for the learner to repair the mischief not strictly in keeping with the act; so that while the principal was quietly reposing in his bed in imaginary security, his servant, unknown to him, had almost necessarily incurred ruinous excise penalties. The excise officer gauged the liquid glass in the pots, which he had the option of charging by weight, at a specific gravity of 32·00; and should the manufactured annealed goods ultimately not amount to two-fifths of that estimate, he had to pay the difference. The lear charge was always considered to be the chief security, as indeed it really was; still, with the utmost excise vigilance, the trader occasionally defrauded; but owing to the great heat of the arch, and the usual excise securities, the revenue was, on the whole, well secured at the lears. Had the lears or kiln been the only departments of the works under excise survey, the manufacturer would not have been so much inconvenienced. The surveillance of the pots was his chief annoyance, since it required endless trouble, and subjected the manufacturer to danger of exchequer prosecutions. To throw into the pots ever so small a piece of metal, during the working, incurred a penalty of fifty pounds for every offence. Neither plate-glass nor bottle-glass manufacturers were subject to the surveillance of the pots: this made it exclusively injurious to the flint-glass maker, and was

almost a prohibition of alteration of tint, or experiments, and consequent improvements. It is matter of astonishment how flint-glass works existed at all, under such a concentration of commercial and manufacturing hindrances as were imposed by the excise regulations; happily, the incubus exists only in reminiscence.

While the greatest stimulus was given to the crown and sheet glass manufacture by the abolition of the duty in 1845, that abolition has produced a somewhat paradoxical result, which is thus stated by Mr. HENRY CHANCE:—While the quantity of glass made has increased in the proportion of three to one, the number of manufacturing firms has diminished in the proportion of one to two. In 1844 there were fourteen companies engaged in the manufacture. In 1846 and 1847, following the repeal of the duty, the number had increased to twenty-four. The glass trade, after the removal of the heavy burden imposed upon it, seemed to offer a fair opening for money seeking investment. The demand for glass was so great that the manufacturers were in despair. Glass-houses sprung up like mushrooms. Joint-stock companies were established to satisfy the universal craving for window panes. And what was the result? Of the four-and-twenty companies existing in the year 1847, there were left, in 1854, but ten. At this time there are but seven in the whole United Kingdom. Two, established in Ireland, have ceased to exist. In Scotland, the Dumbarton works, once famous, were closed in 1831, by the death of the partners, afterwards re-opened, and again closed. The seven now existing are all English.

While thus diminished in number, the immense extent and resources of the principal great glass-houses now existing may be inferred from the fact already alluded to, namely, that the firm of CHANCE and Company executed the large order in sheet-glass for the Great Exhibition structure of 1851 without materially affecting their power of executing their general orders. In such immense establishments, experiments, now untrammelled by the meddling officiousness of an absurd legislation, can be executed on a large scale, and vast improvements have been effected. Minute, and apparently unimportant changes, perceptible only to those near at hand, have in silence done their work.

Still, as one of the eminent members of the firm above referred to remarks, the development both of the processes and applications of the glass manufacture is incomplete. Sir JOSEPH PAXTON's glass arcade, stretching over the streets of London, and Dr. SLEIGH's city of glass, in which invalids will inhale the gentle air of Madeira,—these are faint foreshadowings of the destiny of this wonderful substance. And, perhaps, the day may come when some future chronicler of glass shall smile at the barbarians of the nineteenth century, who could not make window-glass without defects, and shall exhibit those defects as the curiosities of a by-gone age.

The annexed table, from MACCULLOCH, shows the state of the manufacture, quantity exported, and amount of duties, a few years previous to their repeal :—

I. Account exhibiting the Quantities of the different descriptions of Glass manufactured during each of the Three Years ending with 1842, with the Quantities exported, the Rates and Produce of the Duties, *et cetera*.

Description of Glass.	Quantity manufactured.	Quantity exported.	Rate of Duty.	Gross Amount of Duty.	Drawback on Glass exported.	Nett Amount of Duty (Excise), after deducting drawback and other legal allow- ances
	Cwts.	Cwts.		£	£	£
Flint-Glass. 1840	104,889	19,913	{ To 15th May, 1840, 18s. 8d. } per cwt.; since, 18s. 8d. per cwt. and 5 per cent.	101,029	21,199	79,830
Ditto, 1841	97,524	20,516		95,565	22,605	72,960
Ditto, 1842	83,653	13,696		81,973	15,098	66,875
		Sq. feet.				
Plate-glass, 1840	33,623	52,879	{ To 15th May, 1840, £3 per cwt.; since, £3 per cwt. and 5 per cent.	104,117	7,412	96,705
Ditto, 1841	27,639	121,113		87,061	17,483	69,578
Ditto, 1842	21,528	68,318		67,812	9,866	57,946
		Cwts.				
Crown-glass, 1840	129,978	15,318	{ To 15th May, 1840, £3 13s. 6d. } per cwt.; since, £3 13s. 6d. per cwt. and 5 per cent.	492,962	73,530	417,497
Ditto, 1841	116,895	19,118		451,064	92,070	357,337
Ditto, 1842	97,495	12,369		376,205	60,891	313,323
German sheet-glass, 1840	16,859	8,219	{ To 15th May, 1840, £3 13s. 6d. } per cwt.; since, £3 13s. 6d. per cwt. and 5 per cent.	63,986	33,604	30,382
Ditto, 1841	20,855	8,781		80,473	36,876	43,597
Ditto, 1842	25,500	7,701		98,397	32,348	66,049
			{ To 15th May, 1840, £1 10s. per cwt.	13,915	2	13,913
Broad sheet-glass, .. 1840	9,051	1½	{ To 15th Aug. 1840, £1 10s. per cwt. and 5 per cent.; since, £3 13s. 6d. per cwt. and 5 per cent.			
Ditto, 1841						
Ditto, 1842						
Common bottle-glass, 1840	525,574	292,887	{ To 15th May, 1840, 7s. per cwt.; since, 7s. per cwt. and 5 per cent.	189,883	103,926	85,957
Ditto, 1841	501,177	310,937		184,174	114,109	70,065
Ditto, 1842	390,482	225,633		143,496	82,915	60,581
Total nett revenue collected during the three years ending with 1842,						£1,902,595
Annual average nett revenue of the three years ending with 1842,						£ 634,198

All kinds of glass may now be imported free of duty, except flint cut glass, flint colored glass, and fancy ornamental glass of every description, on which there remains a customs' duty of ten shillings the hundred-

weight. The residuary customs' duty of one shilling and sixpence a hundredweight on shades and cylinders, and any kind of window-glass, white, or stained of one color only, expired on the 5th April, 1857.

II. A return of the Rates of Duty on Glass in 1813, with the Quantities of each Kind of Glass retained for Home Use, and the aggregate Nett Revenue in each Year, from 1813 to 1842, both included, noting the Periods when any Alteration of the Duty took place, and the Amount of such Alterations.

Rate of duty in 1813, Per cwt.	Flint.	Plate.	Crown.	German sheet.	Broad.	Common bottle.	Total.	Period and amount of alteration of duty.	Aggregate nett revenue.
	98s.	98s.	73s. 6d.	73s. 6d.	30s.	8s. 2d.			
Years.	Quantities of glass retained for home use.								
	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.		£
1813	23,370	9,398	84,441	..	6,994	47,350	171,553		500,850
1814	24,227	6,778	84,251	..	8,628	140,252	264,136		530,791
1815	24,911	419	77,485	..	8,452	129,461	240,728		473,780
1816	20,011	..	56,151	..	6,140	160,221	242,523		353,188
1817	22,117	1,739	76,561	..	8,374	123,881	232,692		461,849
1818	26,978	6,391	88,893	..	8,319	201,795	332,376		584,399
1819	28,809	6,473	90,726	..	8,267	238,463	372,738	{ From 5th July, 1819, the duty on plate-glass reduced from £4 18s. to £3 per cwt.	606,176
1820	24,745	8,735	74,183	..	7,782	171,495	286,940		500,595
1821	21,927	9,718	86,384	..	8,085	137,117	263,181		521,075
1822	21,400	9,562	95,510	..	8,353	154,492	289,317		559,029
1823	21,829	11,607	101,392	..	9,172	198,456	342,456		607,378
1824	24,954	13,543	123,845	..	9,295	238,725	410,362		728,342
1825	34,184	15,082	140,298	..	8,347	251,932	449,843	{ From 5th July, 1825, the duty of £4 18s. on flint-glass repealed, and a new duty of £12 10s. for every one thousand pounds of fluxed materials for flint-glass imposed.	772,303
1826	47,090	12,527	115,731	..	8,113	282,512	465,973		720,920
1827	46,688	14,209	114,381	..	7,611	239,794	422,683		699,726
1828	54,255	17,096	121,158	..	6,970	254,787	454,266	{ From 5th July, 1828, the duty on common bottle-glass reduced in Great Britain from 8s. 2d. to 7s. per cwt., and the duty on every description of glass assimilated throughout the United Kingdom.	752,097
1829	50,869	13,925	92,252	..	6,864	218,901	382,811		609,406
1830	49,353	12,677	80,926	..	4,845	180,945	328,746		542,261
1831	49,608	14,373	88,688	..	5,915	150,520	299,104		531,718
1832	51,586	11,554	86,007	179	5,304	158,719	313,349	{ From 10th October, 1832, the duty on fluxed materials for flint-glass reduced from £12 10s. per one thousand pounds to 20s. for every one hundred pounds.	558,423
1833	54,818	13,893	105,134	..	6,306	164,000	344,151		645,781
1834	52,890	16,306	106,389	..	6,766	194,143	376,494		664,391
1835	43,936	16,941	111,651	4,248	5,847	201,613	384,236	{ From 10th October, 1835, the duty on fluxed materials for flint-glass reduced from 20s. to 6s. 8d. per one hundred pounds.	640,149
1836	86,866	19,993	117,041	..	7,629	249,145	480,674		663,162
1837	78,121	21,640	101,309	707	7,190	247,446	456,413		608,993
1838	81,594	23,992	113,756	2,262	6,575	243,046	471,225		667,998
1839	82,309	26,465	113,340	5,170	8,514	252,808	488,606		691,467
1840	82,486	31,200	111,316	7,914	9,049	232,834	473,799	{ From 15th May, 1840, the duty on every description of glass increased 5 per cent.; and from 15th August, 1840, the duty on broad glass increased from £1 10s. to £3 13s. 6d. per cwt.	724,343
1841	74,444	22,088	93,033	11,298	..	190,257	391,120		613,588
1842	68,098	18,396	81,715	17,117	..	161,537	346,863		563,437

The following tabular statement, exhibiting the amount of the imports of the different kinds of glass enumerated, for the three years ending 31st December,

1855, and the exports of glass, of *foreign and colonial manufacture*, during the same period, is extracted from the Trade and Navigation Returns:—

	IMPORTS.			EXPORTS.		
	1853.	1854.	1855.	1853.	1854.	1855.
Window-Glass, and Shades and Cylinders,....	Cwts. 27,577	31,639	25,420	5,485	3,012	1,126
Plate-Glass,	Lbs. 221,304	794,194	749,151	16,415	14,175	21,747
White Flint-glass Goods—except bottles—not cut, engraved, or otherwise ornamented,....	Lbs. 106,621	358,472	378,065	15,980	4,584	3,039
All Flint Cut Glass, Flint Colored Glass, and Fancy Ornamented Glass,	Cwts. 6,893	10,692	9,402	1,143	846	585

The above exports refer to glass of foreign and colonial manufacture. The great falling off in these exports during the years 1854 and 1855, is obviously attribut-

able to the war with Russia; but this effect scarcely appears in the following statement of the exports and declared value of glass of *British manufacture*:—

	Hundredweights exported.			Declared value.		
	1853.	1854.	1855.	1853.	1854.	1855.
Flint-Glass,	47,548	53,072	39,283	£162,849	180,896	141,831
Window-Glass,	39,158	34,522	21,473	58,503	57,761	33,821
Bottles,	457,787	481,262	513,128	248,458	274,832	279,620
Plate-Glass—value only,				48,730	35,755	52,283
				£518,540	£549,244	£507,555

It is worthy of remark, that in the year 1844, the year before the excise duties were repealed, and with all the advantage of a drawback, the total exports of glass, of British manufacture, were only of the declared value of twenty-six thousand six hundred and ninety-four pounds; whereas, it will be seen from the preceding table, that in 1855, or ten years after the repeal of the duties, they amounted in value to upwards of half a million sterling.

GLYCERIN.—The basic principle of the several substances contained in the fats of animals, as also of several compounds of vegetal origin, has been called *glycerin*. SCHEELÉ, its first discoverer, named it *the sweet principle of fat*; but since then, the several investigators who have worked upon the subject have modified this title to that above given, from the Greek word, signifying *sweet*. As already noticed—see vol. i., page 406—this body has not as yet been fully investigated, and considerable diversity of opinion exists regarding its origin and nature. It is generally acknowledged to be an oxide of a compound radical, which, upon the decomposition of the stearin, margarin, or olein of the fats, assimilates water, and acquires the composition which analysis has assigned to glycerin. Respecting the nature of this radical, much speculative reasoning has been indulged in. BERZELIUS designated it *lypyl*, and contended that the definite bodies in the natural fats were salts of the fatty acids, with the oxide of this radical. LÖWIG, on the contrary, with whom many concur, terms it *glycil*; all, however, seem to have attributed to it the composition $C_3 H_2$, and agree that, by the assimilation of oxygen and the elements of water, it becomes $C_6 H_8 O_6 = 2 (C_3 H_2) + O_2 + 4 HO$.

PREPARATION AND PROPERTIES.—Originally, glycerin was prepared by a rather troublesome process, and necessarily in small quantity. Olive oil, or any of the natural fats, was boiled with litharge—oxide of lead—and water, till saponification was effected; the fluid matter remaining was decanted, and submitted to the action of sulphide of hydrogen— HS —by which the portion of the metallic base held in solution was precipitated in the form of sulphide. After filtration, the liquid was exposed to careful evaporation under 212° , till all the water was removed, and a viscous fluid remained. This was the glycerin. Prepared so, it is a faintly yellowish fluid, with an agreeable sweet taste; it is soluble in water, which it attracts from the air, and likewise in alcohol, but not in ether. The alkalies, and several metallic oxides and salts, more especially those which are known to deliquesce in the air, are dissolved by it to such an extent that it ranks next to water in solvent power. With acids it invariably yields acid salts. It is a very stable compound, being persistent in air; it suffers partial decomposition when slowly distilled, and passes over unchanged when a temperature of from 500° to

600° is applied; but, when subjected to a heat beyond this, it is entirely transformed into another definite body, known as *acrolein*, acetic acid, and inflammable gases. Thrown upon live coals, or heated in contact with air, it burns with a blue flame; heated with phosphorus in a closed tube, it yields acrolein.

When largely diluted with water and mixed with yeast, after long standing at a temperature between 68° and 85° , it yields, according to REDTENBACHER, a small quantity of gas and metacetic or propionic acid— $C_6 H_8 O_3 = C_6 H_8 O_6$, minus three equivalents of water.

DOBEREINER found that, by the action of spongy platinum, it was converted into an acid. Concentrated nitric acid transforms it into water, carbonic, and oxalic acids; and, by operating upon it with hydrochloric acid and binoxide of manganese, formic acid is produced by cautiously treating it with dilute sulphuric acid. VOGEL states that it may be converted into glucose, which requires confirmation, for the tendency is for both to unite and form an acid salt. PELOUZE found this to be the case; for on mixing one part of concentrated sulphuric acid with half a part of glycerin, much heat was developed, and glycero-sulphuric acid resulted, the formula of which was ascertained to be $C_6 H_7 O_6 SO_3$, $HO SO_3$.

Glycerin is heavier than water, being at 59° of the density 1.28; its composition, deduced from the analyses of itself and its salts by PELOUZE, is:—

		Centesimally.
6 Eqs. of Carbon,.....	36	39.130
7 Eqs. of Hydrogen,.....	7	7.609
5 Eqs. of Oxygen,.....	40	43.478
1 Eq. of Water,.....	9	9.783

$$\text{Formula:—} C_6 H_7 O_6, HO = C_6 H_8 O_6.$$

Until the late investigations of BERTHOLLET it was believed that glycerin was incapable of forming neutral compounds with acids; but from these researches it is evident that such a supposition can no longer be entertained, since synthetically the above-named eminent chemist produced compounds in every respect identical with the natural fats both of animal and vegetal origin, by the union of the respective acids of such bodies with glycerin. He found that this base is capable of uniting with one, two, or three equivalents of the acids respectively, the triacid body being similar in all its properties to the natural fat of which such acid may be a component. The several compounds are prepared by heating the acid and glycerin together, during three or four days, in close vessels, at 212° ; or for as many hours, at a temperature varying from 360° to about 500° , employing an excess of one or other of the constituents, according as the mono-di- or tri-acid compound is to be produced. By treating the mixture of

fatty acid and glycerin with hydrochloric, sulphuric, phosphoric, or tartaric acid, in a close vessel, for some hours, at the boiling point of water, the same results are obtained. These several formations are attended with the separation of the elements of water, which, however, does not take place in proportion to the equivalent

of acid which combines with the glycerin, though the analogous compounds of each of the fatty acids correspond in this respect. This disposition of the bodies will be better understood by collating the symbols of the several fats and their constituents, as in the following :—

				Stearic acid.		Glycerin.	
Monostearin,.....	$C_{42} H_{82} O_8$	$=$	$C_{36} H_{72} O_4$	$+$	$C_6 H_8 O_6$	$-$	2 HO.
Bistearin,.....	$C_{78} H_{154} O_{12}$	$=$	$2 (C_{36} H_{72} O_4)$	$+$	$C_6 H_8 O_6$	$-$	2 HO.
Tri or Ter-stearin,.....	$C_{114} H_{224} O_{18}$	$=$	$3 (C_{36} H_{72} O_4)$	$+$	$C_6 H_8 O_6$	$-$	6 HO.
Monomargarin,.....	$C_{40} H_{80} O_8$	$=$	$C_{34} H_{68} O_4$	$+$	$C_6 H_8 O_6$	$-$	2 HO.
Bimargarin,.....							
Trimargarin,.....	$C_{108} H_{216} O_{18}$	$=$	$3 (C_{34} H_{68} O_4)$	$+$	$C_6 H_8 O_6$	$-$	6 HO.
Monolein,.....	$C_{42} H_{84} O_8$	$=$	$C_{36} H_{72} O_4$	$+$	$C_6 H_8 O_6$	$-$	2 HO.
Biolein,.....	$C_{78} H_{156} O_{12}$	$=$	$2 (C_{36} H_{72} O_4)$	$+$	$C_6 H_8 O_6$	$-$	2 HO.
Triolein,.....	$C_{114} H_{234} O_{18}$	$=$	$3 (C_{36} H_{72} O_4)$	$+$	$C_6 H_8 O_6$	$-$	6 HO.

Until within the last few years, glycerin was invested only with scientific interest, and its production was of rare occurrence; now, however, it has acquired considerable repute, and is manufactured in large quantities. In medicine it is calculated to render very great services as a vehicle for exhibiting the various remedies, besides being itself a specific for many ailments. Under certain circumstances, it acts as a valuable antiseptic, and a solvent in the cure of many kinds of urinary calculi. In perfumery and cosmetics its use is daily extending, being, on account of its emollient qualities and freedom from greasiness, an admirable ingredient for soaps, pomade, hair tonic, *et cetera*. Photographers likewise have latterly employed it with success. In these and several other appliances it is likely that in a short time its consumption will be much greater than at present, although it has already been manufactured extensively.

Several modified processes are pursued to obtain it, some of which may be briefly noticed. As already stated, it was procured as a secondary product in the manufacture of lead plaster. Equal parts of powdered litharge and olive oil were mixed with water, and the mixture boiled till a plumbiferous soap resulted from the combination of the oleic and other fatty acids and metallic oxide. During the ebullition, the contents of the vessel were kept stirred, and water supplied from time to time, to make up the loss by evaporation. When the yellow color of the litharge disappeared, and the mass looked white and homogeneous, the fire was removed, and the liquid portion decanted, and afterwards treated with sulphide of hydrogen, as long as any precipitation occurred. A succeeding filtration removed the metallic sulphide, and after this the liquid was evaporated at a water-bath heat, and finally in an exhausted receiver over sulphuric acid. When the evaporation is performed in contact with the air, the fluid acquires a brownish tinge. JAHN'S process is similar to the foregoing, only that the proportion of the substances is varied. Instead of equal quantities, he takes five parts of litharge and nine of olive oil, and proceeds with them as described, and boils the soap with water three successive times, decanting and mixing the three solutions together. The tinge is removed by filtration through animal charcoal, or by digesting the weak

liquor with a mixture of animal and freshly-prepared wood or peat charcoal, filtering and concentrating in the usual way. By this course, he obtained about seven ounces of glycerin from the above quantity of materials. Glycerin can be obtained from the mother liquor of the soap factories, by adding to it a slight excess of sulphuric acid, heating the solution with carbonate of baryta, filtering, and, after the filtrate has been concentrated by evaporation, extracting the glycerin with alcohol. On distilling off the spirit, the glycerin remains. It may likewise be readily prepared by dissolving castor oil in absolute alcohol, and passing hydrochloric acid gas through the fluid. The fatty ethers are washed away by water, and the residuary fluid affords the glycerin in a state of purity on evaporation. Any adhering fatty matter is separated by digesting the liquid in ether, and decanting the latter.

CAR'S process for the preparation of glycerin from the mother waters of the saponification of stearin with lime in the manufacture of stearic acid candles, is as follows :—The liquid drawn off from the lime-soap is reduced by evaporation in steam kettles over a naked fire; and, after ascertaining how much lime is present, by precipitating a certain bulk with oxalate of ammonia, collecting the precipitate, drying, burning, and weighing it, with the requisite precautions, the necessary quantity of sulphuric acid to combine with the lime is added, when sulphate of lime falls.

After its subsidence, the clear liquid is decanted into another receptacle, in which it is boiled out of contact with the air, and stirred at the same time by some mechanical arrangement. This ebullition expels all the volatile fatty impurities which may be present, and, consequently, the liquid loses both color and odor. As soon as the solution arrives at a density of 14° Twaddell, it is allowed to cool, when the precipitation of a further portion of sulphate of lime occurs. Should an excess of acid be present, as may be known by its action on tincture of litmus, some chalk or powdered limestone must be added fractionally till the liquid is neutral. After this the boiling is continued as before out of contact with air, during which time the contents of the vessel must be actively stirred, till the solution marks 37·5° Twaddell. The sulphate and carbonate of lime are now collected on a filter, and the filtrate reduced by evaporation, till, upon cooling, it marks 49°, care

being taken to keep it well agitated during the time. If any further quantity of sulphate of lime falls, a repetition of the filtration is necessary. To remove the tinge, the fluid is passed through washed animal charcoal or bone black, when a pure colorless solution of glycerin is obtained, marking 45° ; and, by carefully concentrating it further, a fourth of its weight of water may be removed, when the residuary sirupy fluid indicates 51.2° Twaddell. According to WILSON, the product thus obtained, though superior to that manufactured by the old process, is not absolutely pure, no matter how much care is taken in conducting the operations.

A much more economical method is that introduced by TILGHMANN in 1854. By this process the fatty bodies are broken up into acid and basic substances, through the agency of heat, pressure, and steam, as described at page 433, vol. i., and form separate layers in the recipient, into which the products flow from the condenser. The glycerin, which is the heavier of the two, forms the lower stratum, and the fatty acids the upper; the latter can be readily separated mechanically, and the former left devoid of any other impurity excepting water. By careful concentration, the aqueous matter may be expelled, and the product obtained of a specific gravity of 1.24, and containing only four per cent. of moisture; but, by prolonging the operation, two per cent. more of water may be removed, and the pure glycerin is left of a density = 1.260. WILSON, by injecting superheated steam into a hot solution of fat, succeeded in effecting the decomposition of the latter, and at the same time the fatty acid and glycerin are carried over into the receiver, where they form two layers, as in the preceding instance, and capable of being readily separated.

ANALYSIS.—The analysis of glycerin demands all the expertness of the practical chemist. It may be accomplished by submitting it, or some one of its more definite and permanent salts, to combustion with oxide of copper or chromate of lead. If a salt of this base with baryta or lime be the subject, it may be mixed with the powdered oxidizing agent, introduced into the combustion tube, and burned in the usual way; but when glycerin *per se* is to be analysed, it must be inserted into small glass bulbs, the apertures of which are drawn out to a fine point, and two or three of the latter introduced into the combustion tube, placing three or four inches of the oxidizing agent between them. From five to ten grains will be sufficient for the analysis. Attention should be paid to inserting the bulbs, so that the aperture of each may open towards the sealed end of the tube, in order that the fluid may have to traverse through a longer portion, and come in contact with more of the oxidizing agent than if the bulb part was dropped in first. By this means, a more thorough oxidation of the elements is insured. The water and carbonic acid produced during the burning are severally arrested by chloride of calcium and hydrate of potassa in the usual way, and their quantity determined. When operating upon liquid substances generally, the combustion tube should be longer than when required for solid bodies, to present a greater oxidizing surface to the vapor as it passes off.

Glycerin cannot be readily detected in animal fluids, unless it be present in such quantity as will permit its being extracted and subjected to an elementary analysis; but as it is exceedingly difficult, or nearly impossible, to isolate it pure when associated with other animal matters, this method can rarely be successful. A characteristic test remains, however, whereby the presence of glycerin may be ascertained, in the peculiar bodies to which it resolves itself on being decomposed by heat. The most remarkable of these is acrolein—a substance possessing such an intense and marked odor as to render it unmistakeable. When, therefore, the substance suspected as glycerin, after being deprived as far as possible of all impurities, is rapidly heated either *per se* or with a little anhydrous phosphoric acid, an acrid pungent odor, somewhat analogous to that of the wick of an extinguished candle, is evolved, and this is sufficient proof of the presence of glycerin.

GOLD.—*Or*, French; *Gold*, German; *Aurum*, Latin.—This most precious of the metals, so highly esteemed on account of its rarity, beauty, high specific gravity, non-liability to tarnish or oxidize, and consequent admirable adaptation, both as a medium of exchange, and for articles of ornament, has been known and prized from the most remote antiquity. In its pure state, it is of a rich yellow color, high metallic lustre, but nearly as soft as lead, so that it cannot be used in a state of absolute purity either for jewellery or coinage. It is the most malleable of metals, and with the single exception of platinum, it is the heaviest body in nature, being nearly twenty times the weight of its bulk in water. Gold is almost always found in the metallic state, and in this form is largely diffused over the earth; but in many localities it occurs in such minute and widely-scattered fragments, that it will not pay for working expenses. It is found in many forms—in masses, lumps, fragments or nuggets, dendritical threads, scales, dust, and infinitesimally mixed with the auriferous quartz; but almost always mechanically mixed, and not chemically, as with other metallic ores. Hence, the operations for extracting it from its deposits differ from those required by almost every other metal, in being for the most part purely mechanical. They chiefly consist in pulverization and washing—the high specific gravity of the metal greatly facilitating the latter process. But thoroughly to extract the gold, amalgamation is often resorted to—a quantity of mercury being mixed with the ore, which forms an amalgam with the gold, and is afterwards expelled by distillation. If copper and silver be present, which is generally the case, the former is removed by cupellation, and the latter by a process termed *parting*. These operations will be fully described under their proper heads. They have merely been referred to at present to explain the incidental allusions to the metallurgical department of the subject, which cannot be entirely avoided in detailing the history of the metal, and of modern gold discoveries.

HISTORICAL NOTICE.—From the circumstance that gold occurs in the metallic state, often mixed with the superficial soil and sands of rivers, it was probably the first of the metals known to man. Accordingly, one learns from the sacred record, that gold existed in that

part of the earth's surface which was first prepared as the dwelling of the human race. MOSES states, that the land of Havilah, encompassed by one of the four rivers which watered the garden of Eden, not only possessed gold, but gold of a superior quality; and JOB, who is supposed to have written about 1800 years before the Christian era, alludes to the earth having *dust of gold*. With reference to the remark of MOSES, that the gold of the land of Havilah was good, Mr. NAPIER of Glasgow, in a recent publication on the Ancient Workers and Artificers of Metals, justly regards it as warranting two inferences; first, that gold had been found in other localities than the one referred to; and, second, that different qualities of gold were known in the time of MOSES. But as this, like the other metals, is an elementary substance, and not a compound, it follows that all gold, when pure, must be of the same quality. Hence the further inference, that the workers in metal in the time of MOSES, with all the acknowledged skill of the ancients in metallurgy, were not acquainted with the method of reducing gold to a state of absolute purity. That they were acquainted with the refining of the precious metals to a certain extent, plainly appears from different passages in the Old Testament, in which familiar allusion is made to this operation; and made, too, in terms which seem to imply that the methods then adopted were in many respects similar to those now employed. Silver and gold are purified or separated from foreign ingredients by much the same processes; a knowledge of the one implies a knowledge of the other; and JOB says, surely there is a mine for silver, and a place for gold, which men refine; while DAVID compares the words of the LORD to silver tried in a *furnace of earth*, purified many times. MALACHI is still more particular when, in comparing the Judge of all the earth to a refiner's fire, he says: *he shall sit as a refiner and purifier of silver, and he shall purify the sons of Levi, and cleanse them as gold and silver*. Here there is an evident allusion to the last operation required in the refining of silver—that of cupellation—during which the refiner must place himself at the furnace, and watch till the metal emits a bright flash, which indicates that the process is finished. Gold, as will be afterwards explained, is submitted to the same operation; but it requires a further treatment to free it from the silver with which it is invariably mixed to a greater or less extent; and this operation, known as *parting*, is the only process, essential to the perfect purification of gold, which does not seem to have been known to the ancients. There is, at least, no evidence that they were acquainted with this process; but rather the contrary, from the words of MOSES, which indicate that gold from a variety of sources was then believed to possess essentially different qualities; although, it is true, that the sacred historian may refer to the different states of purity in which the metal was found.

The small per centage of silver which is frequently found in gold in the native state, detracts but little from its beauty or value; and as the ancients appear to have been well acquainted with the methods of separating it from other ingredients, there is little doubt that a large proportion of their gold approached to a state of purity. On the other hand, it is frequently

found combined, or mechanically mixed, with a very considerable amount of silver; and hence it may be presumed, that much of the gold in circulation among the ancients, was merely an alloy of these two metals in those proportions in which they are found in nature. This view of the subject is not only rendered probable by the frequent allusions to *fine gold*, and to gold of different qualities obtained from certain specified sources, such as the gold of Ophir, gold of Parvaim, gold from the north, *et cetera*; but it is confirmed by the fact, that the ancients had a special name for the alloy produced by the mixture. This alloy they termed *electrum*, which PLINY states to have been made artificially by mixing four parts of gold and one of silver. Now, it is worthy of notice, that this is about the mean proportion in which the admixture is found native in many auriferous localities; and hence it may be presumed, that the alloy termed *electrum*, for which the moderns have no distinguishing name, was formed by the ancients artificially to imitate a large proportion of the gold which was then in circulation, separated from all its native impurities, except the silver. BECKMANN, who states positively that the ancients were not acquainted with the art of separating gold and silver, affirms that they used the *electrum* as a peculiar metal; and NAPIER is at the pains to argue, that since they made it artificially, it could not have been considered by them a distinct metal. But BECKMANN evidently means that they regarded the mixture in the same light as brass, bronze, German silver, and other useful alloys are viewed in the present day.

On the whole, there is strong ground for believing that the ancients were unacquainted with the method of *parting* these noble metals—the difficulty arising from the fact, that both of them refuse to be oxidized in the furnace; and yet, there is a shade of doubt on the subject, which renders it peculiarly interesting to the archæologist. Nitric acid is said to have been unknown until it was discovered by the alchemists in the thirteenth century; and yet, Mr. HERAPATH, of Bristol, has lately discovered that the markings on a piece of mummy cloth were made with a solution of silver, which he concludes to have been the nitrate, or common marking ink. Indeed, there is some ground for believing that the ancient Egyptians were acquainted with both nitric and sulphuric acids, with either of which the operation of *parting* is performed; and in that case, they could not be ignorant of the fact that nitric acid dissolves silver, and that it is without effect upon gold. On the other hand, it is difficult to suppose, that if these things were known to the Egyptians, they should not have been known to other nations, and more especially to the Hebrews.

But whatever doubt may rest on this point, it is certain that the ancients, in later times at least, were acquainted with the method of extracting gold and silver from the ores or earths by *amalgamation*, for this process is mentioned both by VITRUVIUS and PLINY, writers who lived about the beginning of the Christian era; and, indeed, it is described by PLINY in terms which show that it was practised nearly in the same manner as at the present day. The mercury employed in this operation, merely combines with the

metals in the earths with which it is mixed, and these must afterwards be separated by other processes.

Both gold and silver, more or less pure, were used by the ancients for articles of ornament and utility, as well as for money. Many of the vessels, and much of the sacred furniture of SOLOMON'S magnificent temple, were made of gold. It is stated also, that in forming the tabernacle in the wilderness, gold was beat into thin plates, and cut into wires or threads to work it in the fine linen, from which it appears that the Israelites had learned from their masters, the Egyptians, the art of gold-beating—an art in which, WILKINS states, in his *Ancient Egypt*, the latter were well skilled.

Gold was also in great demand among the heathens, for the statues of their gods or idols; and some of these are mentioned by HERODOTUS and other historians as of immense magnitude. In connection with this subject, the golden calf which was made by AARON in the wilderness, has furnished a curious subject of controversy to modern commentators. With reference to this object of idolatrous worship, it is recorded that MOSES took the calf, and burned it with fire, and ground it to powder, and strewed it upon the water, and made the children of Israel drink of it. In another passage it is stated, that he stamped it, and ground it very small, even until it was as small as dust. Now, the difficulty connected with this passage, which has so much perplexed well-meaning commentators, is the fact, that gold, however strongly heated, is incapable of being reduced to powder by mere stamping or grinding. It is, as already stated, the most malleable of the metals, and is only *flattened* by stamping. Hence it has been affirmed by Dr. KITTO, on the authority of GOGUET, and reiterated by other commentators as a great discovery, that MOSES was acquainted with the wonderful powers of *natron* as a solvent of gold, and that the golden calf was either burned with *natron*, or was heated in the fire to accelerate the action of that solvent. Unfortunately, however, it so happens that *natron* or carbonate of soda has no such action upon gold as that which is ignorantly attributed to it by these writers; moreover, there is no mention of any solvent being used, or of any intention on the part of MOSES to communicate to the water with which the gold was mixed a nauseous taste, though this appears to be the principal object of the commentators. In fact, as NAPIER justly remarks, the whole chemical or metallurgical difficulty, if any such exists, may be got over, by merely assuming that MOSES fused the gold in the fire to cast it into ingots, which were afterwards beat out into thin plates or leaves, and then would readily admit of being reduced to powder—a process which is practised at the present day to procure an impalpable gold dust employed for various purposes.

Although it can scarcely be supposed that the total amount of gold in circulation in ancient times was so great as at present, yet, from the practice of hoarding the precious metals which then prevailed, and from the limited commercial intercourse which then existed, it seems to have accumulated in some countries, and in particular circumstances, to an incredible extent. Conquerors were accustomed to carry off all the gold they could collect or extort from the subdued nations;

and thus, after a series of successes, the coffers of the victorious monarch and his subjects became replenished with treasure. Hence the vast amount of the precious metals which poured into Rome from the provinces, when she ruled the world. Hence also the enormous accumulation of gold and silver which King DAVID is recorded to have collected during his lifetime for building the temple—an amount which has been estimated at not less than nine hundred million pounds sterling, being more than all that has been raised in all the mines in the known world during the last fifty years. It is scarcely possible to avoid the suspicion that some error has crept into the calculations by which this astounding result is arrived at; but still it is quite certain that immense quantities both of gold and silver were often accumulated in ancient times; and to this day no inconsiderable mystery hangs over the sources from which these treasures were derived. Any little knowledge that is possessed on this subject will be mentioned in enumerating the auriferous or gold-producing localities known at the present day.

It is probable that with the decline of the Roman Empire, the art of extracting and refining the precious metals, like other arts, became to a great extent lost in the darkness of mediæval barbarism. It was then, however, that a new art began to appear, which aimed at a still higher object, and which, however chimerical in its pursuits, struck out many important incidental discoveries, and contributed largely to prepare the way for the triumphs of modern chemistry. Any account of the history of gold would be incomplete which did not make some allusion to Alchemy—the chemistry of the middle ages—by which was elaborated, not gold indeed, but much of the apparatus and many of the principles of a science which is infinitely more important to the human race than gold itself. The object of alchemy was not the refining of the precious metals, but their multiplication, by the transmutation of the baser metals into gold and silver. This pursuit, which may be termed sordid, when viewed in the light of the motives by which it was animated, continued through long centuries of darkness to lead the philosophical world on an *ignis fatuus* chase, terminating in disappointment and misery. HERMES TRISMEGISTUS, who is said to have lived in the year of the world 2076, has generally been quoted as the oldest of the alchemists; but there can be little doubt that the writings attributed to him are entirely spurious. The next great name in the history of alchemy was GEBER the Arabian, who is supposed to have lived not later than the seventh century of the Christian era. A work on alchemy, in three books, bearing the name of this philosopher, was published at Strasburg in 1520, and shows a considerable knowledge of the chemical properties of gold. This metal was termed by the alchemists *Sol*, the sun—and silver, *Luna*, the moon. Medical preparations of gold were termed *solar*, and those of silver, *lunar* medicines. One of the chapters of the work attributed to GEBER is devoted to *The Alchemie of Sol*; and after descanting upon different means of refining and dissolving gold, the author describes several solar medicines, which are all solutions of gold in nitro-hydrochloric acid, with the addition of quicksilver or

mercury, common salt or chloride of sodium, and some other saline matters. If the work be genuine, therefore—a point, however, on which considerable doubt rests—nitro-hydrochloric acid was known as *the* solvent of gold in the seventh century. It was certainly known as such not later than the fifteenth, and was termed by the alchemists *aqua regia*, or the royal solvent, from the circumstance that gold was regarded by them as the king of metals. They esteemed it, indeed, the only pure metal, and believed that all the others were merely adulterations or diseased forms of the same substance, which might be purified or revived by proper processes. Mercury and *aqua regia* were the principal agents which they employed. Not a few of them pretended to have discovered the secret; and some were even so disinterested as to publish the process, but in language understood only by the adepts, and which, it may be safely presumed, was rarely intelligible to themselves. In all cases, the student was directed to prepare his mind by suitable acts of piety and charity; and much religious and cabalistic jargon was mixed with their pretended recipes. From the fact that, in the present state of chemical science, the other metals, as well as gold, are believed to be elementary substances, the Editor deems it unnecessary to say that the doctrine of transmutation was founded on ignorance; but at a time when the elementary nature of the metals was unknown, the belief in their possible transmutation was natural; hence it was cherished by not a few persons of acknowledged eminence. The celebrated ROGER BACON, who flourished in the thirteenth century, was a believer in alchemy, and published a work on the subject. VAN HELMONT acknowledges his belief in the making of gold and silver, though he does not degrade himself, like too many of his contemporaries, by professing to have discovered the secret. BERGMAN, in summing up the evidence for and against the possibility and probability of transmutation, arrives at the conclusion that, unless all historical evidence be rejected, some of the accounts given are entitled to confidence. Even the great Lord BACON has been arraigned as a believer in alchemy, though he rather urges the possibility than the probability of transmutation—a view of the subject so far from meriting ridicule that, in the state of chemical science in his day, it would have been unphilosophical to hold a different opinion. That BOYLE was a sceptic on the subject is well known; but it is less generally known, and in fact it has only lately come to light, that in the ranks of the alchemists must now be enrolled the illustrious name of Sir ISAAC NEWTON. This startling fact is a recent discovery, published for the first time in the last edition of Sir DAVID BREWSTER'S life of that philosopher. It is now known that he was absorbed in this pursuit for years; and that the intense eagerness with which he prosecuted this object accounts, to a great extent, for the apparent indifference which he showed in so long delaying to publish some of his greatest discoveries. Associated with such an array of great names, and more especially with the last, the alchemists are not to be contemned or derided as mere dreamers and visionaries; the pursuit of the object which they had in view was as

natural as their belief in the possibility of its attainment was warranted by the knowledge of the composition of matter then existing; but that which excites a just indignation, which constitutes a fair subject for ridicule, and stamps with infamy many of the professors of the art, is the mixture of fraud, pretension, and hypocrisy, which appears in their writings. It is these unworthy professors that have brought contempt on a pursuit that was prosecuted by many good and great men; and which, however fruitless as regards the immediate object in view, elicited many important facts of which science at the present day reaps the full benefit. The history of alchemy—so replete with empiricism and pretension—teaches also the gratifying fact, that not only has the philosophical world advanced in knowledge, but in candor, in honesty, and in moral dignity.

The further history of gold, which has assumed a profound interest in modern times, and demands therefore a larger space than is usually devoted to historical notices in this work, will be given in connection with the sources or localities from which it is chiefly derived.

SOURCES.—With the single exception of iron, gold is more generally distributed than any other metal; but for the most part it occurs in such minute quantities, as either to escape notice, or, as already remarked, not to repay the cost of extraction. On the other hand, many localities in different quarters of the globe, and especially, of late years, portions of California and Australia, have proved splendid exceptions. The principal matrix of gold is quartz rock, and this rock is commonly a vein of greater or less thickness, intersecting beds of granite. The chief sources, however, from which gold is obtained, are the various alluvial deposits, consisting of sand and gravel, produced by the disintegration of silicious, granitic, and other igneous and metamorphic rocks, and which have been transported by the agency of water from the mountainous districts. In these beds it is invariably found in the metallic state, but is never quite pure; it usually contains a certain proportion of silver, and not unfrequently iron, copper, and small quantities of several other metals.

It is difficult, if not impossible, to ascertain the precise localities from which were procured the very considerable quantities of gold that indisputably existed in the earlier ages of the world. There is no doubt that many regions, now exhausted, would formerly yield large supplies of this precious metal. The name of the place which figures most prominently in the Old Testament writings, and which has reappeared as the designation of certain auriferous localities, in modern times, is the land of Ophir. This name occurs in the ancient book of JOB, and is frequently alluded to afterwards in the Jewish history. It seems to have been the great source of gold in those days—the California or Australia of the ancient world; but in what country, or even in what quarter of the globe it was situated, is a problem not yet solved. It is certain that the Hebrews traded with it from the time of DAVID to that of JEHO-SAPHAT, and some have placed it in an island in the Red Sea; but this is inconsistent with the recorded fact, that SOLOMON'S fleet took up three years in their voyage to Ophir, and brought home not only gold, but

apes, peacocks, spices, ivory, ebony, and almug-trees. Accordingly, others have removed it to Zanguebar, on the South-east coast of Africa; others have placed it about Guinea; some at Carthage; some have removed it to the East Indies; and others, still more fancifully, to Peru, or some other place in America. The only conclusion which may be safely drawn from this immense variety of conflicting conjectures is, that the question remains involved in uncertainty, although the most general and best supported opinion is that which identifies the ancient Ophir with the region of the modern Zanguebar.

HERODOTUS states that the people living near the source of the Indus, obtained a large quantity of gold from the eastern border of the great Bactriana, and the desert steppes of Cobi; and he also refers to productive mines in the North, the remains of which, on the South-eastern borders of the Ural mountains, are described by PALLAS in his Travels, and were likewise visited by LEPECHIN and GMELIN. These ruined mines, which have all the marks of a very remote antiquity, are supposed to have been the work of a nomadic people, in all probability the Scythians. It is evident that much gold was produced in ancient times from the mines of Nubia and Ethiopia, which, like those of the Uralian chain, produced a copper-yielding gold. BELZONI discovered that a very extensive tract had been worked in the Sahara mountains, and from these sources the PHARAOKS are supposed to have derived their wealth. Mr. JACOB, from a very close examination of the subject, is led to infer that not less than six million pounds sterling of the precious metal must have been produced annually from these mines.

There were rich silver mines in Attica; gold mines in Thrace, and in the island of Thasus. Thessaly produced ores which were rich in gold; and Epirus, rich silver mines. From these sources the Athenians drew their wealth.

The Romans obtained their treasures from various sources, besides the conquered provinces—from Upper Italy, the province of Aosta, the Noric Alps, Illyria. From this district, at one period, gold was abundantly obtained—partly in large grains on the surface, and partly in mines, so pure that an eighth part only was lost in the processes of smelting and refining. Its great quantity caused a decrease of one-third in the price through all Italy, and induced the proprietors to employ fewer workmen in order to raise the value. The Tarbelli, a people at the foot of the Pyrenees, also streamed extensively for gold.

It is stated on the authority of tradition, that when the Phœnicians visited Spain, they found silver in such abundance, that they not only loaded their ships to the water's edge, but made their common utensils, and even anchors, of this metal—a statement which harmonizes with the representations given by the Spanish discoverers of Peru. But whether this account be exaggerated or not, it is certain that the Phœnicians lost no time in taking possession of the country, and forming colonies in the present Andalusia. Now, it is known that Spain anciently possessed mines of gold in regular veins, especially in the province of Asturias. The Tagus and some other streams of that country were

said to roll over golden sands; and there is little doubt, that when colonized by an active commercial people like the Phœnicians, its mineral wealth would be developed, and would contribute largely to the supply of the precious metals in the ancient world.

It is affirmed, that the Romans extracted gold from the quartz lodes in Transylvania, and also at the Ofogan in Caermarthenshire in this island, during their occupation under Trajan. It is probable, however, that but little would be obtained from these sources; and not much further is known of the ancient gold workings.

The principal workings known at the present day are those of Australia, in the Southern hemisphere; of California, Mexico, and the Appalachian mountains, in North America; Brazil, Peru, and Chili, in South America; Kordofan and Sofala in Africa; the Ural mountains in Siberia; and Hungary in Europe. Gold is found, however, in smaller quantities in various other places; and the Editor will now briefly indicate the various localities in which it is known to exist, beginning with Europe, and concluding with the latest discoveries in Australia.

Europe.—There are probably few countries without traditions of gold, and these have not been wanting in the British Islands, which have furnished from time to time small quantities, although seldom in sufficient amount to be equivalent to the cost of procuring it. Specimens are occasionally found in Wales, in the Cornish stream-works, and in different parts of Devonshire; where mining operations were recently undertaken, but not with remunerative success. In Scotland, it occurs at Leadhills and Cumberhead in Lanarkshire, and Glen Turret in Perthshire, but only in very small quantities; although in the time of Queen Elizabeth, extensive washings for gold were carried on in the alluvial soil of Leadhills. In the county of Wicklow, in Ireland, a considerable quantity of native gold was discovered towards the close of the last century, disseminated in a quartzose and ferruginous sand. This gold was chiefly found in *pepitas* or solid pieces, one of which weighed twenty-two ounces; and so promising was the supply, that the peasantry in the neighborhood of Ballinacorney river actually gathered in the course of two months an amount of gold, for which ten thousand pounds sterling were paid. The extraction was then undertaken by Government; but the supply was soon exhausted, for during the two years that the mines were in operation, only nine hundred and forty-five ounces were obtained, which did not pay the necessary expenses, and the works were abandoned.

In France, the Rhone, and other rivers, present auriferous sands, but there are no workable mines in that country. It is probable that the deposits have been exhausted, like those of Spain, which were anciently rich and valuable, but are now neglected. So with the sands of the Danube, and many other European rivers, which still possess gold in small quantities, but rarely worth the expense of washing. In the valley of the Rhine, between Basle and Mannheim, for example, gold occurs in flakes mixed with titaniferous iron; but so minute are the spangles, that it takes from eleven hundred to fourteen hundred of them to weigh a grain, troy. There are also auriferous sands

in some rivers in Switzerland, such as the Reuss and the Aar.

In Sweden, there is a mine at Edefors in Smoland, where the gold occurs native, and also in auriferous pyrites. In Germany, no mine of gold has been worked, except in the territory of Salzburg, amid the chain of mountains which separates the Tyrol and Carinthia. In Piedmont, there are veins of auriferous pyrites in the gneiss rocks at the foot of Monte Rosa; and these, although they do not contain ten or eleven grains in a hundredweight of the ore, are stated to have long defrayed the expense of working them.

But the only gold mines of any importance in Europe, are those of Hungary and Transylvania; and these are not less remarkable for their position, than for the peculiar metals with which the gold is associated. The principal mines are those of Hungary, in which the operations are carried on in four distinct localities; first, at Königsberg, where the native gold is disseminated in ores of sulphide of silver, which occur in veins and small masses in a decomposing felspar rock, constituting a portion of the trachytic formation; second, at Borsan, Schemnitz; and third, at Felsobanya, in both of which the ores likewise consist of auriferous sulphide of silver; occurring, however, in veins of sienite and greenstone porphyry; fourth, and lastly, at Telkebanya, to the south of Kaschaie, where the gold is extracted from a deposit of auriferous pyrites, amid trap-rocks of the most recent formation. The Hungarian gold mines do not appear to have been worked before the eighth century. In Transylvania, the gold occurs at different places in veins of carious quartz, feriferous limestone, heavy spar, fluor spar, and sulphide of silver. These veins are often of great magnitude, averaging from six to ten, and sometimes extending to forty yards in thickness. In the mine of Kapnik, the gold is associated with orpiment in granite, and in those of Offenbanya, Nagy-Ag, and Zalatna with tellurium, in a sienitic rock. The annual produce of Hungary is stated at two thousand eight hundred and ten pounds' weight, and valued at one hundred and seventy-six thousand pounds sterling.

It may be added, that the mines of Reichenstein, in Silesia, which had been abandoned for more than five centuries, have been recently opened with advantage, in consequence of the application, on a large scale, of a method invented by Professor PLATTNER, for separating gold from the waste of arsenical pyrites, which will be described afterwards.

Asia.—The gold mines of Russia, which are the most considerable in the old world, must come under the head of Asia, as they are situated partly on the eastern flank of the Ural mountains, and partly in the districts of Tomsk and Yeniseik in central Siberia. The Ural mines, including those of Berezovsk, near Ekaterinburg, extend through five or six degrees of latitude. Here there are deposits of partially decomposed auriferous pyrites disseminated in veins of quartz; and from these veins the valuable material is extracted by vertical shafts and lateral galleries. Generally, however, the gold is found associated with other metals, as platinum and palladium, in fragments or debris of

auriferous rocks, mixed or disseminated at some yards' depth in an argillaceous loam.

In the days of Pallas, the gold alluvia of Russia were supposed to exist only near Ekaterinburg; but, in the reigns of Paul and Alexander, they were found to extend through several degrees to the North and South of that locality. It was only in the reign of NICHOLAS that portions of the great eastern regions of Siberia were found to be highly auriferous. In these districts the ground rises into low ridges, similarly constructed to those of the Ural, and like them trending from north to south. They are offsets from the great east and west chain of the Altai, which separates Siberia from China. The amount of gold which is now extracted from these remote deposits far exceeds that obtained from the Ural, although, in the latter, sands of superior richness were discovered in 1842. This discovery was made by the removal of certain old buildings in which the washing operations had been carried on. Under the corner of one of the buildings, at the depth of three yards, a mass of gold was dug up weighing about eighty pounds English. This mass was placed in the collection of the Corps des Mines at St. Petersburg. The discovery of the rich sands was made at the same time; but in the Ural districts, the gold is not usually found in large lumps. It is commonly obtained in very small fragments, which are separated by washing; and the yield seldom exceeds thirty-six grains of gold per ton-weight of soil. In the Altai auriferous district, which is represented to be as large as France, not only is the gold found mixed with sand and gravel on the surface, but considerable quantities are extracted by pulverizing the rocks. It is a remarkable fact that, not many years ago, the gold obtained from this distant region did not amount to a third part of that which the Ural district produced, whereas, in 1843, the Eastern tract yielded considerably upwards of two millions and a quarter sterling, and the Ural little more than half a million, raising the total produce of the Russian empire to near three millions sterling. It now amounts to about four millions. In the century previous to 1841, the mines of Berezovsk yielded about twenty-four thousand five hundred pounds avoirdupois of the precious metals.

Little or no gold comes into Europe from other parts of Asia, because, as Dr. Ure justly remarks, its servile inhabitants place their fortune in treasure, and love to hoard up that precious metal. It is evident, however, from the quantities existing in the East, that it must be extracted in considerable amount from various sources. It is found in the rivers of Syria and other parts of Asia Minor. The Pactolus, a small river of Lydia, is said to have rolled over golden sands, which were supposed to have constituted the origin of the proverbial wealth of Croesus. Numerous gold mines are known to exist on the Cailas mountains in the Oundes, a province of Little Thibet, where the gold is found in quartz veins, which traverse a very crumbling reddish granite. It is met with also in the peninsula of Hindostan, and in the islands of the Eastern Archipelago; and it cannot be doubted that considerable quantities are found in Japan and China.

Africa.—It is now the general opinion that the land of Ophir, so frequently mentioned in the Old Testa-

ment, was in Africa, which still presents in one part a territory known as the Gold Coast, implying by its very name the existence of the precious metal in this quarter of the globe. The territory so called, from which large quantities of this metal were formerly exported, lies on the west coast; but the land of Ophir is supposed to have been on the East coast, opposite Madagascar, where a certain amount of gold is still collected. But the principal supplies of this metal are now found at Kordofan, between Darfur and Abyssinia, known to the ancients as Ethiopia, and the western region extending south from the river Senegal to the Cape of Palms, near the Gold Coast. In these districts the gold occurs in spangles, chiefly near the surface of the earth, in the beds of rivers and rivulets, and always in a ferruginous earth. The gold which is brought from Africa is always in dust, showing that the metal is obtained by washing the alluvial soils. Although this division of the globe is supposed to have been the source of the greater portion of the gold possessed by the ancients, yet the whole supply now obtained from that continent is not estimated at more than five thousand pounds annually.

South America.—Brazil furnishes the greatest part of the gold which is brought into the market from South America, and was once the principal gold region of the new world; but its mines and auriferous sands seem to be nearly exhausted. The greatest quantity of gold was obtained from Brazil between the years 1753 and 1763, and since that time it has always been on the decrease. It was in the valley of the Mandi, a branch of the Rio Dolce, at Catapreta, that the auriferous ferruginous sands were first discovered in 1682; but they have since been found widely extended at the foot of the great mountain chain which runs parallel with the coast from the fifth to the thirtieth degree of south latitude. The precious metal is found in nearly all the rivers which form the upper branches of the Francisco, Araguay, Tocantius, and Guaporè; but the largest proportion is found in the affluents of the Francisco. The rock in these localities consists of primitive granite, inclining to gneiss; and the soil, which is of a red, ferruginous character, often extends to a considerable depth. It is from this soil that the gold is extracted by washing. Indeed the veins containing the metal are seldom worked. The most numerous washings are established near Villa Rica, in the environs of Cocães, where the gold occurs either mingled with the sands of the river, or in the alluvial valley deposits. The pepitas occur in various forms, often adhering to micaceous specular iron. In the province of Minas Gerães, the gold is extracted both by the excavation of veins and by the washing of alluvial deposits.

This metal is likewise found in many other parts of South America, on both sides of the great chain of mountains which runs parallel with the Western coast. Peru is richer in silver than in gold ores, but in some parts gold is mined in veins of greasy quartz, variegated with red ferruginous spots, which traverse primitive rocks. All the gold furnished by Columbia, comprehending New Grenada and Venezuela, is the product of washings established in alluvial grounds. But Brazil is the principal gold region of the South American continent.

North America.—More gold is now produced in the vast continent of North America than in any other part of the world. In this respect it has now taken the place which formerly belonged to South America, while the latter has sunk into comparative unproductiveness, less perhaps from the absolute exhaustion of the auriferous soils, than from the want of the capital and enterprise to work them successfully. North America was a gold-producing continent long before the discovery of the Californian treasures; but for many years, the only source of this precious metal in that quarter of the globe was the argentiferous veins of Mexico, from which it was extracted along with the silver, as in the Peru mines of South America. At a later period, however, an extensive gold region was discovered in the United States, extending along the Eastern slope of the Appalachian mountains, from the river Rappahannock in Virginia Southwards to the river Coosa, an affluent to the Alabama, which flows into the Gulf of Mexico. The metal is found in less quantity Northward along the same mountainous range to the State of Maine, and even extending into Canada, where a search for profitable workings has lately been prosecuted with some vigor. The existence of spangles and pepitas of gold, in several rivers of the East of Canada, has been fully established; and at the Great Exhibition honorable mention was made of the Chaudière Mining Company, who exhibited pepitas of native gold, collected in the washing of those streams. But the States of Virginia, North and South Carolina, and Georgia, afford the most productive deposits. In these, as in those of Brazil and Columbia, the auriferous ores are chiefly pyritical; much of the gold is extracted by amalgamation, after stamping under water.

But all preceding gold discoveries in America, or in any other part of the world, were eclipsed by those that have been made within the last few years in California and Australia. These recent discoveries have produced quite a revolution in the annual production of gold, the effects of which, though already powerfully felt in the new impulse given to emigration and commerce, are only beginning to be developed, and must produce the most important results in the future history of the world. This may be inferred from the fact, that the gatherings of the precious metal, reckoning the average produce of all parts of the new and old world for a series of years previous to 1847, did not amount to the annual value of five millions sterling, whereas the amount now exceeds thirty millions per annum.

The first of these recent discoveries was made in 1847, when California, a hitherto-neglected and little-known region, lying at the most remote South-western limit of North America, rose into sudden importance, as the El Dorado of the new world. The gold region, properly so called, occupies the Northern part of California, commencing near the mouth of the Sacramento river, in lat. 39° north, and long. 122½° west, to the north-east of the bay and town of San Francisco, from which it extends south and north. At this point two rivers unite and discharge themselves into the sea—the Sacramento flowing from the North, along a valley formed by mountain ranges, and the San Joaquin, flowing from

the South, along a similar valley, enclosed on one side by the Rocky Mountains, and on the other by the mountainous ridge which protects the Western coast. It was on the property of an intelligent Swiss emigrant, Captain Suter, who had become a wealthy settler on the banks of the Sacramento, that the first traces of gold were discovered in September, 1847. This happened in the course of the erection of saw-mills on the estate, when Mr. Marshall, the contractor for the building of these, observed glittering particles in the sand of the mill-race, which were ascertained to be gold; and on making further researches, it was found that the precious metal was very extensively diffused in the bed of the stream. The discovery soon became known to the work-people, by whom the intelligence was conveyed to San Francisco, and in no long time, the whole population of the little town, and the scattered and scanty settlers in the neighborhood, abandoned their dwellings and occupations to engage in the exciting search. The supply exceeded the most exaggerated accounts that had been given; new and richer localities were discovered; the gold was found in the beds of various streams flowing into the Sacramento; in the mud of the river itself; in the channels of old water-courses, and along the sides of the hills. The intelligence rapidly spread to the neighboring countries—to Mexico, to South America, to the United States, and thence to Europe. People began to flock from all quarters to the once neglected, but now coveted region; it became, in a few short months, the scene of a considerable population, instead of a few scattered tribes of Indians; miners or diggers in parties spread themselves over the face of the country; and San Francisco, from a mere village, grew up into a place of wealth, importance, and stirring activity. It was at first very generally thought that the supply would soon fail, but this anticipation has proved to be unfounded; and while, on the one hand, the amount of the precious metal disseminated in the rocks and soil appears to be almost inexhaustible—on the other hand, the constant increase in the number of miners, combined with the improved apparatus and methods of working, seems to have hitherto resulted in a steadily increasing annual produce, until within the last few years, when it seems to have been nearly stationary.

Professor BLAKE, who minutely examined the auriferous regions of California, states that, with the exception of the diluvial strata, the whole geological formation of the Sierra range, through which flow the principal rivers, consists of igneous and metamorphic rocks. The former are mostly porphyritic in the lower hills, whilst higher up trachytic rocks are more frequently met with. The metamorphic rocks consist of micaeous schists, slates both talcose and micaceous, metamorphic sandstones and limestones, with occasional beds of conglomerate. In that part of the country which he examined, the extent of the diluvial deposits was commensurate, or nearly so, with that of the gold-bearing region. They are found in a belt of land from thirty to sixty miles broad, and running parallel with the axis of the range. These diluvial deposits are met with towards the lower hills of the Sierra, extending frequently some miles into the plain. The elements

of which they are composed differ considerably in various localities, although there are many points of resemblance through the whole series. In the lower valleys and flats, between the ranges of the lower hills, they appear to consist of beds of gravel, containing occasional boulders of quartz and the harder rocks. On the elevated flats, higher up in the mountains, the surface of these deposits is generally covered by a reddish loam, mixed with small gravel; whilst, reposing on the bed rock, and a few inches above it, is found a stratum containing large boulders and gravel, the boulders being principally quartz. At other points, the whole series consists of conglomerates and soft friable sandstone. Where the deposits are found extending over a large surface on the elevated flats, gold is always met with, generally diffused through the gravel immediately above the rock on which they rest, which yields from fifteen to forty cents to the hundred pounds of earth. There are parts where acres of these deposits have been turned up, in which the gravel never contains less than fifteen cents to the hundred pounds, and generally more. In the valleys in the lower hills, and even on the plains to the west of them, where they are extended over vast tracts of country, these deposits are still auriferous, the gold being very generally diffused, and found in greater quantities the deeper they are worked; but sometimes they will not pay for working, owing to the distance from water. In one place, where water could be readily obtained, a portion of these deposits, situated to the west of the lower hills, was found to yield from five to thirty cents to one hundred pounds of earth, through an extent of one hundred and fifty acres, the soil being found richer the deeper it was worked.

At a spot which was appropriately named Mount Ophir, the auriferous soil was described as soft clay and slate, saturated with gold in small particles and large lumps. This treasure was found from ten to thirty feet below the surface, and seven Mexicans, who made the discovery, and kept their secret eight days, made in that short time two hundred and seventeen thousand dollars. Other searchers, from a shaft twenty feet deep, obtained the soft clayey slate in buckets, and found from eight to twelve dollars' worth of gold in each bucket. In many cases considerable nuggets are met with, but no accounts speak of very large masses of gold having been found in California. The total produce from this region, down to the end of 1855, was estimated at sixty-four million pounds sterling; and, latterly, it has averaged about fourteen million pounds per annum.

Australia.—The world-wide excitement created by the gold discoveries in California had scarcely subsided, when another auriferous region was developed in the British dominions at the antipodes, which promises to prove not less productive. The Californian treasures were discovered in September, 1847; and in the spring of 1851 the long-concealed wealth of Eastern Australia was first announced to the world. It is remarkable that this second discovery was not made sooner; for so early as in 1841, the Rev. W. B. CLARKE, in examining the geological structure of the Blue Mountains of Eastern Australia, was attracted by the plutonic and

metamorphic character of the axis of the range, and by the presence of gold in the quartzites, and in the detrital accumulations derived from the axial formations. This gentleman, a native geologist, had found evidence of the existence of gold within sixty and eighty miles of Sydney, and had affirmed his belief that the Blue Mountains would at some time prove to be auriferous. Again, in 1845, Sir RODERICK MURCHISON expressed the same conviction, when he compared the Eastern chain of Australian mountains with the Ural; and in 1846 he even recommended the unemployed Cornish tin miners to emigrate to New South Wales, and dig for gold in the debris and drift of the Australian cordilleras. His writings and remarks on this subject were not entirely without effect, for in 1847 he received letters from speculators in Sydney and Adelaide, accompanied with specimens of gold, which they had sought and obtained, in consequence of his suggestions; and shortly afterwards he even wrote to Earl GREY, informing him that his anticipations were about to be realized in a manner which might operate a great change in the colony.

The discovery was at length made through the instrumentality of a gentleman named HARGRAVES, who had recently returned from California, and had then occupied himself for two months in exploring a considerable extent of country in Australia. On the third of April, 1851, this gentleman addressed a letter to the Colonial Secretary, stating that he had prosecuted his speculation to a successful issue, and offering, for the sum of five hundred pounds, to point out to the officers of Government the localities in which he had discovered gold. To this proposal the Secretary replied that he was not authorized to make a blind bargain, but that if Mr. HARGRAVES thought proper to trust to the liberality of the Government, he might rely on being rewarded in proportion to the value of the discovery. Accordingly, on the thirtieth April, Mr. HARGRAVES addressed another letter to the Colonial Secretary, expressing his willingness to leave the remuneration of his discovery to the liberal consideration of the Government, and naming the localities from which he had obtained specimens of the precious metal. These were at Summer Hill Creek, and other places near Bathurst, which is situated about a hundred and fifty miles west of Sydney, New South Wales.

Scarcely had this communication been made to Government, when the discovery became generally known, through some persons who had been employed under the directions of Mr. HARGRAVES. The fact was divulged that on the eighth of May these persons had obtained several ounces of gold at Summer Hill Creek; and on the thirteenth of the same month great excitement was created by the report that a solid piece, weighing thirteen ounces, had been found. This, on inquiry, proved to be correct, and hundreds of persons immediately left their accustomed avocations, and started for the *diggings*, as they were now called. The excitement rapidly extended, and on the nineteenth of May four hundred persons were congregated at Summer Hill Creek; on the twenty-ninth, one thousand; and on the fifth June their numbers had increased to fifteen hundred.

The Government now lost no time in adopting the necessary measures for maintaining order. A proclamation was issued, dated twenty-second May, 1851, declaring that, from and after the first of June, all persons digging for gold without a license would be proceeded against; and authorising the crown commissioners to grant such licenses for a fee of thirty shillings per month. A force was appointed for the purpose of collecting the fees, and strong detachments of police were stationed along the principal roads leading to the gold fields. At the same time, Mr. HARGRAVES, and the Government geological surveyor, Mr. STUTCHBURY, with whom Mr. CLARKE was afterwards associated, were ordered to make an immediate survey of the various localities in which it appeared probable that gold would be found.

But the spirit of enterprise was now awakened in the diggers themselves, and soon conducted them to new and richer deposits of the precious metal. From Summer Hill Creek, to which the name of Ophir had been given, a great emigration took place to the Turon River—another of the localities first pointed out by Mr. HARGRAVES, and lying a little to the Northward of Summer Hill; and in the month of December the number of diggers on the Turon amounted to six thousand. Subsequently, gold was discovered at various other places in Bathurst, as well as in the adjoining counties of Wellington, Roxburgh, Georgiana, and Ashburnham. Latterly it was found so far South as St. Vincent, and ultimately over the entire mountainous range of New South Wales, extending from 27° to 37° of south latitude; but more abundantly in the Southern portion of the province.

But the progress of discovery did not confine itself to New South Wales. It still advanced to the South; and in a despatch, dated twenty-fifth August, 1851, Lieutenant-Governor LATROBE communicated to Earl GREY, that large deposits had been found in the colony of Victoria. The three localities first named were: Clune's Diggings, about forty miles from Melbourne, where the gold was found in an alluvial deposit, consisting chiefly of quartz gravel; at Buninyong, near Ballarat, about eighty miles from Melbourne or fifty from Geelong, where the gold was sometimes imbedded in compact quartz; and Deep Creek, only nineteen miles from Melbourne, where the precious metal was found to exist in connection with slate rock. It was afterwards discovered almost in the neighborhood of Geelong, and likewise at a place called Mount Disappointment, about thirty miles to the North-east of Melbourne; and, finally, the people of that town began to break up the streets, which had been macadamized with quartz pebbles obtained from the gold districts.

The excitement created in the colony of Victoria by these discoveries surpassed even that which had taken place at Sydney. The whole neighboring population were moving towards the gold regions; Melbourne and Geelong were almost emptied of their inhabitants; and it was found impossible to retain the services of the Government employés, without an addition to their salaries of—first, twenty-five, and, subsequently, fifty per cent. Even the superior class of farmers and tradesmen were drawn into the vortex, partly from sharing

in the general mania, and partly because, when deprived of their laborers and assistants, they had no alternative but the diggings. For some time Ballarat was the great source of attraction, and the stories told of its productiveness were almost incredible. Eight feet square of that auriferous soil was deemed a fortune. One man had found fifteen hundred pounds' worth of gold in one week—another man a thousand. A party of three men had met with twenty pounds' weight in one day!

But even Ballarat was shortly surpassed by a fresh gold-field discovered in the Mount Alexander range, still further to the north, about ninety miles from Melbourne. This was found to exceed in richness all the diggings previously discovered. So great were the attractions of this new field, that the number of diggers at Ballarat, which had risen to six thousand, was quickly reduced to one thousand six hundred, while the number at Mount Alexander rose to twenty thousand. This was the climax of the excitement created by the gold discoveries. The whole structure of Australian society became for a period completely disorganized. Subsequently the precious metal was discovered at various other localities, and the supply was so far increased that gold arrived at the seaports at the rate of two tons per week. The excitement has now subsided; and no new localities have been reported, yielding the same fabulous treasures as Ballarat and Mount Alexander, when first discovered; but various new sources have been opened up, and a map of the country, exhibiting the gold regions, seems to indicate the precious metal as disseminated in greater or less abundance over the whole of the mountainous range which extends through New South Wales and Victoria. The field of operations, therefore, continues to extend; improved machinery is brought into action; and the consequence is, that, while less excitement exists, there is more of steady productive labor, and the aggregate supply of the precious metal has continued to increase yearly till the present time, when it seems to have attained nearly its maximum, at thirteen millions per annum. It is expected, however, that when the labors of the large numbers now employed in deep sinking and in quartz mining are brought to a profitable consummation, the yield, if not greatly increased, will at least be permanently sustained. Further details on this subject, and the produce of the principal mines and auriferous regions throughout the world, will be given at the close of the present article, under the head of Statistics.

ORIGIN AND POSITION OF THE GOLD DEPOSITS.—The matrix of the gold in Australia, as in other auriferous regions, is quartz. The general character of the soil may be inferred from the description given of the Turon and Summer Hill Creek districts, where the gold was first found, and where, according to Mr. STUTCHBURY, the Government geologist, the whole area may be considered as schistose, principally clay-slate, accompanied by nearly all the other varieties of slate rocks, and also by a large amount of quartzites in veins or lodes, parallel to the stroke of the schist. In this district, the trend of all the waterways, or *creeks*, in which the gold is chiefly found, is into the Macquarrie river. The

quartz is amorphous, very rarely crystallized; and in the neighborhood of the gold-yielding localities, it is accompanied by titaniferous iron, both crystallized and in loose grains. Many instances occur in which the quartz remains attached, and interlaced by the gold, as also the iron. It is a fact worth recording, that no gold has been found in Australia, without the iron sand—incorrectly termed *emery*—accompanying it.

Gold in small quantities has been found on the summits and upon the flanks of the mountain ranges; but, with few exceptions, it bears evidence of abrasion; and the larger produce in every instance has been found in the lower levels. Assuming that the auriferous deposits originated in the quartz rock, says Mr. STUTCHBURY, there is no difficulty in accounting for its presence most abundantly in the various gullies and creeks so numerous in this remarkably broken country. The schistose rocks, so readily acted upon by the atmosphere, constantly disintegrating and exposing the quartzose dykes, leave them unsupported; and gravitating downwards, the largest blocks are crushed and crumbled in their onward course, letting loose the tenacious gold in large or small portions, which, in obedience to their gravity, and the force of the impelling torrents, roll on until they are arrested for a time in hollows, or the cleavage fissures of the slaty rocks, or quietly deposited in the sand and mud, as the case may be, by the cessation of the flood, until they are again removed by the repetition of similar causes; or they may remain for ages undisturbed, by the torrents taking another course, of which there are so many instances, leaving ancient bars of shingle debris now covered by accumulated soil. It therefore follows that gold, even if it be of the earliest geological origin, may and will be accumulating in the lower valleys, as long as mountains waste and valleys exist for its reception.

It has been asserted, however, by some writers, that the gold, instead of being torn out by the waters from the veins and primitive rocks which they traverse, actually belongs to the grounds washed by the waters as they glide along. In proof of this, it has been urged that gold is almost always found among the sands of rivers only in a very circumscribed space, and that on ascending these rivers, their sands cease to afford gold, whereas, did this metal come from the rocks above, it should be found more abundantly near the source of the rivers. Thus, the late Dr. URE remarks, that the Orco contains no gold except from Pont to its junction with the Po. In like manner, the Ticino affords gold only below the Lago Maggiore, and consequently far from the primitive mountains, after traversing a lake where its course is necessarily slackened, and into which whatsoever it carried down from the mountains must have been deposited. The Rhine gives more gold near Strasburg, than near Basle, though the latter be much closer to the mountains; and the sands of the Danube contain no gold, so long as the river runs in a mountainous region—that is, from the frontiers of the Bishoprick of Passau to Efferding—but they become auriferous in the plains below. The same thing is stated of the Ems, and other rivers; and it must be admitted that the opinion, to which it naturally leads,

rests upon very strong grounds, and is supported by some of the highest authorities.

Though gold is frequently found at the surface, mixed with the sands of rivers, yet the auriferous stratum is often buried at considerable depths, and hence the necessity of opening *pits* or *diggings*. Figs. 204 and 205 will afford some idea of the Australian gold-field strata. The latter represents what the diggers call a surface gullet, the gold being met with at about sixteen feet from the surface; the former is a



Fig. 204.

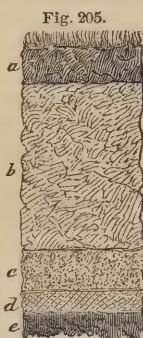


Fig. 205.

section of a deep gullet, in which the auriferous ore is at a depth of thirty-six feet. The corresponding letters, in both sections, indicate similar strata; *a*, black loam and quartz; *b*, white loam, clay, and sand; *c*, brown clay; *d*, gold layer; *e*, yellowish-brown rock; *ff*, quartz in a concrete mass; *g*, stratum of sand; *h*, common clay. The auriferous ore earth is generally of a light color, or largely mixed with quartz pebbles, very tenacious and difficult to wash. It lies upon a yellowish brown rock, of a rotten texture, known as fixed slate, whilst higher up, above the gold, the strata present igneous features.

Probable abundance of Gold at great depths.—The probability that gold exists in almost unlimited amount at greater depths than have been yet explored for this metal, is thus argued by Mr. W. BRIDGES ADAMS: Quartz rock is the matrix of gold, and quartz rock is commonly a vein of greater or less thickness intersecting the beds of granite. In this quartz the metallic gold is distributed, in particles of more or less fineness, and sometimes it is found in lumps. If the granite be supposed to have been once in a state of fusion, and cracked in cooling, forcing up into the fissures the liquid quartz containing the gold, it seems more than probable that the greater part of the molten gold would settle to the bottom of the fluid mass, as the metal precipitates in an iron furnace, beneath the slag. The fragments that are found in rivers and alluvial ground have probably been thrown out by subsequent volcanic action. The spangle-gold, the nuggets, the gold-dust, and other varieties, seem to confirm this; and probably, in depths of alluvion greater than have yet been penetrated, large golden fragments will be discovered, just as the hugest pieces of rock are found undermost in the beds of mountain torrents. If this theory be correct, it is quite within possibility that the gold-hunters, who have as yet explored but a small portion of the earth's surface, may light upon larger deposits—may yet penetrate to some mass larger than the famed native iron of Santiago del Estero, or a quartz vein gradually changing into the

pure metal. The lighter fragments washed to the edges by the stream have alone been gathered; they are but indications of the larger masses that lie in deposit below; and it may be predicted that wherever gold has been superficially gathered at any period, it will be found in larger masses at some greater depth.

If there be any truth in this ingenious conjecture, it will soon be brought to the test of experiment by the operations now in progress in Australia, with a view to deep sinking and quartz mining on a very extensive scale.

METHOD OF EXAMINING AURIFEROUS DEPOSITS.—

As a general rule, the rocks in the district to be examined for gold should be either granitic, porphyritic, or quartzose, although it is also found in other formations, and particularly in clay-slate. The auriferous quartz is often stained of a rusty brown color, from the presence of peroxide of iron, and in many instances presents a cellular or honeycombed appearance. The points to be most carefully examined are the sands of the rivers and streams, or old water-courses, as well as the particles of disintegrated rock which often accumulate in the eddies of ravines formed on the sides of hills by the action of water during great floods. The sections of rock exposed by this action must also be examined with a view to the discovery of veins of auriferous quartz, from which specimens are broken off and afterwards carefully assayed.

The method of conducting a systematic assay of gold ores and alloys will be fully explained afterwards. It is a somewhat tedious and difficult process, requiring considerable experience and a regular assortment of apparatus. But even in the absence of these, a tolerably correct estimate of the amount of gold present may be readily arrived at by the following simple method.

The fragment of rock, supposing the ore to be quartz, is first pounded very fine and sifted, a portion of the sand or powder thus obtained is washed in a shallow pan, and, as the gold sinks, the lighter portions of the substance are allowed to float off. The greater part of the gold is thus left in the angles of the pan; and by adding more of the powder, and repeating the same process, a further portion is obtained. When the bulk of powder, with which the gold is mixed, is thus reduced to a manageable quantity, mercury is added to the mass, and forms with the gold an amalgam, which is afterwards heated in an iron retort to expel the mercury. In this way the proportion of gold contained in a specimen of rock may be ascertained with considerable exactness. The sands brought down by rivers are examined in much the same manner, but do not require the previous pounding; and a fair estimate of their value may be generally formed without the amalgamating process. Sometimes, indeed, the gold may be present in considerable quantity, although in a state of division so minute as not to be readily perceived by the unassisted eye, and, therefore, in examining the earthy residuum, a small magnifying lens will be found of great use.

It is generally considered that the sand of any river

is worth working for the gold it contains, provided it will yield twenty-four grains to the hundredweight; but the sands of the African rivers often yield sixty grains in not more than five pounds weight, which is in the proportion of more than fifty times as much, while the Australian rivers have been known to yield considerably more.

SUBSTANCES OFTEN MISTAKEN FOR GOLD.—

Though gold, in its separate and pure state, is readily distinguishable from other metals and minerals, by its color, softness, high specific gravity, and insolubility in the simple acids, yet in the mixed state in which it is generally found it requires an amount of chemical skill to apply these tests, and hence, where glittering particles of other minerals appear, they are often mistaken for gold, even by persons who are not entirely ignorant of its characteristics. The substances which most generally lead to this mistake are iron pyrites, copper pyrites, and yellow mica.

Common iron pyrites, or bisulphide of iron, which is more frequently mistaken for gold than any other substance, occurs in small cubical crystals, in veins disseminated in the various slate rocks, and in the coal measures. It is of different shades of brass-yellow, and often in fact contains minute traces of gold, though seldom a sufficient amount of that metal to render its extraction profitable. It may be readily distinguished from gold by the application of the magnet, as well as by the following characters: first, instead of flattening like gold under the hammer, it is extremely brittle, and, therefore, readily broken; second, its weight or specific gravity is only about one-fourth that of gold; and lastly, when heated with nitric acid it is dissolved with evolution of copious red fumes, whilst gold, when so treated, remains unaffected. It was only recently the Editor was consulted by a gentleman who imagined he had discovered a gold mine in Ireland. The sample brought turned out to be a fine specimen of sulphide of iron embedded in quartz.

Copper pyrites, or yellow copper ore, the second mineral which is frequently mistaken for gold, is a ferrosulphide of copper, and may be considered as a compound of two equivalents of sulphide of iron, and one equivalent of sulphide of copper. This is the ore from which the largest proportion of the copper of commerce is derived. It occurs in a variety of forms, its primitive crystal being the regular tetrahedron. It is formed in lodes or veins, which usually occur either in granite, grauwacké, or clay-slate, and has a strong metallic lustre, and deep brass-yellow color. It may readily be distinguished from gold by the circumstance, that when heated on a piece of charcoal before the blowpipe it loses this yellow color, and fuses into a dull black globule, which, from the presence of the iron, is magnetic. If mixed with carbonate of soda and a little borax, it yields, when similarly treated, in skilful hands, a button of metallic copper. But an easier method to determine the presence of copper is to pulverize the ore in an iron mortar, or with a heavy hammer, dissolving the powder thus obtained in nitric acid, and evaporating the solution nearly to dryness; water is then added, and afterwards ammonia in excess, when, if copper be present, the liquor assumes a rich pur-

plish color, an unmistakeable sign of the presence of copper.

Another method for determining the presence both of iron and copper, is to take some of the scoria left after submitting it to the blowpipe, and, putting this in a test-glass, to pour over it a few drops of hydrochloric acid, when an effervescing solution will be obtained. A little of this liquid is then transferred to another glass—the one to be treated for iron, the other for copper. Into one of the glasses introduce a few drops of ferro-cyanide of potassium, and liquid ammonia into the other. If iron is present, the liquid in the glass to which the ferro-cyanide has been added will become blue, the iron combining with the ferro-cyanogen, and producing Prussian blue. If copper is present in the same glass, but no iron, the liquid will become of a reddish-brown tint, ferro-cyanide of copper being formed. If iron and copper are present together, the two metallic precipitates will be the result, and a purple tint arises from the mixing of the red and blue colors. The liquid in the glass to which ammonia was added will be changed to a brownish tint if iron is present, and to a fine blue if copper is there.

Mica, the third substance often mistaken for gold, is one of the constituents of gneiss granite and mica slate, and gives to the former its lamellar structure. In 1853 great excitement was produced at the Cape of Good Hope, in consequence of the discovery, near Simon's Bay, of a substance said to contain a large proportion of gold. A quantity of this suspected mineral was sent home for analysis, and was found to possess a glistening, yellow, semi-metallic lustre; but when submitted to the searching powers of the microscope, its metallic brilliancy disappeared, especially when viewed by transmitted light. It had then a darkish-grey color, being in thin semi-transparent plates. It was not acted upon by nitric or nitro-hydrochloric acid; and hence, doubtless, arose the error in taking it to be gold. In reality, it was nothing but mica, highly colored with the oxide of iron, and yielding, on analysis, the following constituents:—

	Centesimally.
Silica,	46
Alumina,	23
Potassa,	14
Oxide of iron,	16
Manganese,	1
	100

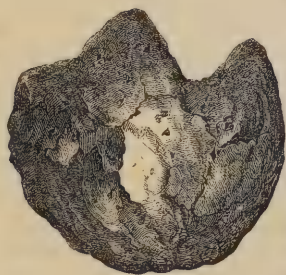
The specific gravity of mica never exceeds 3·00; and this circumstance, together with its foliated structure, is quite sufficient to distinguish it from gold, which it somewhat resembles in color; but even in this latter particular, the microscope will dispel the illusion.

CHARACTERS OF NATIVE GOLD.—Gold, as already stated, almost always occurs in the metallic state, generally in small grains or scales known as *gold dust*, sometimes in particles so minute as to be invisible, but occasionally in pieces of considerable weight, termed *nuggets*. It appears doubtful, indeed, whether, when this metal occurs in pyrites, it exists in every instance in minute metallic particles, or whether, in some cases at least, it may not be present in combination with sulphur. The auriferous pyrites, as DUMAS remarks, con-

tain the gold disseminated through their mass in such small quantities, that it is almost always impossible to ascertain, even with the aid of the microscope, in what state the precious metal exists. As a preliminary roasting of this auriferous ore is generally useful, with a view to the subsequent amalgamation, a doubt may be entertained whether it is really present in the metallic state, though this has been generally assumed hitherto. But DUMAS thinks that the powerful electro-negative tendency of sulphide of gold affords a strong presumption in favor of the hypothesis, that this metal may exist partly, or even entirely, under the form of a double sulphide, in iron and copper pyrites, *et cetera*. BROGNIART observes, that it is chiefly in its association with these sulphides, as also with galena or sulphide of lead, blende or sulphide of zinc, and mispickel or arsenical pyrites—a sulphide of arsenic and iron—that the gold becomes invisible to the eye, a circumstance which is justly regarded as strongly confirming the opinion expressed by DUMAS. The other minerals with which it is found associated are grey cobalt, lithoidal manganese, native tellurium, malachite, sulphide of silver, red silver, and sulphide of antimony.

When the gold is found in the form of nuggets, these generally communicate the impression of their having been melted; and in many newspaper accounts, and

Fig. 206.



letters received from the diggings, the gold is described as having been evidently in a state of fusion, and as resembling drops of melted metal poured into sand, the indentations being visible even upon the smallest particles of the gold when microscopically examined. It is certain that such indentations may be observed in most

specimens, as indicated in Fig. 206, which exhibits a microscopic view of a fragment of Australian gold magnified seven hundred times. Mr. J. B. JUKES, however, who may be regarded as a competent authority, conceives that this is probably a mistake, and that the idea may have originated from the gold having been deposited in small holes, crevices, and interstices of the quartz rock, and subsequently rolled, so that it assumes such forms as melted lead is seen to do. It does, certainly, appear remarkable that the particles of gold should retain indentations received in a state of fusion, after being tossed about, probably for a long period, among water and gravel.

Fig. 206 has been given as the greatly magnified representation of a very small grain. Fig. 207, on the contrary, is a much reduced delineation of a lump of almost pure gold, weighing 27 lbs. 6 oz. 15 dwts, which was found in the diggings, at Forest Creek, Mount Alexander, in the Colony of Victoria. Among other pieces brought home with it in the same vessel, were several nuggets weighing upwards of a pound each,

and one of 1 lb. 8 oz. 6 dwts. These smaller lumps, however, contained quartz, whilst the larger one appeared a massive lump of nearly pure gold, of a very fine color. It measured eleven inches in

Fig. 207.



length by five in breadth, at the widest part. This was supposed to be the largest nugget which had been found in Australia up to the time of its discovery, but one or two others considerably larger have been since obtained.

Gold is also occasionally, though rarely, found in a crystallized state; and when met with, the crystals should be carefully preserved as cabinet specimens, for which purpose their value is much greater than that which they are intrinsically worth for the gold they contain. The most common forms are the cube and octahedron, with their various modifications. The faces are generally dull, and in most instances the edges are slightly rounded. Some years ago, several interesting specimens of crystallized gold, from California, were described in *Silliman's American Journal*, by Mr. FRANCIS ALGER of Boston. The collections in which the specimens were found were brought from California by Mr. G. E. TYLER of Boston, and Mr. H. B. PLATT of New York. The crystals were distinctly octahedral, simple and modified, the surfaces being but slightly disfigured by attrition, or the effects of transported action—a very unusual circumstance, as gold is generally found in comparatively minute grains, at a distance from the rocky matrix in which it is supposed by some to have been primarily embedded. Mr. ALGER states in his paper, which was read before the Boston Society of Natural History, that he had never before seen what was unquestionably a genuine crystal from California. He adds that an irregular crystalline plane could only occasionally be traced out in former specimens; but among those exhibited were examples of crystallization as perfect, among the small ones especially, as are to be seen in magnetic iron ore or in spinelle.

Of the larger specimens in these collections, the most striking examples were three octahedrons of the sizes exhibited in Figs. 208, 209, 210. Each of these crystals was found in an isolated state. The smallest one—Fig. 208—was the most perfect, and was entirely free from any adhering portion of the matrix. This unusually perfect crystal exhibits, as partly shown in the Figure, four pretty regular faces in the lower half, and three of its six solid angles are perfectly formed to a point. Two of its faces are sunk or depressed; and in one of them, the cavity thus formed, is very deep and regular, like an interior triangle; the depression extend-

ing not quite to the edges, but so as to leave all round a narrow ridge or border, the interior sides of which are parallel with the edges of the crystal. Mr. ALGER in-

Fig. 208.

Fig. 209.

Fig. 210.



ferred that this depression, which is shown by a darker shade in the wood-cut, had been formed when the crystal was in a liquid state, and that, soon after the outside had congealed or solidified, the inner portion, or a part of it, had run out, leaving the surrounding consolidated edge in a perfect form. He remarks that he has seen something similar to this formed among artificial crystals, as, for instance, metallic lead—which takes the form of an octahedron—and lead ore partially desulphurized, when the metal was allowed to flow off slowly, just as the outer crust had formed over the surface of the crystals. Indeed, this parallel case is of not unfrequent occurrence in the crystallization of the ductile metals.

In the largest—Fig. 209—of the three crystals of which the preceding sketches are given, it will be observed that only one-half of the octahedron is formed, its base blending with the rough gold, or showing only the commencement of the planes of the upper pyramid. Three of the planes are quite smooth, except along their edges, which are permanently marked by the same projecting border or edge described on the smaller crystal. The depression, however, is not so great as in the latter. Mr. ALGER remarked that this peculiarity was confined to the unmodified crystals.

In some there was a double series of these ridges, the inner one appearing to exhibit the commencement of another crystalline face within the cavity of the larger one. This phenomenon was strikingly shown in a crystal represented of the natural size in Fig. 210.

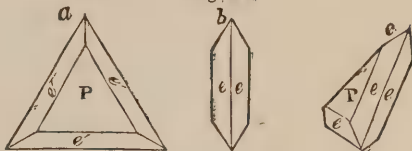
The two larger crystals—Figs. 209 and 210—were obtained from the collection of Mr. PLATT, who resided a couple of years at San Francisco, and being in a situation which brought him into constant intercourse with persons returning from the mines, purchased, at no small expense, the most interesting specimens he could find. His collection was described by Mr. ALGER as of singular beauty and value, comprising a great variety of ramified, arborescent, dendritic, and other imitative forms, all of them, sometimes, fantastically joined together in the same specimen. In obtaining his valuable collection, he had examined gold to the amount of more than four millions of dollars. The remarkable size of the two larger crystals thus described, and the fact that some of the others contained portions of oxide of iron, induced a suspicion that the greater part of them were pseudomorphs of sulphide of iron; but Mr. ALGER believed that they were formed

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under the ordinary circumstances of crystallization, either in an open space, or while surrounded by a matrix, in such a fluid state as to allow them full freedom to take their natural form. His reasoning on the subject, if not perfectly conclusive, leads to a strong presumption in favor of the octahedron as the primary form of gold; and if this were more generally known, much disappointment and trouble might be saved in cases where sulphide of iron and other crystalline metallic forms are mistaken for the precious ore.

In Mr. TYLER's collection, Mr. ALGER found several rare modifications, some of them resembling those which come in their most perfect forms from Brazil. Fig. 211 exhibits in three positions, *a*, *b*, *c*, a compound form produced by the union of two opposite segments of an emarginated octahedron. Fig. 212 is a modifi-

Fig. 211.

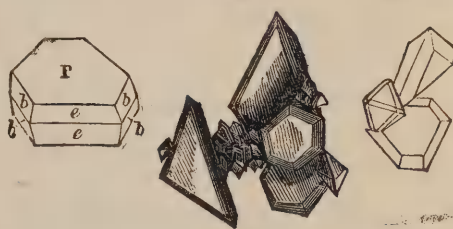


cation of the same form, though apparently consisting of irregular six-sided tables, with truncated edges. Some of the unmodified macles, as shown in different positions, in Fig. 211, were stated by Mr. ALGER to be very distinctly formed, the edges between *ee*, uniting the two segments of the octahedron, being well

Fig. 212.

Fig. 213.

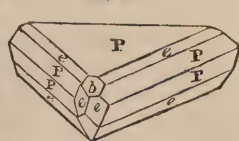
Fig. 214.



defined. This is very strikingly shown in Fig. 213, in which the crystals are exhibited as magnified to twice their natural size. Fig. 214 shows the opposite side of the same specimen, connected with two other crystals, one a very beautiful and smooth-planed octahedron with emarginated edges.

Fig. 215 exhibits a macle of gold which came from Malto-Grosso in Brazil, and is in the collection of the School of Mines, Paris. It is similar to that represented in Fig. 211, from which it only differs in exhibiting more of the planes of the octahedron and dodecahedron. This figure is copied from the volume of crystallographic illustrations accompanying M. DUFRÉNOY's treatise; but besides conforming his lettering to the notation of PHILLIPS, those are made primary planes which are given by DUFRÉNOY only as secondaries of the cube.

Fig. 215.



In all these the octahedral form is manifest, which may therefore be assumed to be the form natural to gold when its particles crystallize in cooling; but as nearly all of these crystals show the effects of abraded action, it is often difficult to distinguish planes confined within such narrow limits, and which are too small or too rough to admit of accurate admeasurement. Indeed the faces of the crystals are in most instances slightly rounded, even in specimens obtained directly from veins, and which, consequently, cannot have been exposed to attrition.

COMPOSITION OF NATIVE GOLD.—Native gold is never quite pure, being almost invariably alloyed with silver, and containing frequently small proportions of copper and iron. In Siberia it is often associated with platinum, and in the Gongo Soco mines in Brazil, an alloy of gold and palladium of a pale yellow color is sometimes found. In Columbia a somewhat similar

mixture is procured, in which the palladium is replaced by another rare metal called rhodium. In Hungary it is met with in combination with tellurium and other elements. The specific gravity of native gold varies from 13.3 to 18.5.

The proportion of silver, the principal ingredient which is found in combination with gold, varies from one to fifty per cent.; and not only differs greatly in specimens of native gold obtained from diverse regions, but even to a certain extent in specimens from the same auriferous district. In general, however, the composition of the gold of the same district is remarkably constant; so much so, that the knowledge of the locality whence it is derived is often sufficient to enable the experienced assayer to guess pretty nearly the quantity of pure gold which the compound contains. The subjoined table presents the composition of native gold from various parts of the world:—

SIBERIA AND URAL.					
Locality	Authority	Gold.	Silver.	Copper.	Iron.
Schabrowski,	Rose,	98.96	0.16	0.35	—
Boruschka,	Rose,	94.41	5.23	0.36	—
Katherinenburg,	Rose,	92.80	7.02	0.06	0.08
Gozuschka,	Rose,	83.85	16.15	—	—
Ural,	Awdejew,	70.86	28.30	0.84	—
AFRICA.					
Anamaboc,	T. H. Henry,	98.06	1.39	0.15	—
Anamaboc,	T. H. Henry,	88.25	11.17	0.10	0.36
AMERICA.					
North of Brazil,	Rivot,	91.0	8.7	0.3	Palladium.
Gongo Soco,	T. H. Henry,	83.36	6.44	0.50	3.58
Ojas Anchas,	Boussingault,	84.5	15.5	—	—
Santa Rosa De Osos,	Boussingault,	82.4	15.5	—	—
Marmato,	Boussingault,	73.45	26.48	—	—
Titiribi, Columbia,	Rose,	76.41	23.12	0.03	—
California,	T. H. Henry,	90.12	9.01	0.87	Iron.
California,	T. H. Henry,	86.57	12.33	0.29	0.24
Canada,	T. H. Henry,	90.33	9.53	—	—
AUSTRALIA.					
Bathurst,	T. H. Henry,	95.68	3.92	—	0.16
EUROPE.					
Transylvania,	Rose,	60.49	38.74	0.77	—
Wicklow,	Mallet,	92.32	6.17	—	0.78

From this table it will be seen that the gold both of California and Australia contains silver, but that the specimen from the latter was remarkably pure; and such, indeed, is the general character of Australian gold. Neither platinum nor palladium, nor any trace of the metals of that class, is found in the newly discovered gold regions. There is, however, a trace of iron in the Australian specimen, and a small proportion of both copper and iron in those from California.

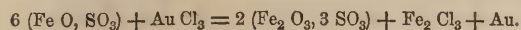
PREPARATION OF PURE GOLD.—Like native gold, that which is used in the currency, as well as in the manufacture of jewellery, is never absolutely pure, being always alloyed with some other metal, such as copper or silver, to give it the requisite hardness. The proportions of the metals which enter into these alloys will be afterwards stated. The methods adopted, also, for obtaining pure gold on the large scale, or, in other words, the metallurgical treatment of gold ores, with a view to the extraction of the precious metal in a state of purity, will be fully explained. In the meantime, it may be desirable, before proceeding further, to show

how a small portion of pure gold may be prepared in the laboratory.

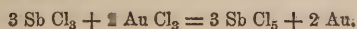
For this purpose, a piece of native gold, a small quantity of gold dust, or a few coins or fragments of old jewellery are dissolved in nitro-hydrochloric acid—the *aqua regia* of the alchemists—consisting of four parts of hydrochloric with one of nitric acid. This will give a solution of terchloride of gold, mixed with chloride of silver, if any of that metal be present. The solution thus obtained is evaporated with an excess of hydrochloric acid for the purpose of destroying the excess of nitric acid. The residue is then treated with hot water, by which it is dissolved, with the exception of the chloride of silver, from which the solution is decanted or separated by filtration.

An excess of protosulphate of iron in solution is then added to the auriferous solution in the proportion of four or five parts of the crystallized protosulphate—green vitriol—to one of gold; and the mixture is put in a warm place, and allowed to stand for several hours. In the reaction which occurs, the chlorine that was combined with the gold unites with a portion of

the iron of the protosulphate, part of which is thereby converted into sesquisulphate, while sesquichloride of iron is at the same time formed, and metallic gold is precipitated. This reaction is represented in the annexed equation:—



To precipitate the gold from an acid solution of its chloride, LEVOL prefers to the protosulphate of iron an acid solution of terchloride of antimony, in which case the following equation exhibits the reaction that takes place:—



In this case, if chloride of silver be present, it is retained by the hydrochloric solution.

The precipitated gold is in the form of a finely-divided powder, which, when suspended in water, is brown by reflected and purple when viewed by transmitted light; but under the burnisher it readily assumes the metallic lustre and characteristic color of malleable gold. It also admits of being aggregated and welded together by percussion; and if heated to whiteness, and in that state struck repeatedly with a heavy hammer, its particles become united into a solid mass, without having been raised to the point of fusion.

To obtain the gold in a perfectly pure state, however, the precipitated powder is boiled with hydrochloric acid of specific gravity 1.1, which is then decanted, and the residue is boiled twice with fresh acid. The gold is *not* washed between these successive treatments with acid, which remove the last traces of iron, and nearly all the chloride of silver.

Lastly, the gold is well washed, dried, and mixed with its own weight of bisulphate of potassa, or a small quantity of borax and nitre, and fused in a Hessian crucible exposed to a very strong heat. By this operation, the last portions of chloride of silver are removed, and a button of perfectly pure gold is obtained.

PROPERTIES OF PURE GOLD.—Pure gold is of a rich reddish-yellow color, and high metallic lustre; in the pulverulent state it is brown and dull, but acquires, as has been stated, the metallic lustre by pressure. The specific gravity of fused gold is 19.2; of hammered gold, from 19.3 to 19.4. In this respect, therefore, it stands only second to platinum, of which the specific gravity is about 21.5. Finely-divided gold, precipitated by sulphate of iron, was found to vary in density from 19.55 to 20.72; and when precipitated by oxalic acid, its density was 19.49. Its equivalent is 197. In a pure state it is softer than silver, and nearly as soft as lead; but its tenacity is so great that it may be drawn out into very fine wire; and such is its malleability that it may be hammered out into leaves only one three hundred and seventy thousandth of an inch in thickness. A single grain may be extended over 56.75 square inches of surface, or drawn out into a wire five hundred feet long. RÉAMUR, by rolling out a fine gilt silver wire, reduced the coating of gold to the twelve-millionth of an inch in thickness, and the surface appeared to be perfect when viewed under the microscope.

Gold does not combine directly with oxygen, and,

therefore, suffers no change by exposure to air and moisture at any temperature—not even by being kept in a state of fusion in open vessels. It is not attacked by the mineral or any of the simple acids, except selenic, and this by the aid of heat. The alkalis do not affect it, and hence a crucible of gold is a valuable instrument in the analysis of minerals which require fusion with the caustic alkalis. It is not acted on by sulphur, and, consequently, sulphide of hydrogen is not decomposed by it, as in the case of silver. Iodine has only a weak action upon it, but bromine and chlorine attack it easily at ordinary temperatures; and it is dissolved by any substance which liberates chlorine. It is therefore dissolved by hydrochloric acid, if binocide of manganese, chromic acid, *et cetera*, be added thereto. Its usual solvent is that already stated—a mixture of one part of nitric acid, and four parts of hydrochloric acid. *The proper solvent of gold is nascent chlorine*, which is eliminated by the mutual action of the mixed acids.

Gold is one of the most perfect conductors both of heat and of electricity. It fuses at a bright red or a white heat, the temperature of which has been estimated at 2016° Fahr. It is therefore less fusible than silver or copper, the former fusing at 1873°, and the latter at 1996°. In fusion it exhibits a bluish-green color. It is not sensibly volatile in the strongest heat of a blast furnace; but in the focus of a large convex lens, in the intense heat of the oxyhydrogen jet, or under the influence of a powerful electric discharge, a gold wire is dispersed in vapor; and if, in the latter case, the wire be placed just above the surface of a sheet of paper, the course of the discharge is marked by a broad, dark, purple stain, produced by the finely-divided gold. If, instead of the sheet of white paper, a plate of polished silver be employed, it is traversed by a brightly-gilded line, which is firmly attached to its surface. When a globule of gold is placed between the terminal charcoal points of a powerful voltaic battery, it enters almost immediately into fusion, and gives off abundant metallic fumes.

Gold contracts on cooling, and cannot be advantageously employed for castings, as it shrinks greatly at the moment of solidifying. GRAHAM states that it cannot be obtained in crystals by cooling; but according to other authorities, when large quantities of gold have been fused, and are then allowed to cool slowly, cubes more or less modified on their edges and angles are frequently the result. It has been shown that native gold affords numerous well-defined crystals belonging to the cubic system, and that of these the greater number, if not all, is affected by the faces of the regular octahedron.

CHEMICAL EXAMINATION OF GOLD ORES.—A rude method of ascertaining the presence of gold in crushed quartz, or earthy ore, by washing with the hand-basin, has been described; but gold is often present in the matrix in grains or particles so minute that it cannot be detected by the eye, and sometimes it is quite disguised by admixture with other metals or minerals. Many cases occur, however, in which it is of great importance to ascertain the presence of gold, not only as a first step in the examination of suspected auriferous ores, but likewise in the assaying of alloys of gold with dif-

ferent metals. In commencing mining operations, the fact of the *presence of gold* in the ore, in any appreciable quantity, is the first point to be determined; and if this be decided in the affirmative, the next point is to determine the *proportion or quantity of gold* contained. The first process is termed *testing for gold*, or the *qualitative examination* of a suspected mineral; the second is the *quantitative examination*, or *assaying process*.

Sulphate of iron, protochloride of tin, and oxalic acid are the tests or reagents pre-eminently employed in seeking to determine the presence of gold.

Before any of these tests can be applied, the substance supposed to contain the gold must be brought into a state of solution; and this can only be done by means of the mixture of nitric and hydrochloric acids already mentioned. If the substance consist of earthy or quartzose matter, this must be reduced to powder by trituration in a mortar before it is subjected to the action of the solvent; but if the matter under examination be simply a metallic alloy, it can be dissolved without any previous preparation. An excess of acid should be avoided, and for this purpose some carbonate of soda should be added. When the solution is effected, the liquid should be evaporated to about one-eighth of its original bulk, and then diluted with three or four ounces of water. The action of the reagents is as follows:—

1. *Sulphate of Iron or Green Vitriol*.—If a few crystals of this salt be dissolved in distilled water, and dropped into the suspected solution, the result is the precipitation of the gold, if any be present, in the form of a dark-brown powder, which is metallic gold in a very fine state of division, as already described in connection with the laboratory process for preparing pure gold. If the solution has been mixed with a considerable quantity of water, the liquid, on the addition of the green vitriol, is colored brown by reflected, and blue or a dingy green, by transmitted light; and this is obvious even when forty thousand parts of the menstruum are present to one part of gold. If the liquid amount to eighty thousand parts, it is colored sky-blue; with one hundred and sixty thousand parts, it becomes violet; with three hundred and twenty thousand parts of liquid, the violet tint is still very obvious; but with six hundred and forty thousand parts, it is with difficulty perceived.

The deposit formed when the sulphate of iron is added may be corroboratively proved to be gold, by its being insoluble in nitric acid, but readily soluble in aqua regia.

2. *Protochloride of Tin*.—If to another portion of the nitro-hydrochloric solution be added a small quantity of a solution of protochloride of tin—commonly known as *salts of tin*—there will be immediately produced, if any gold is present, a dark brownish-purple precipitate, known as *purple of Cassius*. This substance is used in enamel and porcelain painting, and also for tinging glass of a fine red color, in connection with which applications it will be noticed afterwards. Its color, though not a brilliant purple, but rather a reddish-brown, is characteristic, and after being once seen is not likely to be mistaken. Its appearance, when the chloride of tin is added to the liquid, affords

an infallible proof of the presence of gold, for a very minute portion of that metal gives a manifest reaction when this test is employed.

When the first test—sulphate of iron—has been applied, and its evidence corroborated by the solution of the precipitated gold powder in aqua regia, the protochloride of tin may be employed to produce the purple of Cassius in this solution also.

3. *Oxalic Acid*.—This substance, either in crystals, or dissolved in water, causes, when added to the nitro-hydrochloric solution, the precipitation of any gold that may be present, in the form of a brown or greenish-black powder, in the same manner as the sulphate of iron; but the precipitation does not occur so rapidly. Indeed, it requires not less than forty-eight hours for the whole of the gold to be thrown down by the oxalic acid, unless heat is applied, by which the process is accelerated. The precipitate is pulverulent gold, and may be tested, as in the first case, by its insolubility in nitric acid, while readily dissolving in aqua regia. A crystal of oxalic acid, wetted with a solution of gold, becomes soon covered with a thin film of the metal, having its distinctive color and lustre.

These are the tests most easily applied by persons unaccustomed to chemical manipulation. At the same time, it may be useful to know the reactions of gold with various other substances, the most important of which, including the three already mentioned, are summarily tabulated as follows by Dr. LYON PLAYFAIR, in a lecture delivered by that chemist at the Museum of Practical Geology:—

TESTS FOR GOLD.	
Tests or reagents.	Results.
Sulphate of iron,.....	In acid solution, brown precipitate; if very dilute solution, only a blue coloring.
Protochloride of tin,.....	In dilute solution, a purple-red coloring; when strong, almost brown precipitate.
Metallic zinc,.....	Precipitates metallic gold as a voluminous brown precipitate.
Potassa in excess,.....	No precipitate; after some time a green coloring and slight precipitate.
Ammonia,	Yellow precipitate—fulminating gold.
Carbonate of soda, or carbonate of potassa,	No precipitate in cold solutions, but when heated, voluminous precipitate like oxide of iron.
Bicarbonates of soda or potassa,	No precipitate.
Carbonate of ammonia,.....	Behaves like ammonia, carbonic acid being evolved.
Oxalic acid,	Dark, greenish-black precipitate, more quickly produced by heat.
Tartaric acid and soda,.....	Dark precipitate when boiled.
Sulphide of ammonium and Sulphide of hydrogen,.....	Dark brown or black precipitate.

These reactions are so characteristic that it is impossible to mistake gold for any other metal. At the same time, it may be stated that the protochloride of tin is the most infallible test, and is indeed quite conclusive. It has the advantage of being more delicate than the others—that is to say, it will indicate the presence of a smaller quantity of gold than any other reagent, not excepting the protosulphate of iron or the oxalic acid.

TESTS FOR METALS USUALLY ASSOCIATED WITH GOLD.—In examining an ore or alloy supposed to contain gold, it is often an object of great importance to determine the nature of the metals with which the gold is associated. These may be of high value on their own account, and, according to the quantities in which they are present, may greatly affect the value of the ore or mineral in question. To enter fully into this subject in connection with the rarer metals that are found associated with gold, would be of little practical use. The Editor will therefore confine his attention to the means of detecting and distinguishing those of most common occurrence—copper, silver, and platinum.

1. *Copper.*—It has been shown that copper is almost always associated with gold even in quartz, and that copper pyrites is one of those substances frequently mistaken for gold. When dissolved in acids, however, it gives characteristic actions, which render its presence easily distinguishable. One of the readiest tests is to introduce into the solution a piece of clean iron, when, if copper be present, it will be deposited on the iron in the metallic state. This experiment, remarks Dr. LYON PLAYFAIR, apparently showing the conversion of iron into copper, deceived the alchemists in their researches, and gave much support to the idea that one metal may be transmuted into another. The action depends, however, upon a simple exchange, the iron going into the solution in proportion as the copper goes out. Again, when ammonia is added in excess to a solution in which copper exists, it communicates to the liquid a rich deep-blue color. Ferrocyanide of potassium produces, with copper, a brownish-red precipitate, even when the metal is present in very small quantity. Carbonate of soda precipitates copper from its hot solutions in the form of an apple-green compound, which is a carbonate of copper, known, when artificially formed, as *verditer*, and when it occurs native, as *malachite*. Copper ore in the latter form exists abundantly in Australia—not, indeed, mixed with the gold, but constituting valuable mines, from which the ore is sent over to this country, with great profit, to be smelted in South Wales.

2. *Silver.*—It has been shown that gold appears to be invariably alloyed with this metal, sometimes to a very large amount. In its separate state it is readily distinguished, not only by its white color, but also by its specific gravity, which is only 10·4, or about one-half that of gold. It may be useful to state, that when in a very fine state of division, it is of a dark-grey color. It may be easily recognized by its chemical behavior to reagents, in which respect it differs from gold by its solubility in nitric acid at all temperatures, and in boiling or heated sulphuric acid. On the contrary, with hydrochloric acid, it forms a white curdy precipitate, which is the chloride of silver. If the nitric acid employed to dissolve it contain the least hydrochloric acid, the solution will become turbid by the formation of the chloride. Hence, when a mineral containing gold and silver is submitted to the action of aqua regia—nitro-hydrochloric acid—the appearance of this white precipitate will immediately indicate the presence of the latter metal. The chloride of silver is soluble in ammonia, and may thus be distinguished from many

other white precipitates; or it may be further tested by putting the precipitate into a crucible with carbonate of soda, and exposing the mixture to a strong red heat, when a button of pure silver will be obtained. By careful manipulation the amount of silver present may be accurately determined in this manner. If the mineral containing the silver be dissolved in oil of vitriol, it is readily detected by inserting a few fragments of copper, which causes the precipitation of the silver in a pulverulent state.

From the fact that silver, in greater or less proportion, is uniformly associated with gold in the native state, it may be useful to compare the following reactions with those given in the preceding page for the metal of higher value:—

TESTS FOR SILVER.	
Tests or Reagents.	Results.
Potassa,	Brown precipitate, becomes black on boiling.
Ammonia,	Brown precipitate, soluble in excess of ammonia.
Carbonate of soda or potassa,	White precipitate, soluble in ammonia.
Carbonate of ammonia,	White precipitate, soluble in excess of reagent.
Phosphate of soda,	Yellow precipitate, soluble in ammonia.
Oxalic acid,	In neutral solutions, white precipitate.
Sulphide of hydrogen and sulphide of ammonium,	Black precipitate.
Hydrochloric acid,	White curdy precipitate, soluble in ammonia.
Zinc or copper,	Precipitates white metallic silver.
Sulphate of iron,	In neutral solutions, white metallic silver.

3. *Platinum.*—This is another metal frequently associated with gold; and as it is one of the noble metals, and ranks in price between silver and gold, an ore which contains it in any considerable quantity is of great value. The specific gravity of platinum is about 21·5, and is, therefore, greater than that of gold. In short, platinum is the heaviest of all known substances. It is of a light steel-grey color, less ductile than gold or silver, but more tenacious, and will support greater weights on equal thicknesses of wire than any metal except iron or copper. It is distinguished from gold not only by its color, but also by its extreme difficulty of fusion; it does not melt by itself in the highest heat of a furnace, but softens sufficiently to admit of forging and welding, and in the arc of flame of the voltaic current, or before the oxyhydrogen blowpipe, it admits of being fused even in considerable masses. On the other hand, it resembles gold not only in its high specific gravity, as already stated, but also in the fact that it resists the action of all the simple acids, and is soluble only in aqua regia. This circumstance, together with its great infusibility, renders it importantly useful in many of the arts, and indispensable for various purposes in the chemical laboratory. It is the metal universally employed for apparatus which requires to be exposed to high temperature and powerful chemical agencies, without undergoing any change. It is, therefore, very desirable, as Dr. LYON PLAYFAIR has remarked, that those who go to the gold regions should look well for this precious metal, as it is likely to escape

the notice of the common observer from its less glittering appearance.

There are, however, certain chemical reactions by which platinum may be readily distinguished and separated from the gold in solution. Sulphate of iron and oxalic acid, which precipitate gold, do not precipitate platinum. When the latter is dissolved in aqua regia, and the acid neutralized by carbonate of soda, it is deposited as a black powder, if the mixture be boiled with tartaric acid and soda—the ingredients of a Seidlitz powder. Further, the addition of chloride of ammonium and alcohol to a strong solution of platinum, causes the deposition of a yellow crystalline precipitate, which is characteristic of this metal. These and other reactions may be summarily stated as follows:—

TESTS FOR PLATINUM.

Tests or Reagents.	Results.
Chloride of potassium or chloride of ammonium,	Yellow crystalline precipitate produced readily by the addition of alcohol.
Potassa or ammonia,	With chloride of platinum acts like the chlorides of potassium and ammonium.
Carbonates of potassa and ammonia,	In chloride solution yellow precipitate.
Carbonate of soda,	No precipitate.
Sulphate of iron,	No precipitate.
Oxalic acid,	No precipitate.
Protochloride of tin,	Dark-brown red coloring, no precipitate.
Sulphide of hydrogen and other sulphides,	Dark-brown nearly black precipitate.
Tartaric acid and soda,	On boiling, metallic platinum falls as a black powder.
Zinc,	Slowly precipitates metallic platinum as black powder.

Application of the Reagents.—Having thus described the properties and characteristic reactions of the different metals which it is desirable to look for as being frequently associated with gold, let it now be assumed that the substance to be examined is a piece of auriferous quartz. This must be first reduced to powder, and then boiled for some time in an earthenware or glass dish with aqua regia. The solution is then diluted with water, passed through a filter, and allowed to cool. If any silver be present, it will remain in the filter as a white precipitate, mixed with the quartz.

To the liquid which has passed through the filter, a solution of carbonate of soda is now added, until no more effervescence takes place. This will precipitate all the other metals which may be present except gold and platinum. These will remain in solution.

The liquid is again filtered, and a solution of oxalic acid is added until it ceases to produce effervescence, and has a sour taste; then boil; if there be any gold present, it will be precipitated as a black powder. The platinum, if any be present, will still remain in solution.

Decant or filter the liquid from the gold precipitate, and add to the former protochloride of tin, when a reddish-brown coloring will appear if platinum be present. Or, by boiling with tartaric acid and soda, the platinum will be thrown down as a black precipitate.

It has been stated that if any silver be present, it will be found on the first filter, mixed with the quartz. Wash this with ammonia, which, if copper be present, will produce a deep blue tinge. To the solution which comes through, add hydrochloric acid until the smell

disappears, and the silver will be thrown down as a white curdy precipitate.

It is evident that other methods and reagents may be adopted. For example, the original solution in aqua regia may be concentrated by evaporation, until it is very much reduced in quantity; then add about three-fourths of its bulk of spirit of wine, and, lastly, a saturated solution of chloride of ammonium. By these reagents the platinum will be thrown down as a yellow crystalline precipitate, while the solution filtered from this, and treated with sulphate of iron or boiled with oxalic acid, deposits gold.

By carefully weighing the gold obtained, the amount present in a given quantity of the ore or alloy may be exactly determined; but full details of the different methods of conducting the quantitative examination, including the assaying of gold ores and alloys by the dry process, will, to avoid repetition, be postponed to the close of the article.

GOLD-DIGGING TOOLS.—When the fact has been ascertained that a rock or soil really contains gold, and this in sufficient quantity to repay the labor of extracting it, the first operation is that of digging the soil or reducing the rock to fragments, with a view to its preparation for the subsequent processes. For the former of these purposes, the spade, the hammer, the pick-axe, and other common tools are employed; but for the special use of the gold-digger, who cannot conveniently carry a complete assortment of these, an ingenious combination of five tools, adapted for a single handle, has been contrived by Mr. T. LEE of Birmingham. Four of these are represented in the three annexed cuts.

Fig. 216.

Fig. 218.

Fig. 217.

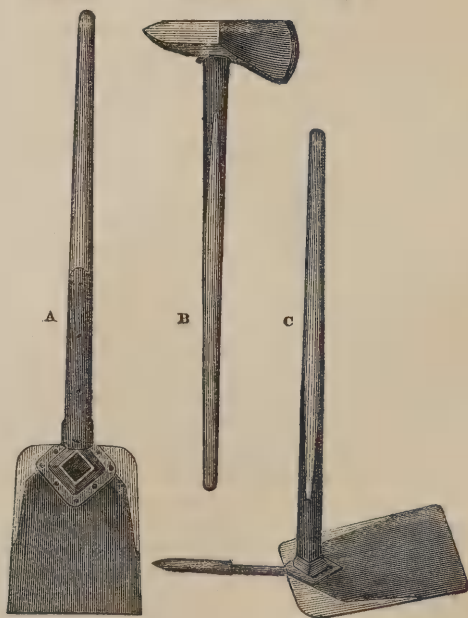


Fig. 216 is a steel shovel, with loose handle fitted to it, to suit all the varieties. Fig. 217 is the same shovel, altered for use as a pick and scraper; this alteration is effected by withdrawing the prong of the pick from a

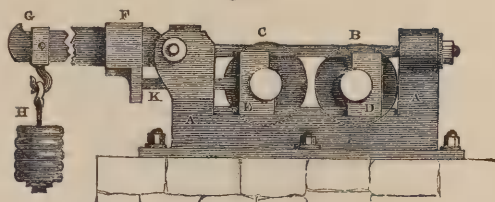
hollow socket made in the handle for its reception, and fitting the end of the handle into the eye shown in the shovel. Fig. 218 is the same handle fitted with an axe, formed with a pointed hammer, for granite-breaking. A fourth arrangement admits of forming the fifth tool, a powerful crow-bar, by fitting a short additional bar to the universal handle. Armed with this combination-tool, as the inventor terms it, the gold-digger is independent of the extensive array of ordinary implements; since, with the form of the apparatus represented in Fig. 217 on his shoulder, and the axe-head and short point of the crow-bar in his hand, he may journey freely to the scene of his operations; and when he commences work he is ably assisted by the peculiar fitness of the several combinations for the purposes of excavation. The incessant hard work of a pick rapidly wears away its point; but the combination-tool makes provision for one or more extra points to fit on the end of the pick. These are of small weight, and may be carried in the pocket. The pick, working in conjunction with the steel plate of the shovel, which is in the position of a scraper, to remove the loosened earth, effects a saving of time, while the quick change from one tool to another causes but little delay, in proportion to the convenience secured by the great portability of the arrangement.

MECHANICAL PREPARATION OF GOLD ORES.—Before subjecting the ore, or the auriferous gangue, to the chemical or metallurgical processes by which the gold is extracted, it has certain mechanical operations to undergo, the number and nature of which will be determined by the character of the ore itself, and its state of aggregation. The metal is rarely found in the shape of large nuggets, requiring only to be cast into ingots. It is generally either in the shape of dust, or spangles, or small grains intimately mixed with the quartz rock or the alluvial soil; and though far the greatest amount of gold is obtained by the direct washing of alluvial deposits, yet, as a considerable and perhaps increasing proportion is extracted from the solid rock, it seems to be the natural order to begin with those operations by which the rock is artificially reduced to the state of an auriferous sand or pulverized ore. These operations are *crushing*, *stamping*, and *grinding*, and are usually conducted by regularly-established mining companies, while individual diggers confine themselves to the washing of soils on which the same operations have already been performed by nature.

Crushing.—To reduce the fragments of ore, as obtained from the mine, to the proper size for their subsequent mechanical concentration, it is obvious that various arrangements may be employed, although in every instance the principles involved must be very nearly the same. For this purpose, the machine represented in Fig. 219 is frequently used, and consists of two large cylinders or crushing rollers, B, C, of cast-iron, moving in contrary directions in a strong iron framework, A A, secured to a solid wooden frame by means of screw-bolts. The bearings, D, E, of the rollers are so arranged as to slide in grooves, and consequently admit of the cylinders being either brought nearer to each other or separated to a greater distance. To admit of

the passage of large pieces of stone too hard to be broken, a certain elasticity is given to the machine by means of the lever, F G, which, by a sliding bar, and

Fig. 219.



the shoulder, K, constantly tends to keep the surfaces of the two grinding cylinders in contact, being loaded at its extremity with a heavy weight, H, which is adjusted to the hardness of the mineral to be broken.

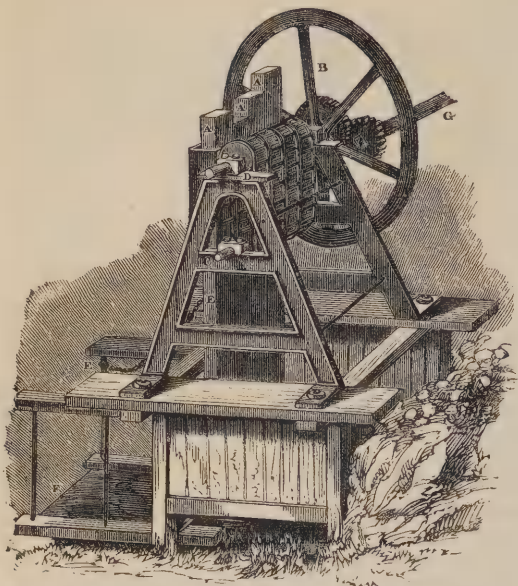
After passing between the rollers, the crushed ores fall into the upper end of an inclined cylinder of coarse wire gauze, similar in construction and operation to that which is described in Vol. I., p. 169, in connection with the alum manufacture, and is there represented on the right hand side of Fig. 97. This cylinder receives an oscillatory motion from the same steam or water power which impels the rollers, and divides the pulverized ore into two classes; that which passes through the meshes of the gauze falls on the floor of the building, whilst those grains which are too large to pass through the sieve are carried out at its lower end, and fall into the buckets of an endless chain, by which this portion is again brought to the level of the hopper over the rollers for the purpose of being subjected to another crushing.

Stamping.—When the ore is required to be reduced to a finer state of division than can be readily effected by means of the crushing rollers, it is usually subjected to the pounding action of large wooden pestles, armed with iron heads, and moved either by steam or water power. The vertical wooden beams of which the pestles consist, are placed in a row, and are successively raised by cams fixed around a movable axle, so as to correspond with tongues attached to the pestles themselves. The cams are so arranged in three spirals that each pestle shall give three blows during each revolution, and as soon as the first in the series has been released from its cam, and begins to fall, the second cam of the same spiral comes in contact with the tongue of the next pestle; and so on until each has successively struck a blow, when the first pestle is again caught by the first cam belonging to the second spiral, and another series of rapid blows is given. The size of the iron stamp-heads varies according to the nature of the mineral to be broken; but their general weight is from three hundred to four hundred pounds.

In some of the more modern stamping-mills, both the axles and pestles are of iron; and a great improvement in the method of lifting the pestles has been recently effected by Mr. WALKER, of London, who substitutes a series of endless chains for the axle, and thereby increases the height of the fall of the pestles to any required extent. This arrangement is shown in Fig. 220, where A A A represent three of the pestles, while the top of the fourth is nearly on a level with the

collar through which they pass; and B denotes the endless chains revolving on the axles, C, D. When motion is given to the machine, the pestles are successively

Fig. 220.



raised through the whole distance from C to D, by projecting links on the chains, which are caught by tongues on the pestles, and these tongues are so arranged that each of them may in rotation be raised and released, as in the case of the spirals already described. A rapid succession of blows is thus struck; and each of the pestles when released falls on the mineral placed below with its whole weight, to which much additional force is given by the impetus acquired in descending through the space, D C.

In Mr. WALKER'S arrangement, as in the older stamping-mills, the minerals to be pounded are placed in a large wooden trough, in which are openings provided with sieves, or strainers, made by punching small holes in thin sheets of iron. The pulverized ore is carried through these sieves by a current of water admitted into the trough, which is then conducted over an inclined table, F, set in motion by the chain, E. The heavier and richer portions accumulate on this table, whilst the lighter are washed away into a series of reservoirs, in which they subside in the order of their specific gravity. The machine may be worked either by the hand or by steam or water power.

Grinding.—If it be deemed desirable to reduce the ore to a still greater degree of fineness, any form of apparatus, commonly used for grinding, may be employed. In Mexico the sands obtained from the stamping-mills are afterwards ground, with water, in a machine similar to the common mill-stone. Edge-stones, resembling the apparatus represented in Vol. I., Fig. 97, are also employed for the same purpose. It is necessary, however, that the grinding-mills be either of iron or granite. In the stamping-mill, the ore is already reduced to the state of sand; and, therefore,

the further pulverizing, if thought necessary, is usually associated with the operations of washing and amalgamating.

Washing.—It has been stated, that the greater portion of the gold is obtained from the alluvial soils or sands, on which nature has already performed the operation of crushing or pulverizing the rock. In general, therefore, the washing process is that with which the gold-digger commences; and this, indeed, together with the labor of extracting the soil from the pit, or from the bed of the stream or river, is the only operation usually resorted to for procuring the gold dust or nuggets which are sent from Australia and California. At the same time, the further process of amalgamation, when it can be conveniently employed, extracts the auriferous particles more thoroughly. These two processes—washing and amalgamation—which now remain to be described, are equally applicable to the pounded or pulverized rock, and to the auriferous soils which constitute at present the chief source of the supply of gold. The absolute necessity of washing the soil, to procure the precious grains, even when amalgamation is subsequently resorted to for more effectually extracting the metal and removing impurities, teaches the great importance of opening the pits or diggings in a situation where an ample supply of water can be obtained.

Hand-Washing.—The operation of hand-washing, which is the simplest method of separating the gold dust or grains from the soil, in a state of greater or less purity, has been already described. This method is extensively practised in South America, and the instrument employed is a round iron or zinc pan, Fig. 221, shallow at the sides, but sinking into a deep cavity in the middle, where the heavy particles of the gold accumulate, during repeated washings, which carry off the earth or stony matters. The gold is still mixed with impurities, from which it is ultimately separated by amalgamation.

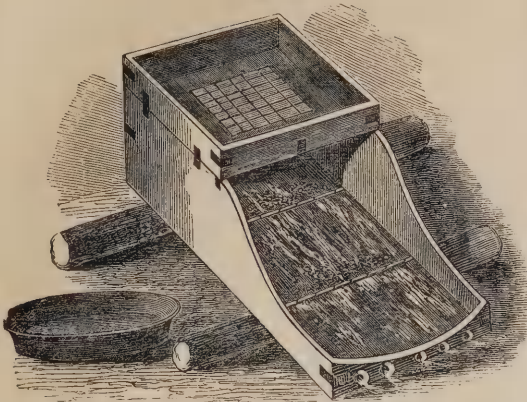
Fig. 221



The Cradle.—Next in point of simplicity to the pan or basin, is the cradle, or rocking machine, which is much used in Australia and California, and is so named from its resemblance to the common article of domestic furniture. It consists, as shown in Fig. 222, of a wooden or tin trough, six or seven feet in length, under and across the bottom of which two curved bars of wood are fixed, to serve as rockers. Sometimes it is suspended by ropes from a cross-bar, supported at each end by two poles. The cradle, whether suspended or resting on the ground, is made to have a slight inclination from one end to the other, to allow the water to run off. At the upper end is placed a sieve, or coarse grating, on which the sand to be washed is charged; and the interior of the bottom of the vessel is provided with a few transverse bars, to arrest the heavier particles in their descent, while the water and lighter matters flow off. Four men are required to work this apparatus efficiently—one to dig and collect the auriferous sand, another to carry it to the cradle, and deposit it on the grating, a

third to rock the trough, and a fourth to attend to the supply of water, and the uniform washing of the material. The grating intercepts the stones and coarser

Fig. 222.

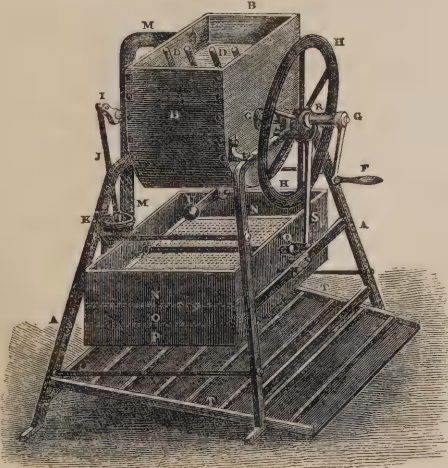


gravel; the earthy matters, containing the particles of gold, pass through; and the latter, with the heavy ferruginous sand, are arrested by the transverse bars, while the lighter portions are carried down by the water to the lower end, which is left open, or where a perforation is made to allow the current to escape.

After continuing the operation, with repeated charges of the auriferous sand, during a sufficient period, which will vary according to the richness of the material, the concentrated ore which has accumulated behind the bars of the cradle, is collected in a tin pan, shown in the same figure, and after being dried in the sun, the lighter impurities still remaining are removed, by blowing strongly on the mixture with a pair of bellows or otherwise.

Gold-Sifter.—A more refined apparatus, for washing and sifting the auriferous ore, which was registered by

Fig. 223.



Messrs. LAMBERT and DANBY of Liverpool, is represented in Fig. 223. It consists of an open frame, A A, carrying a receiver, B B, in which is a revolving barrel, set with a series of pins, D, working in gear with other

corresponding pins, which are made fast in the receiver. The pin-shaft, G, which carries a fly-wheel, H H, is driven by the winch F. The other end of the shaft works a crank, I, from which a connecting-rod, J, passes down to a pump, K, for supplying water through the pipe, M M, to the working-chamber. Beneath the latter is a box, containing three separate sieves, N, O, P, of graduated fineness, and made to oscillate by a lever arm at Q, acted on, through a rod, S, by an eccentric, R, on the shaft, G. At the foot of the frame is an incline, T, for running the water away into the reservoir—strips of wood being set across it, to arrest any small particles of gold which may escape through the last sieve. At U is a valve, beneath the receiver, B, for discharging the agitated mass upon the sieves.

This is a very complete and easily-worked machine. By the simple turning of the winch handle, not only is water supplied in abundance, either from a river or cistern, but the mass is well comminuted, intimately mixed with the water, and reduced to an impalpable slime by the action of the pins, D; so that when accumulated in sufficient quantity to force a passage through the valve, U, the great body of the mixture readily passes through the sieves, and flows away into the reservoir, leaving only the grains of gold and other hard substances which cannot penetrate the meshes, while the finer particles of the precious metal, or what may be termed the gold dust, collect by their superior gravity behind the transverse bars of the incline, T. The series of graduated sieves is important for assorting the particles of gold, and the stony or earthy matters with which they are mixed, into grains of different sizes—the product or contents collected in each sieve being nearly uniform. This greatly facilitates the ultimate washing; for when the grains of an auriferous mixture are of different sizes, the smaller surface of one fragment, in proportion to its weight, compensates in some measure for the greater density of another grain, and thus causes it to assume a position in the series of deposited layers, to which, by its constitution, it is not entitled. This difficulty is found to constantly occur in practice; and it is with the view of obviating it as much as possible that care is taken, in the best machines, to separate, by means of sieves, into distinct parcels, the fragments which have nearly the same size.

Methods of Washing in Brazil.—In Brazil, the excavations and river-washings are entirely conducted by negroes, who are furnished with a large wooden bowl, about two feet in diameter, and nearly one foot in depth; as also with a leathern bag, which is tied before them, for the reception of the particles of gold dust collected, after repeated washings, in the bottom of the bowl. Sometimes, however, the final washing of the auriferous sands is conducted in long shallow troughs, the bottoms of which are covered with coarse baize, or with skins tanned with the hair on, and placed with the grain against the current of water. The baize, or skin, is at short intervals removed from its frame, and beaten over a shallow tank, containing water; it is then carefully washed in the same vessel, until every particle of the gold is removed, after which it is replaced in the trough for receiving the auriferous sands, already partially washed. To obviate the inconvenience of so frequently

removing the skin or cloth from the vessel in which the washing is conducted, an endless web of the same material has lately been introduced, which is made to move by means of rollers impelled by the water-wheel employed for stamping the ore. The motion communicated in this manner is opposite to that of the stream of water flowing over the table; and while the upper portion moves upon this table, extended between the two rollers, collecting, in its progress against the stream, the particles of gold, the lower or returning portion hangs down loosely, and is drawn through a vessel of water, in which the gold is washed off and collected.

Methods of washing in Hungary and the Ural.—In Hungary and the Ural the methods of washing are various, but the principle generally adopted is that of inclined troughs or tables, traversed by transverse grooves—a principle adopted in the cradle, and almost all other washing-machines. On the large scale, however, these inclined tables may be compared to the apparatus for washing coal, represented in Fig. 74, at page 95 of this volume. The sand to be washed is placed in the

first groove of the series, and is there exposed to a current of water, until the gold, mixed with a portion of ferruginous sand, alone remains in the furrows. The concentrated ore is then removed into flat wooden basins, in which the impurities are gradually separated by repeated washings, or these may be removed at once by amalgamation.

Among the different methods adopted in the Ural districts, there is one by AGTÉ, in use at Alexandrowsk, which is precisely similar in principle to that above described, though somewhat more complex in the arrangements. These are represented in the annexed engraving—Fig. 224—where B is a conical cylinder of sheet-iron, about eight feet in length, and having a mean diameter of about three feet six inches. This cylinder is pierced with holes of about half an inch in diameter, and is fixed on a spindle communicating by a train of wheels and shafts, with a water-wheel, horse gin, or any other prime mover, from which it is capable of receiving a rapid rotatory motion, so as to make from thirty to forty revolutions in a minute. A crank on

Fig. 224.



the shaft which communicates motion to the cylinder, works the double pump, C, at the back of the frame, which raises water from a well or some other convenient reservoir to the cistern, D, and from this it is conducted by pipes into each end of the cylinder, B. The ends of the cylinder are open, and the pipes are so arranged as to diffuse the water pretty equally over its interior surface. Nearly on a level with the top of the arrangement is a line of rails, on which the auriferous sands are brought in wagons to the hopper, E, from which they fall into the smaller end of the revolving cylinder. The latter by its centrifugal action ejects through its numerous perforations the water and finer particles of sand and gravel, which are received upon the inclined platform below, whilst the larger fragments are carried down to the under end of the cylinder, and there fall into a box which does not appear in the engraving. Any gold nuggets which may be mixed with these fragments, being well washed and burnished in their

gradual progress through the cylinder, are now readily perceived and picked out. The platform, which receives the water and auriferous sand expelled through the holes in the cylinder, is provided like the cradle, the sifter, and the arrangement last mentioned, with numerous cross bars, for the purpose of checking the current, and arresting the heavier particles of the ore; and after traversing this platform, the current descends to a concave table or tye, G, which is also furnished with a series of wooden bars, at intervals of two or three feet. The sands which have arrived at this part of the machine are kept constantly stirred or agitated by square frames carrying blunt iron knives, and suspended, pendulum-wise, by vertical bars, H H, from a wooden axis above the tye, turning on gudgeons, and placed in the direction of its length. The frames are made to fit into the cavity of the tye, and a swinging alternating motion is given them by means of the rods, L L. In this way the sands are well stirred; and while the heavier or

richer portions are retained and accumulated behind the check-boards, the lighter materials are carried away with the current at the lower end, &c, of the tye or buddle, from which, if not sufficiently impoverished, they are received on a fresh series of tables, furnished with similar agitating apparatus, and are finally allowed to pass off. This machine is able to operate on two hundred tons of alluvial sand in the course of an ordinary working day of ten hours, with the labor of twenty men and six boys, including ten men for removing the waste, if in a level country, without advantages for otherwise clearing it away.

The partitions in the bottom of the tyes are ribs of two inches high and two and a half inches wide, held by screw-bolts and nuts, and are removed every now and then for the washing out of the concentrated auriferous sand. This is done the more frequently in proportion as the sands are richer in gold.

Fine Washing.—The gold obtained from all the preceding operations, is still so much mixed with sand and other substances, as magnetic iron, pyrites, *et cetera*, that it requires to be further concentrated, either by additional washing or by amalgamation. The powder collected in the buddles or tyes is commonly of a grey color, and is termed *grey schlich*. By the cylindrical machine above described, the original ore or auriferous sand is concentrated to about three tons of schlich for every two hundred tons of the crude material employed. For its further cleaning and concentration by washing, it is treated on uncovered tables or frames, seven to ten feet long, by three or four broad, and divided into an upper and lower part by a lath nailed across the bottom. Also, across the upper part, are fixed two boards, which regulate and equalize the flow of water. The schlich to be washed is placed upon the upper division, and the workman, standing upon the frame in wooden shoes, mixes the sand with the water, and gently moves it against the current, towards the head of the arrangement, with a small wooden hoe or heath-broom. The gold thus arranges itself chiefly near the head-board, and when a certain amount is collected, he rakes it with his hoe or broom, just strongly enough to draw down the earthy particles over the lath to the lower division, without disturbing the heavier and richer deposit. This delicate operation requires skill and dexterity, and must be continued till all the coarse fragments are removed, after which the flow of water is reduced. The workman, by light brushing, raises again all the slime which may still remain, and as much as possible of the magnetic iron ore, and takes up as the product of his manipulation the *black schlich* which is left. The upper department of the box being thus cleared, he now brings upward that which has settled in the lower part, and passes it once, twice, or thrice, through the same operations. This process, for which the most skilful and experienced workmen are required, is termed *fine washing*. The black schlich or ore thus concentrated is dried, and is freed from a further quantity of magnetic iron, by the use of an artificial magnet or a piece of loadstone.

The *gold troughs* used in Hungary and Transylvania for the final washing of the powder or schlich obtained from the cloth-covered tables already alluded to, as well

as the process of washing, are similar to those just described. In these countries a broom of heather or birch is generally used instead of the hoe; and in Transylvania the troughs, which are of larger dimensions, are fitted with two traps in their channels, into which the different qualities of schlich are swept at different stages of the process. Even after this fine washing, the resulting products are sometimes further concentrated in the bowl or washing-pan, and so reduced to a state fit for melting, or they are subjected to the process of amalgamation.

AMALGAMATION OF GOLD ORES.—The greater part of the gold of commerce is imported in the shape of dust, or small grains, extracted from the auriferous soil by the simple washings above described, and brought, by a frequent repetition of that process, to a state of sufficient purity to be immediately melted into ingots, more or less mixed with silver or copper. Sometimes, however, instead of the tedious process required to bring the gold by mere washing to that degree of concentration which is necessary for its subsequent fusion, the purification of the gold by this method is only carried to a certain point, and the operation is concluded by amalgamation, or, in other words, by mixing the partially-concentrated ore with mercury, which seizes on the particles of gold, and thus completely separates and extracts the precious metal from the soil or gangue in which it is found.

It may be laid down as a general rule that amalgamation would be advantageously resorted to in all cases, as the finishing process in those operations which precede the metallurgical treatment of gold. By no other method can the precious metal be thoroughly extracted from the gangue, and so effective is its action, as compared with mere washing, that it has often been applied with success to extract a remunerative return from the refuse or waste sands which have passed through the gold-digger's cradle. Its profitable application, however, will depend on the nature and richness of the auriferous soil. If the gold is abundant, and is found in considerable grains, as in many parts of the recently-discovered gold regions, the greater and most valuable part of it is readily separated, and easily concentrated sufficiently by mere washing. On the other hand, if, as often happens, the gold is diffused through a dense and heavy gangue, in particles so minute as to be invisible to the unassisted eye, it is evident that these particles will float away with the current when the sand or crushed ore is washed on inclined tables, and that their extreme minuteness will counteract the effect of that difference in specific gravity by which it is so easy to separate the larger grains when diffused through a less dense soil. On the whole, therefore, while amalgamation must be applied in all cases where it is desired to extract, practically, the whole of the gold, it is more especially applicable to its extraction from quartz rock, from heavy pyritous ores, and from other descriptions of gangue, through which it is diffused in a state of extreme division. And as the mercury exerts no chemical action, but may be again separated from the gold with little loss, the advantages afforded by the great efficiency of this process are not materially restricted by economical considerations.

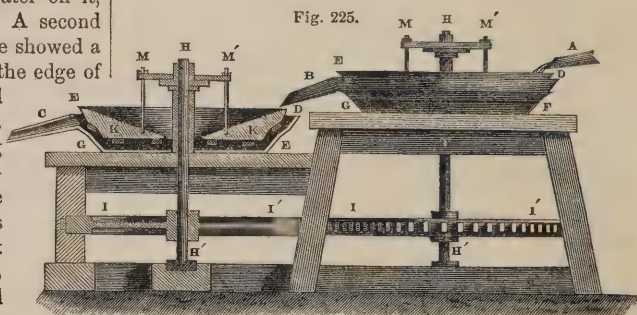
From the nature of the ore which is usually treated by amalgamation, this operation is generally associated with the preliminary processes of stamping or grinding, as well as partial washing. One of the simplest and most primitive methods adopted is described by Mr. W. B. ADAMS as having been witnessed by himself, in the course of a week's trip which he made with a South American *cateador* or gold-mine hunter, for the purpose of acquiring information. When the travellers had passed the extreme limit of vegetation, and entered a narrow ravine between lofty ridges of hills, the *cateador* began to examine carefully the stones at his feet, which became more and more abundant, till nothing was seen but clay-slate shingle. On the second day, after turning up another ravine, he picked up a stone, which he examined with some attention, and then went on. About mid-day the travellers stopped, and the gold-hunter picked up a fragment of quartz from amidst a great variety of stones. He then placed it on a flat piece of rock and pounded it, and ground it to powder, which he placed in a horn, and poured some water on it, shaking it about with a peculiar motion. A second and a third water were added, and finally he showed a fringe of fine gold on the black horn, along the edge of the quartz sand. No vestige of gold could be observed in the quartz before grinding. Satisfied with the result, he went on tracking the fragments of quartz, till at last the travellers came to the vein, in granite rock. He selected a few pieces, which he put in his wallet, then piled up some stones to mark the spot, and they set out on their return home. In a neighboring valley, he exhibited his stones to a proprietor, whose business it was to extract gold from quartz, and sold him his discovery for the sum of twenty-five dollars.

The mode of extracting the gold was very simple, and is thus described. A vertical running-stone traversed in a circular stone trough. Quartz, broken to the size of walnuts, was thrown into the trough, with several pounds of mercury. A small stream of water trickled into the trough, and flowed over at a particular spot, carrying with it the finer ground particles. At the depth of a foot it fell into a goatskin bag, with some quicksilver in it; thence into a second, third, fourth, and fifth bag, as long as any fall could be obtained. After working several hours, the mill was stopped, and all the mercury collected in a long narrow linen bag. Into this it was forced with a stick, and then the bag was squeezed till all the uncombined mercury passed through, and only the amalgam of gold was left. This was placed on a piece of strongly-heated iron, resting on a brick standing in water. An earthen cupola was laid over the whole, forming a water-joint at bottom, and the neck of the cupola descended into water. Thus the fumes of the mercury, sublimed by the hot iron, were condensed and collected in the water, and the metal saved. The spongy gold, called *pine-gold*, was left on the iron plate.

In Piedmont, where veins of auriferous pyrites have been worked from a very remote antiquity, the extraction of the gold is effected almost entirely by amalgamation. The produce is very variable in different

localities, but averages about twenty shillings in value from 150 pounds avoirdupois of the auriferous ore. The amalgamating mills are erected in great numbers on the banks of the various rivulets which traverse the mountains. These establishments usually consist of small wooden buildings, each of which contains four amalgamating machines. They are erected at intervals over the whole length of the valley of Anzasca, from Chamnaga to Pie di Mulera; and in this valley there are more than two hundred mills procuring a remunerative return from a very poor soil, by the process of amalgamation.

The ore or mineral, when extracted from the mine, is first subjected to a grinding or triturating process in a machine resembling in its action and operation the common millstone, and driven by a water-wheel. When thus reduced to powder, it is carried off by a stream of water to the amalgamating mills, represented in Fig. 225. Whilst held in suspension in the water, it is conducted first to the upper mill by the spout A, from



this to the second by the spout B, and so on in succession through the whole series. Each mill consists of a cast-iron basin, D E G F, fastened by screws to the top of a strong frame or table, and fitted in its centre with a tubulature, traversed by the axis H H', moved by the toothed wheel I I', and with which revolves a wooden muller, K K, fixed to the upright spindle by the iron collar M M'. This movable part of the mill has externally the same form as the internal cavity of the fixed iron casting, G, in which it revolves horizontally, at the distance of about half an inch from its surface; at the same time it is furnished with several iron ribs, which come nearly in contact with the interior of the casting. The rotating muller is made of hard wood, and is hollowed out like a funnel, in which the auriferous slime accumulates, and gradually penetrates into the interval between its external surface and the bottom or interior surface of the iron basin, from which it flows to the next mill by the spout B or C.

In the bottom of the fixed vessel is put about half a hundredweight of mercury, which lies to the depth of about half-an-inch, and when the machine is set in motion, the pounded mineral is constantly agitated and mixed with this fluid metal by means of the iron ribs nailed to the bottom of the muller. The minute particles of gold are thus immediately dissolved and taken up by the mercury, while those which escape combination in the first mill are arrested and retained by the second, third, or fourth of the series.

After working the mills continuously for several weeks, the time required being longer or shorter according to the richness of the mineral under operation, and when the mercury is judged by the workmen to be sufficiently charged with the precious metal, the mills are stopped, and the amalgamated mass is taken out. It is important not to protract the process unnecessarily, otherwise a serious loss of mercury is sustained, occasioned, perhaps, by its partial conversion into a sulphide, which is carried away with the current. The mercury, when drawn off, is washed, and then strained or filtered through a piece of chamois skin, for the purpose of obtaining the solid amalgam, which usually contains about one-third of its weight of pure gold. This is separated from the combined quicksilver by distillation in an iron retort, the beak of which dips into a vessel containing water. The whole of the mercury in actual combination with the gold is thus recovered, and the only loss sustained is that which has been carried away by the current in the shape of sulphide and otherwise. DUMAS states that the loss incurred in this manner is equal to about one-fourth of the quantity employed; but so large a waste must result from careless manipulation.

In the Salzburg Alps, the gold ore is worked in lodes or veins, and the precious metal is separated by three processes—washing, roasting, and amalgamation. It is chiefly in actual *mining*, not in what is popularly known as *digging*, that the latter two operations are brought into requisition. The mineral extracted from the lodes, in the locality above-mentioned, is divided into two classes or qualities—first, that which is so poor in the precious metal that the grains or particles are not visible; and, second, that in which the golden grains may be detected. Both are crushed or stamped; but in treating the former this operation is preceded by roasting, to facilitate its pulverization under the action of the stamps. This roasting, though not practised at all the mining establishments, is useful, not only for the purpose above-mentioned, but also for converting the sulphides and arsenides into fine light oxides.

The mineral, whether roasted or not, having been passed under the stamps and well ground, is washed first on movable inclined tables, and then in wooden hand-bowls. The gold is thus obtained in a state of considerable concentration, and then the work is completed by amalgamation. In the Salzburg country this last operation is conducted in a peculiar manner, and requires a machine constructed with much care, somewhat resembling in its principal parts the common flour mill. The upper mill-stone revolves horizontally in a hollow cylinder, and over it is placed a hopper, which can be depressed or elevated at pleasure. The object of this hopper is to spread over the mill-stone a uniform layer of mineral. Below are placed three iron cylinders, in which the amalgamating mills revolve, with their axes resting on bearings which admit of being raised or depressed according to the nature of the mineral under treatment. Water is admitted by a stopcock into the upper mill, where it is intimately mixed with the mineral into a slime or paste, and from this it descends to the amalgamating mills by an inclined plane terminating in three pipes or gutters, which

divide it equally between the three cylinders. From these the fluid amalgam is conducted by a second inclined plane to a washing apparatus.

The process begins with pounding and washing. The mineral, thus pulverized and partially concentrated, is then mixed with a certain quantity of chloride of sodium and thrown into the hopper, from which it descends over the inclined plane into the hollow cylinder containing the large mill-stone. When the hopper is emptied of the first charge, more mineral is poured in till the upper cylinder is full, and then water is admitted, which carries the auriferous slime, so formed, over the second inclined plane into the three amalgamating mills below. Before introducing the quicksilver into the cylinders containing these mills, the machine is allowed to work on the mineral for the space of two hours; the mercury is then added, in quantities of about fifteen to eighteen pounds at a time. The quantity of mercury, water, and mineral introduced should be in the proportion of fifty, thirty, and one hundred; or, in other words, *for every hundred pounds by weight of the mineral, there ought to be fifty pounds of quicksilver, and thirty of water.* In some establishments, a quantity of mercury equal in weight to that of the mineral is introduced, and the work proceeds with all the greater certainty, although the waste or loss of mercury sustained may in this case be more considerable.

In this operation the amount of water introduced is not a matter of indifference. If it be too small, the mixture will be pasty, the motion of the mill will be obstructed, and the ore will adhere to the sides of the cylinders, without undergoing amalgamation. If, on the contrary, the mixture be rendered too fluid, the particles of gold and silver, which are generally found together, will be carried away too rapidly, and in this case also will escape combination with the mercury.

On the other hand, it is evident that an adequate supply of the fluid metal is a point of the greatest importance, as it acts on the gold only in proportion to the extent of surface which it exposes to the mineral. To enlarge this surface, the vessels in which the amalgamation is conducted have latterly been formed like an inverted cone, terminating in a hollow sphere. It is with the same object in view that a rotatory motion is given to the mass; for the centrifugal force thus communicated raises the mercury against the sides of the cylinder or cone, which widens or expands upward so as to increase the extent of surface exposed, and then the mercury falls back again into the mass by its own weight.

Although the numbers given above may convey a general idea of the proportions of the three ingredients to be employed, it deserves to be remarked, that these must be varied according to the nature of the mineral under treatment, and that indeed the quantity of mercury should be proportioned rather to the bulk or volume of the ore than to its weight. The lighter the ore, the more space will it occupy in the cylinders; and as the mercury should rise over the mass, more of it will be required in this case to insure its union with the gold or silver present. If the mercury be in small quantity, the amalgam is not sufficiently fluid, and is partially converted into a dust or

frothy substance, which flows away with the water when the latter is allowed to escape from time to time, so that a considerable loss is sustained both in gold and quicksilver. If, on the contrary, the quicksilver be present in excess, the gold combines with it more rapidly and more thoroughly; the amalgam remains fluid, and readily separates from the other materials with which it is mixed. It is therefore by no means economical to stint the supply of mercury.

There are some indications by which a judgment may be formed as to whether the mill is operating in a satisfactory manner. If particles of gold, not amalgamated with the mercury, are observed in the cylinders, this is a proof that the millstone is too high, and does not come into close enough contact with the mineral, in which case the mercury, not being agitated, remains inactive at the bottom of the vessel on account of its superior gravity. If, on the contrary, a quantity of quicksilver-dust and frothy amalgam be observed on the cylinders, this is an evident sign that the former has ceased to absorb the gold, and that more must be added.

It usually requires about sixteen or eighteen hours to complete the amalgamation. The final washing is then proceeded with, and is effected by a current of water, which carries away the earth, and purifies the amalgam from those substances not combined with the mercury. This operation is performed in a wooden vessel of a conical form, the bottom of which slopes to the centre, and is fitted with a stopcock. A circular movement is given to this vessel, that the mass may be kept in a state of agitation, and the lighter parts carried away by the current of water admitted, while the amalgam falls by its own weight to the bottom of the vessel. This operation is repeated several times.

When the washing is concluded, the next and last step in this process is the separation of the mercury. With this view the liquid amalgam is put into a chamois-skin or woollen bag, and well squeezed. The mercury which passes through the skin or cloth, still retaining a small quantity of gold, is carried back to the cylinders to be employed in amalgamating the next charge. There remains in the bag a semi-solid amalgam of gold, which is put aside for distillation. By wetting the bag which is to be used for straining, a larger amount of amalgam remains, and the mercury which passes through carries with it less gold. When the solid amalgam is very pure, it is rather white in color; but when alloyed with lead or copper it is less so, and does not produce the same crackling noise when crushed or broken. The amalgam, as in the other cases already mentioned, is deprived of its mercury by distillation; or, if a small portion of that metal still remains, it is expelled in the subsequent fusions to which the gold is subjected with a view to its final purification.

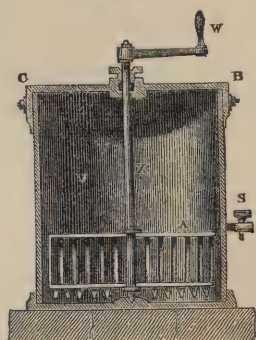
The preceding process, which is practised, as already stated, in the Salzburg Alps, presents some peculiarities. The amalgamating mills are somewhat similar to those employed in the Tyrol, but these mills are fed in a different way, and a larger proportion of mercury is used. The last circumstance is highly advantageous, and ought to be imitated in all cases where the nature

of the gangue, or mineral under treatment, will admit of it; for, with an ample supply of quicksilver, the extraction of the gold is not only more rapid, but more complete. But, with a strongly pyritous gangue, like that of most of the Piedmontese mines, the employment of a large excess of mercury would seem to be productive of a heavy loss of that metal arising from its conversion into a sulphide.

For effecting the amalgamation of the concentrated auriferous ore or black schlich *by manual labor*, the machine represented in Fig. 226 is sometimes employed.

This consists of a species of churn, *v*, made of sheet-iron, through the lid of which passes a spindle, *x*, of the same metal, carrying a kind of paddle-wheel, *A*, which is turned by the winch-handle, *w*. The bottom of this machine is first covered to a small depth with mercury, and then the concentrated ore is added by an opening at the top in successive small portions, while, at the same time, the whole mass is continually agitated by stirring; and this process is continued till the mercury is judged to be sufficiently saturated with the gold. The amalgam is then taken out and treated in the usual manner, by washing, straining, and distillation.

Fig. 226.



It may be stated that the same apparatus is highly convenient for the original washing or concentration of the ore, or auriferous sand, and, when employed for that purpose, is familiarly known as the *dolly-tub*. In this case it is nearly filled with water; and whilst one man keeps the agitator in constant motion, another throws into it, in small portions at a time, the auriferous earth. When the full charge has been thus introduced, the cross-bar, *B C*, through which the spindle works, is removed, and the agitator is quickly taken out. The materials held in suspension are then allowed to settle according to their respective gravities, and, consequently, the gold, together with all the heavier particles, will sink to the bottom. When these have subsided, the water is drawn off by the stopcock, *s*; the upper portions of the deposit are cautiously removed and thrown away, while the heavier portions at the bottom are collected for further concentration, either by the hand-bowl or otherwise. But although the *dolly-tub* may thus be applied to the double use of a washing and amalgamating machine, it is less convenient for the former purpose than the cradle, and other kinds of washing apparatus already mentioned.

Another machine, which is easily worked by the hand, was contrived by Mr. BERDAN of New York, in the heat of the Californian mania, and is known as BERDAN'S Gold Ore Pulverizer and Amalgamator. In this machine, the pulverizing process is effected in a large hemispherical iron vessel, rotating on an inclined spindle, and having within it a weighty iron sphere, connected by a pivot and bearings set in an inclined

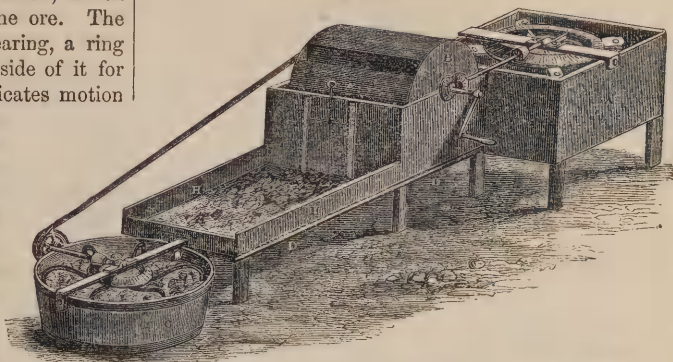
position loose upon the central spindle of the basin, in such a manner that its gravity causes it constantly to maintain the lowest possible position in the basin, whilst its axis of rotation, owing to the pivot connection, is inclined to that of the basin. The motion thus communicated to the sphere is not a mere rolling, but a species of spiral action, which is said to be very effective in reducing the ore. The basin is made to revolve by suitable gearing, a ring of teeth being cast or fitted on the outside of it for this purpose, and its revolution communicates motion to the sphere. A quantity of mercury is placed in the bottom of the basin, and the ore is reduced to powder entirely beneath its surface, being latterly washed away by a current of water which runs into and out of the basin, and is kept in a constant state of agitation by the motion of the vessel. As heat considerably strengthens the affinity of the mercury for the gold, a new and important feature was introduced into this machine by the employment of

a furnace in connection with the apparatus. This furnace or fire-place is of a conical shape, and rests by its lower smaller end on a collar upon the basin-spindle, just above the step. It was stated, though probably with much exaggeration, that while the machines previously employed extracted only from thirty to forty per cent. of the gold in a given quantity of quartz, the most searching chemical analysis was unable to detect any gold remaining in the *tailings* or waste matter from Mr. BERDAN'S machines, and that these, moreover, were very profitably employed in re-working the tailings from other machines. It does seem probable that the introduction of a furnace to heat the mercury might greatly increase the efficiency of this apparatus, and that the same improvement might be applied with good effect in other machines. At the same time, it is obvious that if caution is not exercised to prevent the heating of the mercury beyond a certain point, a very great loss must be sustained by its volatilization.

SMITH'S Portable Gold Amalgamator, which is represented in perspective in Fig. 227, also admits of being worked by the hand, and is designed for the use of emigrants, and the proprietors of mines and estates where gold may be supposed to exist. This machine is divided into three compartments. In the first, A, are arranged a set of powerful crushers, and a series of agitating plates, intended for stiff and hard clays; two or three revolutions reduce the matter to a floating pulp, which flows off through a pipe, DD, leading from this part of the machine to the amalgamator, C. The pipe is provided on its lower side with a series of boxes or valves, which can be opened or shut at pleasure, and only that portion of gold passes on to the amalgamator which cannot be detained in these valves. The second compartment, B, is constructed for the reception of the looser earth, and consists of a drum or barrel in which revolves an agitating apparatus. Nothing is allowed to leave this until it is perfectly worked, when the opening in the side of the barrel is turned downward, and all stones and other foreign matters are dis-

charged into the chamber beneath, in readiness for receiving a fresh supply of the auriferous earth. The chamber into which the contents of the barrel are thus discharged is relieved from time to time by raising a sluice; and the floating matter then passes over a long

Fig. 227.

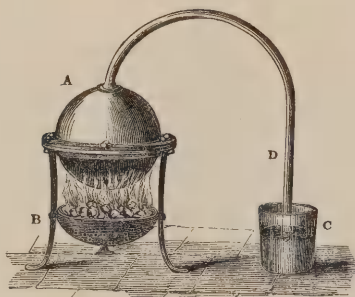


trough, H, provided with check-bars, to empty itself into the amalgamator—all solid particles being, in this case also, arrested in their passage from the washer, while, by a simple arrangement which it is unnecessary to detail, the action of the machine keeps up a constant supply of water. The third portion, C, of the machine, or that compartment which is properly the amalgamator, is so constructed as to expose a large surface of mercury to the action of the floating matter, and by means of washers and balls made of wood, to render it impossible for any portion to escape coming into contact with the mercury. This part of the apparatus admits of being locked up, so that none of the gold can be abstracted without the knowledge of the party possessing the key. The machine requires only two men to work it; but it may also be driven by steam or water, and gives, when properly constructed and managed, very satisfactory results.

DISTILLATION OF THE MERCURY.—When the amalgam has been formed by any of the methods or machines above-described—in all of which the object kept in view is to place the particles of gold in the most favorable condition for coming into contact with the mercury, and combining with it—and when the fluid metallic mass has been washed, and the excess of uncombined mercury strained off, the last operation required in this method of treatment is the separation of the mercury which remains combined with the gold in the form of a semi-solid amalgam. This is performed by distillation at a high temperature, in a cast-iron vessel prepared expressly for that purpose. Different forms may be given to the apparatus, according to the scale on which the operation is conducted; but a very convenient one is that represented in Fig. 228, where A, is a cast-iron sphere or shell made in two parts, and capable of being joined together in the middle by a flange and screws. From the top of the upper hemisphere proceeds a bent iron pipe, D, which dips into water contained in the vessel, C—the whole forming a convenient iron retort. When used, the hemispheres are taken asunder; the amalgam is intro-

duced, and the two halves are again screwed together and well luted with some refractory substance. The retort is then placed on any convenient support over the fire, B, which may be of wood or coal; the heat is

Fig. 228.



gradually raised, and the sublimed mercury, which is conveyed away by the tube, D, is condensed and collected in C. Care must be taken to prevent the end of the pipe from dipping too deeply into the water; for if the temperature of the fire happens to fall, a vacuum is produced in the retort, which, if the pipe be too deep, will cause the water to rush up into the globe, and produce an explosion. The end of the pipe is therefore introduced just below the surface of the water, so that if a small portion of the water be drawn up into the pipe, that which remains in the condenser, C, immediately sinks beneath the level of the orifice, and all danger is averted.

When the distillation is concluded, which is known by the cessation of any further accumulation of quicksilver in the condenser, this distilled mercury is collected to be used for future amalgamations. The gold which remains in the retort, A, is now comparatively pure; but still contains a mixture of silver, copper, or other metals, in greater or less proportion, according to the sources or localities from which it has been procured. The separation of these, with a view to the obtaining of the gold in a state of absolute purity, will form the subject of the next department of this treatise.

In the meantime, it may be repeated that the amalgamating process is chiefly applied in the working of auriferous veins, or *gold-mining* properly so called, in contradistinction to the much more common method of extracting the gold from drift-beds or stream-mines, by the mere operation of washing. In the former case, the gold, generally in very minute particles, is mingled with various other minerals and rocks, as pyrites, zinc-blende, quartz, *et cetera*, and can only be extracted after the whole has been reduced by stamping, to a very small size—in which state, the gold, often so minute as to be invisible, would be almost entirely carried away by a stream of water. It is here therefore that amalgamation offers peculiar advantages, as the mercury seizes on the gold, however finely reduced, and none of the precious metal is lost—provided the precaution be taken not to pulverize or stamp the ore too fine, when about to be submitted to those preliminary washings which precede the amalgamation. On the contrary, when about to be brought into actual

contact with the mercury, the ore or schlich cannot be reduced too small; and hence the importance of actually pounding it, if possible, under the surface of the mercury.

From these considerations it will be readily seen that the process of amalgamation is not only applied with advantage in the working of auriferous veins or lodes, but that it may also be employed to procure a profitable return from the re-working of the tailings or refuse of the Australian or Californian gold-diggers. The Editor has little doubt that the greater part of the abandoned diggings, which have yielded a large return by mere washing, will, in course of time, be worked over again by amalgamation; and, indeed, this *gleaning process*, as it may be termed, has already been applied in many cases with highly satisfactory results. To give an idea of what may be done with poor ores, when system and skill are brought to bear, it may be sufficient to state the average produce obtained from the stamped ores at Schemnitz, in Hungary, in 1842—recollecting that these had to be broken from the solid lodes at depths extending to two hundred fathoms. The total quantity stamped in that year was above forty thousand tons, and the average of the useful metals extracted from fifty tons was: gold, three ounces; auriferous silver, derived from the separating processes, by buddles or tyes, *et cetera*, three pounds three-quarters; lead, similarly obtained, eight hundredweight one-third; the ratio of the gold to the other materials being in this case as one part to half a million. In the case of a particular mine, called Siglisberg, not producing lead with the stamped ores, the ratio of gold was only as one part to seven hundred and sixty thousand; of auriferous silver, one to twenty-four thousand. Now, it is interesting and instructive to compare with this economical extraction of minute quantities from poor ores by the process of amalgamation the produce of the manipulation by washing at the Siberian workings, where a common average of the sands worked to profit is half an ounce in one hundred hundredweight, or fully double the amount last mentioned, and yet even the poorer ores of Hungary yield a remunerative return by amalgamation. It follows, that by the same process many auriferous sands in Siberia, as well as in other countries, which are at present neglected, as being too poor for washing, might be advantageously worked.

Separation of Gold from Arsenical Pyrites.—Another illustration of the importance of scientific knowledge in the working of gold mines, is furnished by the recent application of PLATTNER's method for the separation of gold from arsenical pyrites, in consequence of which the mines of Reichenstein, in Silesia, which, as already stated, had been abandoned for more than five centuries, were reopened with advantage eight or ten years ago. This successful application of a purely scientific suggestion is due to the skill and enterprise of W. GUETTLER, of Reichenstein, to whom, in conjunction with Professor PLATTNER, the inventor, a council medal was awarded at the Great Exhibition of 1851, for a series of specimens illustrating the different stages of the process. The principal agents employed are chlorine and sulphide of hydrogen. The following account of this novel and ingenious process is given in the published re-

ports of the Jurors :—The ore at Reichenstein is an arsenical pyrites, containing about two hundred grains of gold in the ton. The ore is roasted in a reverberatory furnace, surmounted by a large condensing chamber, in which the arsenious acid is condensed as fast as it is volatilized. There then remains, on the floor of the furnace, oxide of iron mixed with a certain quantity of arsenic, together with the whole of the gold. This is placed in a vessel so arranged that a current of chlorine can be passed through it, by which the gold and iron are taken up, and afterwards separated from the residuum by the aid of a certain quantity of water, and the gold is afterwards precipitated from this solution by sulphide of hydrogen. To prevent the admixture of iron at this stage, a few drosses of hydrochloric acid is added to the solution before the sulphide of hydrogen is introduced. The auriferous compound having been separated from the liquor, is washed and heated in an open porcelain crucible, to drive off the sulphur, after which the gold is reduced to the metallic state by fluxing it in the usual way.

This simple and ingenious method, which has made it worth while to reopen the Reichenstein mine, is equally applicable to the vast quantity of refuse accumulated near many other old works.

METALLURGICAL OPERATIONS.—Fusion.—When the gold is received from the *gold-washer*, in the shape of gold-dust, or when it has been separated from its ores by amalgamation or otherwise, it has now to be subjected to a series of metallurgical operations to obtain it in a state of perfect purity. The first of these operations is that of fusion with borax, and casting the metal into ingots, by which it is obtained in a convenient form, and freed at the same time from earthy and other impurities. For this purpose, the gold dust from the washings, or the spongy gold obtained by amalgamation, is mixed with a little dried borax, and is introduced into a black-lead crucible, which has been previously heated in a common melting furnace. After the fusion of the metal, a slag, consisting of the grosser impurities, accumulates on the surface; this must be thickened by the addition of a little bone-ash, and then skimmed off. The metal is now cast into bars, by being poured into iron ingot-moulds, which should be previously warmed, and oiled, by wiping the internal surface with a piece of tow dipped in sweet oil. It is an old practice, now discarded by some metallurgists as useless, to add to the metal, when thoroughly melted in the crucible, a small quantity of corrosive sublimate; the contents are then well stirred, and, in consequence of the volatilization of the sublimate, effervescence takes place. That this is attended with no injurious effect seems to have been fully established by a long experience, and that it may even be productive of benefit is probable, by bringing to the surface any extraneous matter which might be detached from the interior of the crucible, and so permitting its removal along with the slag. The crucibles which have been used in a series of such operations, retain a portion of gold, which renders it important to preserve them, with a view to the subsequent extraction of the precious metal by smelting.

SMELTING OF GOLD ORES.—Although the readiest method of extracting the gold from rich alluvial sands

is by repeated washings, in the manner already described, and although in the treatment of quartz rock, iron pyrites, and other auriferous minerals, the method involving the tedious operations of pounding, washing, and amalgamation is usually adopted, yet, in the latter case, the same object may be accomplished by direct *smelting*—a term technically applied to a process, or series of processes, by which a metal is extracted, by the agency of fire, from the substances with which it may be combined or mixed in nature. It is well known that by this method iron is extracted from its ore in the blast furnace, and some years ago a Russian gentleman, named ANOSSOW, even proposed to smelt in this manner the auriferous sand of the Ural, alleging that a much larger quantity of gold could be so obtained than by the most skilfully conducted process of washing. His method consisted in smelting the sand with iron, the latter being employed simply as a vehicle to collect the gold, or to perform, in its melted state, the same part as mercury in the processes already described. When the gold was obtained in this state of combination, the mass was exposed to the action of sulphuric acid, by which the iron was dissolved and the gold remained in the insoluble residue. From some experiments which were made at the Museum of Practical Geology in London, it was found that, if it were advantageous on the score of economy, cast-iron might really be so applied; and that when it is melted with gold, an alloy seems to take place, from which the greater part, if not the whole of the gold may be extracted by again melting the alloy in contact with lead, which abstracts the gold. With regard to ANOSSOW's process, experiments were reported to have been made on the large scale, which had perfectly succeeded; but a strong proof of its want of success is the fact that it has never been practically adopted.

Of late years much has been said and written respecting the smelting of what has been called *gold quartz*, or, in other words, the extraction of the metal from the quartz in the furnace. The Editor, therefore, in proceeding to explain the common method of smelting, will assume, in the first place, that quartz or silica is the auriferous ore which it is proposed to subject to this operation. From the well-known infusibility of this substance, it is evident, that mere exposure to the strongest heat of a blast-furnace, without the addition of a flux, would be of no use; for, although the gold would be melted, it would remain in the quartz, and no separation of the precious metal would take place. Even supposing the quartz to be first reduced to powder, the gold is present in too small quantity to separate from the infusible mass, and sink to the bottom. It is therefore necessary to add some substance which, at a high temperature, shall combine with the quartz, and produce a fusible compound, in which case the gold, more especially if combined with some other heavy metal, will, in virtue of its high specific gravity, fall to the bottom of the vessel.

The best flux for silica is carbonate of soda, but this is too expensive to be employed on the large scale. Lime, therefore, aided by the addition of oxide of iron, is usually employed for this purpose. Lime alone, or lime and clay in certain proportions, will combine with

quartz at a high temperature, and produce a fusible slag. Oxide of iron alone will also suffice. When practicable, it is desirable to obtain the oxide of iron by roasting auriferous pyrites, such as that found in California or the Tyrol, for then the proportion of gold is increased by that contained in the pyrites. Whatever flux be employed, it is necessary, in the first place, to reduce the quartz to a comparatively fine state of division, otherwise a considerable loss of time and waste of fuel would be incurred in effecting the perfect combination required to ensure the complete separation of the gold. Even in smelting, therefore, the crushing or pulverizing process is not dispensed with. Assuming that lime and oxide of iron are the fluxes employed, and supposing the pulverized ore to have been partly concentrated by washing, these substances are mixed in about equal proportions, and raised to a white heat in a blast or reverberatory furnace. When oxide of iron is employed as the flux, the reverberatory furnace is to be preferred, because in the blast-furnace a considerable portion of the oxide would be reduced, and a corresponding quantity of metallic iron liberated, long before the mixture attained the degree of heat requisite for the combination of the silica with the oxide.

The product of the combination is a fusible *slag* or glassy substance, through which the gold, also in a melted state, tends to sink to the bottom of the furnace. But as the portion of this metal present even in a large quantity of ore is very small, compared with the bulk of the materials through which it is now diffused, it would be difficult to collect it *per se*, without very serious loss, in a crucible, and still more so in a furnace, whether reverberatory or blast. The operation is therefore materially assisted by adding another metal which shall combine with, and absorb, the whole of the gold, and from which the latter can afterwards be easily separated—some metal, in short, which shall serve the same purpose at a high heat, as mercury serves at the ordinary temperature. Of all metals, lead is found to be the best-adapted for this purpose, not only on account of its readily combining with the gold in a melted state, but also as offering peculiar facilities for its subsequent separation from that metal. Lead has, therefore, been uniformly employed in the processes hitherto generally adopted for smelting gold ores. The lead may be added to the mixture of ore and flux, either in the metallic state, or in one or other of its combinations, from which the metal may be set free. The materials most commonly employed to furnish the lead are litharge and galena—the former the protoxide, and the latter the native sulphide of that metal—although the rich slags obtained both from the smelting furnace and ore-hearth are also occasionally used. When litharge is chosen as the medium for the introduction of lead, it must be mixed with charcoal, small coal, or coke-dust, in order to determine the reduction of the necessary quantity of lead to the metallic state; but when galena is used, it is mixed with scrap-iron, for the purpose of combining with the sulphur, and setting the lead free. The lead-slag which comes from the ore-hearth or the reverberatory furnace, is generally the most convenient and least expensive

material, as it contains a considerable per-centage of lead, and is readily prepared for use by grinding it to powder under the edge-roll, and mixing it with charcoal or other carbonaceous matters. In this case, also, it is important to add some scrap-iron to combine with any sulphur which may be present in the slag. Whichever of these substances be employed, the lead evolved, under the conditions mentioned, percolates through the mass, and subsiding by virtue of its high specific gravity to the bottom of the furnace, carries along with it any particles of the precious metal it may meet with in its course. The lead is afterwards separated by *cupellation*—a process to be explained shortly.

Smelting with Iron Pyrites.—Instead of directly employing lead as the means of concentrating the gold ores, a method has been practised in Hungary, in which iron pyrites, generally itself containing a portion of gold, is used with economical effect for the same purpose. When this mineral is heated to a certain temperature without access of air, it loses exactly half of its sulphur, and becomes converted into a fusible sulphide of iron, such as is produced by bringing a roll of sulphur in contact with a bar of iron raised to a white heat. Let it be assumed, therefore, that the ore consists of a mixture of auriferous iron pyrites and quartz, and that this ore is mixed with the appropriate flux for the quartz, as already described, and exposed to the requisite heat,—in this case a slag will be formed, and the sulphide of iron will unite with the greater portion of the gold present, forming a heavy regulus, which will subside to the bottom. The stratum of sulphide of iron thus found beneath the surface of the slag and scoriæ produced by the fusion of the earthy and siliceous gangue, is technically termed a *matt*. If this matt, containing the gold, be now roasted, or *oxidized by heating it with free access of air*, whereby it is deprived of a further portion of its sulphur, and the product be mixed with a fresh quantity of crude auriferous pyrites, and smelted again, a second matt will be obtained, which will contain the gold from the first and second charges of the auriferous ore. This process may be repeated a third, fourth, or any number of times, until the precious metal has been sufficiently concentrated in the substratum of sulphide of iron to admit of its profitable extraction. The last matt, containing the whole of the gold which has accumulated from the successive charges, and brought, therefore, to any required richness, is then fused with metallic lead, litharge, or with a mixture of galena and metallic iron. The gold is abandoned to the liberated lead, from the top of which the impoverished sulphide may be readily skimmed off.

By this process, the gold is obtained in a more concentrated form, or mixed with a smaller proportion of lead, than when the latter is used directly as the means of separating and collecting it from the smelted ore. Still as the lead must be used for its final separation from the ore in all cases—even when the gold has been concentrated by washing and amalgamation—the employment of the iron pyrites in the manner above-described is only attended with advantage when it constitutes part of the ore itself, or when it can be readily and cheaply procured in sufficient abundance. When

it forms a principal ingredient in the ore, it is manifestly highly advantageous, in point of economy, to employ it as a vehicle for the concentration of the precious metal, while it contributes at the same time to increase the amount of the product.

Patent Smelting Process.—Some years ago a patent was secured for another smelting process, invented by Mr. LONGMAID, which consists in separating the gold from the quartz or siliceous ore, by introducing plates of wrought-iron into the melted mass. The quartz is first crushed to a fine powder, and fluxed with a mixture of lime and oxide of iron, as usual. Into the fused mass thus obtained, plates of wrought-iron are from time to time introduced, and withdrawn when their surface is found to be coated with a film of gold. The plates are then plunged into a vessel of melted lead, which dissolves off the precious metal, and afterwards again put into the furnace. This process is constantly repeated till the whole of the gold is extracted from the ore, and it is said to be thus obtained both more economically, and in greater proportion, than by the usual process of washing and amalgamation; but the Editor is not aware that this method has yet been extensively practised.

CUPELLATION.—The next metallurgical operation is the extraction of the gold from the lead, and this has been performed from the most remote antiquity by a process termed *Cupellation*. This process, which is very simple in principle, is, at the same time, one of the most elegant chemical operations ever invented. It depends on the circumstance that when silver and gold are exposed in a state of fusion to the action of the air or oxygen, they neither give off perceptible vapors nor are sensibly oxidized—they remain, in short, unaffected; whereas, under similar circumstances, lead and almost all the other metals are oxidized with greater or less rapidity. There is also an important peculiarity connected with lead, which renders it the only metal, excepting bismuth, applicable to the process of cupellation. This peculiarity consists in the circumstance, that the white oxide of lead, known as litharge, is fusible at a bright red heat, and in this state liquefies and absorbs into its mass any other metallic oxide with which it may happen to be in contact, but which, without the influence of the oxide of lead, would remain unliquefied by the heat. For example, if the oxide of copper be present, this oxide, which is a fixed infusible substance at the temperature of a common furnace, is taken up by the melted oxide of lead; and if the latter can be separated from the gold and silver, the oxide of copper will be expelled along with it.

This separation may be effected by different methods, but particularly by means of bone-ash, which possesses the peculiar property of absorbing the melted litharge, even when mixed with a certain proportion of other oxides, whereas it remains impermeable to the unoxidizable metals. Hence, if a vessel be formed of pounded and compressed bone-ash, and into this vessel a compound be introduced consisting of a mixture of litharge or oxide of lead, oxide of copper, and native gold, which always contains a certain proportion of silver; and if this mixture be exposed to the powerful heat of a furnace, the whole will be reduced to a state

of fusion; the oxide of lead, in melting, will combine with and dissolve the oxide of copper, and both will be absorbed by the bone-ash, while the mixture of gold and silver will remain in the vessel, melted by the heat, but otherwise unaffected. Hence it follows that gold and silver, or a mixture of the two, may readily be deprived of copper or any other oxidizable metals by cupelling them with oxide of lead. For this purpose it is not necessary to employ the oxide itself in the first instance. When metallic lead is heated to a temperature above its melting point, it rapidly combines with the oxygen of the air, the product being in the first place yellow oxide of lead, which appears as a scum on the surface; and when the temperature is raised to about bright redness, this oxide is converted into litharge or the white fusible oxide, which immediately melts. Pure copper requires not less than sixteen or seventeen times its weight in lead to be absorbed in the manner above-mentioned.

A vessel of bone-ash, formed for this purpose, is termed a *cupel* or *test*; and in using such vessels for *assaying*, the absorptive power of the cupel is the only agency employed to separate the gold from the lead and other oxidizable metals, as will be explained afterwards. It is otherwise in cupellation on the large scale; in this case the cupel is soon saturated, and the greater part of the litharge is expelled by a different method.

The English method of cupellation or refining is as follows:—A piece of bar-iron, about half an inch thick and four inches deep, is bent into the form of an oval hoop, and the ends of the bar are welded together. The greater diameter of this hoop, which is destined to form the containing circumference of the cupel or test, may be about four feet, and its lesser two feet six inches; but the dimensions vary considerably according to circumstances. On the lower part of the hoop are fixed a series of four or five flat bars of iron, arranged parallel to each other in the direction of the short diameter. The first of these is placed about nine inches from one end of the oval, and the others at about equal distances between this bar and the other extremity. The hoop is then placed with the cross-bars downwards upon a solid floor, and a quantity of pounded and sifted bone-ash is beaten firmly into it with a mallet or rammer until it is entirely filled, or the bone-ash is level with the upper edge of the hoop. The bone-ash employed for this purpose is mixed with about one-tenth, by measure, of fern-ashes, or one-fortieth by weight, of American pearl-ashes, and moistened sufficiently to become coherent by pressure. The fern or pearl ash has the property of giving greater consistency to the bone-ash when heated. When the hoop or frame has been well filled with this mixture and solidly beaten down, the surface is carefully scooped out with a trowel all round the centre, so as to form a shallow concavity of about two inches and three-quarters in depth, leaving a wall of bone-ash all round, about two inches in thickness at top and three inches at bottom, except at one end, where a thickness of five inches is left; whilst the thickness of the sole itself is reduced to one inch above the upper surface of the iron cross-pieces. At that end of the test where the wall was left five inches thick,

and which is termed the *breast*, a segment of the bone-ash, contiguous to the hoop, is removed.

This apparatus is represented in Figs. 229 and 230, of which the former is a plan, and the second a longitudinal vertical section of the cupel or test. In these drawings, the letters *A A* denote the iron hoop; *a a*, the

Fig. 229.

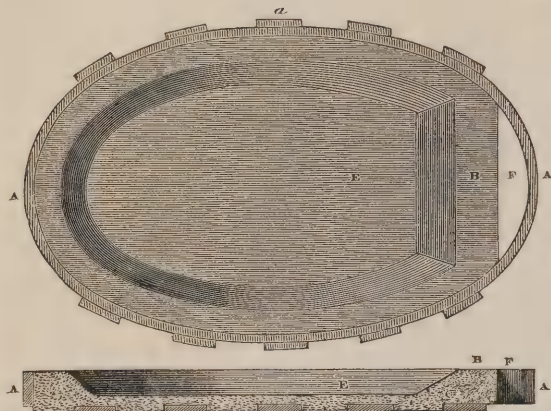


Fig. 230.

transverse bars; *E* indicates the cavity in the bone-ash; *B*, the breast; and *F*, the space where the bone-ash is removed between the breast and the iron.

When fully prepared, the test is allowed to dry, and is then placed in a furnace, constructed in all respects like a common reverberatory, except that a space is left open in the bed of the furnace to receive the test, and that the long axis of the arch is very short. The test, in fact, forms the bed of the furnace, in which it is adjusted with the long diameter transversely. It is supported in its place by an iron ring built into the masonry, or by iron bars placed underneath, between the two walls of the furnace. The fire-place of a cupelling furnace is usually about two feet in breadth, and two feet six inches in length. This is separated from the body or bed of the furnace by a fire-bridge eighteen inches in breadth, so as to allow the flame and heated air to pass directly over the surface of the cupel, from whence it escapes through separate flues into a high chimney. At the side of the furnace opposite to the breast of the cupel, the nozzle of a pair of large double bellows, or a fan-blast, is introduced.

When the cupel is inserted and the furnace lighted, the heat must be applied in the first place with much caution; for the cupel or test, if exposed suddenly to a high temperature before it has become sufficiently dry, is liable to split and fall to pieces. In the meantime, the lead containing the gold and silver, and which, from this circumstance, is termed *rich lead*, is brought to a state of fusion in a cast-iron pot, set in brickwork at the side of the furnace; and when the test has been cautiously raised to a cherry-red heat, the rich lead is laded into it till nearly full. Oxidation now proceeds rapidly. At first the lead becomes covered on the surface with a yellow or grayish dross; but on further raising the

heat, the surface of the bath uncovers, and a film of melted litharge begins to appear. Part of this litharge sinks into the bone-ash of the test, which it soon saturates. The blowing apparatus at the back of the test is now set in motion, and forces the litharge as it forms forward to the breast, *B*, across the surface of which a channel is cut, through which the litharge begins to flow, and runs over at the end through the vacant space, *F*, into a movable iron pot, placed on the floor for its reception. By this means the oxide of lead is prevented from coming in contact with the iron frame of the test, on which it would exert a powerfully-corroding action. The current of air introduced at the back of the cupel not only assists in clearing away the litharge, but readily supplies the amount of oxygen necessary for its rapid formation. In proportion as the litharge flows away, more of the melted lead is gradually supplied to the test, which is done by lading it into a channel from the pot outside the furnace.

After a certain period, the channel first formed in the breast, *B*, becomes much corroded; it must then be stopped, and a second and third channel successively formed for the same purpose. In this manner the operation may be continued until six or eight tons of the rich lead have been refined on the same test. Sometimes, however, two tests are employed, the first to concentrate the lead, and the second to separate it entirely from the precious metals. In this case, when the lead has been so far concentrated in the former that the whole of the gold and silver contained in the alloy may remain in combination with only two or three hundredweight of that metal, a hole is made through the bone-ash of which the bottom is composed, and the concentrated lead is received into a pot which is placed below. The tapping-hole is then closed with a pellet of moistened bone-ash, and a fresh charge of the original rich lead is concentrated in the same manner. When a sufficient amount of concentrated lead is thus accumulated to yield, as ascertained by assaying a small portion, from one to two thousand ounces of the precious metals, the whole is again melted down, and submitted to a second cupellation in another test, in which the operation of refining is completed.

Towards the conclusion of the operation some striking appearances are presented. As soon as the last portions of lead are removed, the liquid alloy of gold and silver in the cupel suddenly assumes a bright and resplendent surface; and, if the gold present is mixed with a considerable amount of silver, the surface of the mass, as it cools, is suddenly thrown into agitation; cones, or little craters, sometimes several inches in height, are thrown up, from which oxygen gas escapes with violence, projecting particles of silver with considerable force. This phenomenon is termed *spitting*, or sometimes *vegetation*, from the beautiful arborescent forms which are presented; and arises from the circumstance that metallic silver, when melted, has the property of temporarily combining with or absorbing much more than its own volume of oxygen, which escapes or is ejected with violence at the moment of solidification. For reasons especially connected with the final process of *parting*, and which will be afterwards explained, there

is almost always introduced into the alloy, before cupellation, a comparatively large amount of silver, so that the phenomena above described are almost uniformly observed at the conclusion of that process. Even in the cupel, the presence of a considerable proportion of silver is important, for the purpose of diluting the gold, and so diminishing the chance of loss.

After the cupelling, the test, with its cake of alloy of gold and silver, is withdrawn from the furnace; the metallic mass is removed and cleaned from external impurities; and the bone-ash, saturated with litharge, and any other oxide that may be present, is knocked out and preserved for subsequent treatment, as it contains not only a considerable quantity of lead in a state of oxide, but also a small proportion of silver.

On the Continent, the process of refining is conducted without the use of a cupel, properly so called. No bone-ash is employed. The test, if it may be termed so, is the bed of the furnace itself, which consists of a kind of marl, firmly beaten down into a circular cavity, sloping from the sides to the centre, and allowed to dry. The roof of the furnace, which consists of a flat dome of bricks, built in a strong circular hoop of bar-iron, is movable by means of a crane. Several tons of lead are introduced at once, and after the roof has been replaced, the blast is transmitted through one or more apertures in one side of the furnace; the whole mass of metal is then worked off continuously, without any addition, till the lead is entirely removed, and the alloy of gold and silver is left fine.

PARTING.—The final operation of separating the silver from the gold, is termed *parting*, and is generally performed in this country by means of nitric acid, which dissolves the silver, without attacking the gold. On the Continent, the same effect is produced with *hot sulphuric acid*. In assaying operations, nitric acid is always employed, and therefore the precautions necessary to be observed in this case will be fully explained in connection with the subject of *assaying*. In the meantime, the process with sulphuric acid, as practised on the Continent, will be first detailed.

1. *By Sulphuric Acid.*—It is only of late years that the use of sulphuric acid for this purpose has been generally introduced on the Continent, in consequence of its being now manufactured so much cheaper than nitric acid, which was formerly the only acid employed. The operation is performed in a very simple manner, and if any copper has been left in the alloy, it is separated along with the silver. It is true that the copper should be entirely expelled by the process of cupellation; but, as this process is practised on the Continent, a considerable amount of that metal often remains in the mixture; and its presence is by no means injurious, but is rather useful, in the subsequent operation of parting with sulphuric acid. It is true that if too much copper be present, a sulphate is produced, of which only a limited proportion will dissolve in the concentrated acid. The proportion of gold also must be less, as compared with the amount of the silver, than when nitric acid is used. Experience has shown that the alloy should not contain more than one-twentieth part of copper; and that the proportion of the gold to the silver should not exceed one-fifth; whereas, with nitric

acid, it is sufficient if the weight of the silver amount to about three times that of the gold.

When the silver is not already present in the required proportion, which is never the case with native gold, the requisite excess must be introduced; for, when the amount of gold exceeds the proportions above-stated, the particles of silver are so enveloped in that metal as to resist for a long time the action of the strongest nitric or sulphuric acid. In the process of assaying, the proportion of rather less than three parts of silver to one of gold is very closely adhered to, for reasons to be afterwards mentioned; but in operating on the large scale with sulphuric acid, the proportion of the gold to the silver may vary from one-fifth to one-tenth, without inconvenience; and DUMAS states that the operation may be conducted with profit when the ratio of the gold to the silver does not exceed 1 : 1000.

The alloy being prepared in the requisite proportions, which is generally done by introducing the excess of silver before cupellation, is melted in a crucible, and granulated by pouring it into cold water. For one part of the granulated alloy, three and a-half parts of concentrated sulphuric acid are taken, and the mixture is put into a platinum vessel, which is then introduced into the furnace. The vessel should not be more than two-thirds filled, to guard against the effects of effervescence, which might throw out part of the liquid. It is then covered with a platinum hood, provided with a beak or tube for conveying the gases and vapors into a condensing apparatus. The capacity of the platinum retorts varies, and there is usually an assortment of different sizes, for treating alloys of different qualities, without the necessity of mixing them. After two or three hours' boiling, varying the time according to the size of the retorts, the silver, and any copper that may be present, are completely dissolved.

On the first application of sulphuric acid to this purpose, the operation was performed in iron retorts. Vessels of platinum were afterwards introduced, as this was considered to be the only metal which could perfectly resist the action of hot and concentrated sulphuric acid. Afterwards, however, the enormous expense required for a complete assortment of platinum retorts, induced the attempt to return to the use of iron, and successful experiments were made by M. TOCCHI, which proved that iron retorts might be safely employed, though platinum is still in use in many establishments. It was found that the very concentration of the acid presented, of itself, an obstacle to the precipitation of the silver or copper by the iron; and, further, that the interior surface of the retort acquired a coating of silver, so that the iron and the liquid soon ceased to be in contact. This point has not been sufficiently studied; but the fact has been placed beyond doubt that the operation succeeds very well in iron vessels, and accordingly, in many refining establishments, no other are employed.

It cannot fail to be observed that, assuming the proportions above given, the quantity of sulphuric acid is much greater than would be strictly necessary to convert the silver and copper into sulphates. Supposing the alloy to be as poor as possible in gold, theory would

indicate the following quantities of acid as being sufficient for this purpose:—

	Parts.	50 would require	Parts.	155 sulphuric acid.
Copper	949	"	861	"
Silver	"	"	"	"
Gold	1	"	0	"
Alloy	1000	"	1016	"

But as the amount of sulphuric acid employed is actually 3500 to 1000 of alloy, there is an excess of about 2500 of acid, intended to hold the sulphates, and especially the sulphate of copper, in solution.

When the silver and copper are completely dissolved, the retorts are withdrawn from the fire, and the solution is left to cool, that the gold may settle to the bottom. The liquid is then decanted; the gold, which remains in the vessel, is carefully washed, and the waters employed in this operation are added to the sulphate solution. Lastly, the purified gold is melted, and after being cast into ingots, is ready for commerce.

The acid liquor, containing the sulphates, is poured into a leaden boiler, containing water and copper shavings. Heat is applied, and the sulphate of silver is soon completely decomposed. The precipitated silver is collected, and submitted to repeated washings, always adding the water to the boiler, for use in the next operation. Lastly, the silver is dried in a small iron pan, and is then melted in a crucible, to be cast into ingots.

The acid solution, which now contains only sulphate of copper, is evaporated in lead boilers till it is fit to crystallize. It is then put into the crystallizing pans, and the mother waters are further evaporated, to obtain more crystals. This process is continued till the liquid becomes very concentrated, and consists almost entirely of sulphuric acid. In this state it is termed *black acid*, on account of its color, which is due, in great part, to organic matters, dust, and other impurities, which fall in it during the evaporation in the crystallizing pans. The black acids, purified by concentration, may either be employed to repeat the same operation, or turned to useful account in different manufacturing processes, which do not require that the sulphuric acid should be pure and highly concentrated.

2. *By Nitric Acid.*—The operation of parting is performed with nitric acid in much the same way; but all the details of the process with this acid will be minutely explained in connection with the subject of assaying, for which it is uniformly used.

3. *By fusion with Sulphur.*—Another method of separating the gold from the silver, which is sometimes practised with alloys containing but very little gold, is by fusing the granulated alloy with three-tenths of its weight of sulphur; this combines with the silver, and forms a liquid sulphide, in which the finely-divided gold remains suspended. A small quantity of litharge is then added, which gives rise to the formation of sulphurous acid and sulphide of lead, and again separates a portion of the silver, which then combines with the gold, forming an alloy richer in the latter metal. This alloy, by its greater gravity, sinks to the bottom of the crucible, and, after cooling, is separated by the hammer from the superincumbent mixture of sulphide of silver and lead. When this mixture, which is

termed *plachmal*, is fused with a small quantity of litharge, it yields silver, which for the most part still contains a little gold. The richer alloy which subsided to the bottom of the crucible, is treated repeatedly with sulphur in the same manner, till the proportion of gold is raised to one-fourth, after which the final separation of the silver is usually effected with nitric or sulphuric acid. It will be observed that this process is similar in principle to the method already described for concentrating auriferous pyrites.

4. *By fusion with Sulphide of Antimony.*—In this case, the alloy is mixed with two parts by weight of sulphide of antimony, and fused, with constant stirring, in a crucible, which should be previously glazed with borax. By this means sulphide of silver is formed, and the gold combines with the antimony, forming a lower stratum of alloy, which is afterwards separated from antimony by simple ignition in the air, or by fusion with nitre. If the amount of silver in the original alloy exceeds one-third, a proportional quantity of sulphur must be added in the crucible. The sulphide of silver forming the upper stratum retains a small portion of gold, to separate which it is again twice fused with sulphide of antimony, and this is again removed by ignition or fusion with nitre. The same operations are repeated on the whole amount of antimonide of gold thus obtained, and the antimony is finally removed either by fusing the antimonide alone, while air is blown upon it, or by fusion with three times its weight of nitre. Sometimes it is melted into a mass by heating it with three-fourths of its weight of borax, one-fourth of nitre, and one-fourth of glass.

5. *By Cementation.*—Another method, which is practised in America, consists in arranging the granulated alloy in alternate layers, with a mixture of two parts of brick-dust and one part of chloride of sodium in *porous crucibles*, which are exposed to a low red heat in a wood fire for a period varying from twenty-four to thirty-six hours. The aqueous vapor from the wood permeates the crucibles, and acts upon the salt in such a manner as to separate hydrochloric acid, which then forms chloride of silver with evolution of hydrogen. The chloride of silver, together with the chloride of sodium, sinks into the brick-dust, and the gold obtained after washing, contains not more than from one-tenth to one-eleventh of silver.

In this case, without the brick-dust, the conversion of the silver into chloride would be only superficial, because the chloride first formed would protect the inner portions of the alloy from the action of the hydrochloric acid. But when the alloy is enveloped in brick-dust, the chloride of sodium is partly decomposed by the silica, yielding silicate of soda and hydrochloric acid; the latter converts the silver into chloride, which then fuses with the rest of the chloride of sodium, and this, sinking into the brick-dust, leaves a new surface of alloy exposed to the action of the hydrochloric acid.

The reader will observe that the three methods last mentioned are all more or less imperfect in their results, and that for the complete separation of the silver, recourse must always be had to the action of sulphuric or nitric acid.

ALLOYS OF GOLD.—STANDARD GOLD.—By the preceding series of mechanical, metallurgical, and chemical operations, gold may be brought to a state of nearly absolute purity; but in this state it is too soft to be employed with advantage in the arts, or for the purposes of the coinage. Gold is therefore almost always alloyed with a greater or less proportion of some other metal, except when it is found in the shape of the finest gold leaf, which requires for its proper manufacture the highest possible purity, because, although it readily forms alloys with most of the other metals, its malleability is greatly impaired by their presence in even a very small proportion. With some metals this effect is very remarkable; even one two-thousandth part of antimony, bismuth, tin, or lead, will render the gold quite brittle. At the same time, as a natural consequence, its hardness and sonorousness are increased.

The only alloys of gold of any importance in the arts are those formed with silver and copper, which tend to increase its hardness and durability, and are used also by jewellers to give the gold different tints, according to the proportions employed. It singularly happens that these are the metals with which it is chiefly combined in the native state, although it is likewise found associated with iron, platinum, tellurium, and other metals.

Gold may be alloyed with silver in almost all proportions, and, by its combination with this metal, it becomes not only harder and more sonorous, but also more fusible. As the proportion of silver increases, the color quickly passes through pale greenish-yellow into white. The malleability of gold is less diminished by silver than by any other metal. The maximum of hardness is found in the alloy containing two parts of gold to one of silver. The *green gold* of the jewellers contains twenty-five per cent. of silver.

The most useful alloy of gold is that which is formed with copper, and this is the alloy which is used for coinage. The addition of copper renders gold redder, harder, and more fusible. The maximum of hardness is exhibited by an alloy of seven parts gold and one of copper. An alloy containing twenty-two parts of gold and one of copper has a density of 17.157. English standard gold contains 8.33 per cent. of copper, or one part of this metal to eleven parts of gold. In France, the standard gold contains ten per cent of copper. Gold contracts in the act of solidifying from a state of fusion, and cannot, in consequence, be made to receive sharp impressions by casting it in moulds. Coins are, therefore, stamped with a die, and plate is either stamped or embossed, and afterwards chased and carved, if necessary, by cutting tools.

Valuation of Gold Alloys.—In this country the standard of the alloys of gold is calculated in fractions of unity expressed in carats. Perfectly pure gold is taken as unity, and this is assumed to consist of twenty-four fractional parts termed *carats*, each of which is divided into four imaginary grains, and these are again subdivided into quarters and eighths. The carat is, therefore, ultimately divided into thirty-two thirty-seconds; so that unity, or absolute fineness, represented by twenty-four of these carats, may be con-

sidered as made up of $24 \times 32 = 768$ thirty-seconds. On this system, an alloy of gold, according to its composition, is spoken of as being so many carats fine, or so many carats and thirty-seconds of a carat. It has been stated above that the standard alloy of the English gold coinage contains eleven parts of gold to one of copper, or, in other words, twenty-two parts of gold to two of copper; it is, therefore, said to be twenty-two carats fine. If the alloy contained twenty-three parts by weight in the twenty-four, it would be twenty-three carats fine, or one carat *better than standard*. If, on the other hand, it contained only twenty-one carats, it would be one carat *worse than standard*; if it contained 18.5 of pure gold, it would be said to be eighteen carats, and sixteen thirty-seconds. The report of the assayer is always given in relation to standard. Fine or pure gold would be twenty-four carats fine, that is, there would be no alloy.

In calculation it is easier to use decimal fractions than the clumsy empirical system of counting by carats; and in estimating silver the decimal method has lately been introduced into the mint of this country by Sir John Herschel. In France the same method is generally extended to gold. Upon the decimal system, fine gold or silver is termed 1000.0, and the report upon any sample of alloy simply indicates the number of parts of pure gold or silver in 1000 which the sample contains. Unfortunately the English standard does not admit of expressing the amount of copper in a terminable decimal, the nearest convenient fraction being 90.91 of copper in 1000 of alloy. In France, the standard is conveniently expressed by 900 of gold to 100 of copper. This decimal standard admits of the ready comparison of gold alloys with other chemical compounds, because in analytical investigations the results are always sought with reference to the percentage or centesimal composition of the subject under examination; but, under the system existing in this country and on many parts of the Continent, it is often necessary to convert the per-centage into the corresponding value expressed in carats. The following table, which expresses the relation subsisting between a series of decimal fractions of unity and the carats and thirty-two thirty-seconds respectively, will be found convenient for immediately effecting the conversion:—

Thirty-seconds of the carat.	Decimal.	Carats.	Decimal.
1	0.001302	1	0.041667
2	0.002604	2	0.083334
3	0.003906	3	0.125001
4	0.005208	4	0.166667
5	0.006510	5	0.208333
6	0.007912	6	0.250000
7	0.009215	7	0.291666
8	0.010415	8	0.333333
9	0.011718	9	0.374999
10	0.013021	10	0.416667
11	0.014323	11	0.458330
12	0.015625	12	0.500000
13	0.016927	13	0.541667
14	0.018230	14	0.583333
15	0.019531	15	0.624555
16	0.020833	16	0.666667
17	0.022135	17	0.707333
18	0.023436	18	0.750000
19	0.024740	19	0.791666
20	0.026042	20	0.833333
21	0.027343	21	0.874999
22	0.028646	22	0.916666

Thirty-seconds of the carat.	Decimal.	Carats.	Decimal.
23	0.029948	23	0.958333
24	0.031250	24	1.000000
25	0.032552	—	—
26	0.033854	—	—
27	0.035156	—	—
28	0.036460	—	—
29	0.037760	—	—
30	0.039062	—	—
31	0.040364	—	—
32	0.041667	—	—

JEWELLERS' GOLD.—The jeweller receives his gold in the form of ingots, which approach to absolute purity, or twenty-four carats fine. He begins his operations by alloying it with copper or silver, or both, in certain calculated proportions, either to reduce it to the legal standard, or to give it the particular color required. The following are the three standards fixed by the latest statutes enacted in France on the subject:—

1. *High standard gold*, consisting of nine hundred and twenty parts of pure gold in one thousand of alloy, which is equivalent to twenty-two carats, one thirty-second and one-half. This is the alloy usually employed by the French jewellers, and is nearly identical with the standard gold of the English coinage.
2. *French standard gold*, consisting of eight hundred and forty parts of gold in one thousand of alloy, or twenty carats, five thirty-seconds, and one-half. Sometimes it is reduced to only twenty carats.
3. *Common gold* is seven hundred and fifty parts in one thousand, or eighteen carats. The licence or *tolerance* allowed is three parts in a thousand.

In order that the gold may be easily worked, the alloy must be perfectly homogeneous, and the jeweller accordingly brings it to this state by repeated fusions. If the alloy has been badly made, and still exhibits a grainy appearance, with a liability to crack under the action of the hammer or between the laminating rollers, it must be again introduced into the crucible, and thoroughly fused with a mixture of borax and saltpetre.

In the *Dictionnaire des Arts et Manufactures*, the colors most commonly required in articles of jewellery, are stated to be composed as follows:—

Colors.	Composition
Yellow gold,	Pure or fine gold, 1000.
Red gold,	Fine gold, 750; rose copper, 250.
Green gold,	Fine gold, 750; silver, 250.
Dead-leaf gold,	Fine gold, 700; silver, 300.
Water-green gold, ...	Fine gold, 600; silver, 400.
White gold,	{ An alloy of gold and silver in which the latter predominates.
Blue gold,	Fine gold, 750; iron 250.

The last-mentioned alloy is somewhat difficult to prepare. It is obtained by introducing thick iron wire among the melted gold, and withdrawing the crucible from the fire as soon as the alloy is formed. When poured out and cooled, it should have no appearance of porosity. It is then forged, and formed into sheets or wires of different thicknesses.

Various shades of color are likewise given by the jeweller to articles or ornaments of gold, by the finishing process, which consists in exposing them to certain chemical agents, to dissolve out a portion of the copper or silver from the surface, without attacking the gold. By this means the surface of the article is made to appear like pure gold, which it really is, while below the

surface the quantity of copper or silver may be considerable. The liquor usually employed by the goldsmiths and jewellers for this purpose is a mixture of two parts of nitrate of soda, one part of chloride of sodium, and one of Roman alum, in three or four parts of water. The trinkets or other articles are kept in this solution, at the boiling point, from fifteen to twenty-five minutes, according to the shade required. They are then taken out, washed in water, and after burnishing with blood-stone, the operation is finished. The pickle, or sauce, as the liquor is termed, dissolves not only the copper or silver alloy on the surface, but likewise a certain quantity of the gold itself, and the articles lose, on the whole, about one-sixteenth of their weight by the operation. To recover the gold, the liquor is diluted with at least twice its bulk of boiling water, and a solution of very pure protosulphate of iron is poured into it. The precipitated gold is washed upon a filter, dried, and purified by fusing in a crucible, along with a mixture of equal parts of nitrate and bichlorate of soda. The other metals can likewise be recovered by very simple methods.

GOLD-BEATING.—The art of beating gold into thin leaves seems to have been known from a very remote period. The fact that the Hebrews were acquainted with it has been already stated,—and from the circumstance that, on the coffins of the Theban mummies, specimens of leaf-gilding are met with, in which the gold is so thin as to resemble modern gilding, it may be inferred that the Egyptians had carried the art to a high degree of perfection. This art is distinctly referred to by HOMER, and was practised extensively by the later Greeks, even to decorate the external sculpture of their temples and statues. PLINY states that after the destruction of Carthage the Romans began to gild the ceilings of their temples and palaces, and that luxury advanced on them so rapidly that, in a little time, even private and comparatively poor persons gilded the walls, vaults, and other parts of their dwellings. HORACE's remark, that *neither ivory nor gilded arch figured in his house*, is familiar to the classical student. PLINY further states, that one ounce of gold was extended to 750 leaves, each four fingers square. LUCRETIVUS compared the Roman gold-leaf to a spider's web, and MARTIAL described it as little other than a vapor; yet, according to PLINY's account, it must have been three times the thickness of the ordinary leaf-gold of the present time.

Experiments have been made to ascertain to what degree of thinness gold and silver could be reduced: it was found that one grain of gold was spread to the extent of seventy-five square inches, and the same weight of silver to the still more extraordinary dimensions of ninety-eight square inches. Taking one cubic inch of gold at four thousand nine hundred grains, it will be found that the gold was the three hundred and sixty-seven thousand five hundredth part of an inch in thickness, or about one thousand two hundred times thinner than ordinary printing paper. Thus, if three hundred and sixty-seven thousand leaves of gold were placed on one another they would constitute a pile only an inch high, while the same number of leaves of paper would form a pile half the height of

the Monument of London. The same *weight* of silver, though extended over a much larger surface, was thickest, owing to the difference in its specific gravity. In practice, the gold leaf is never extended beyond the one-two hundred and ninety thousandth part of an inch in thickness.

The late Dr. URE erroneously states, that the gold used in gold-beating ought to be of the finest standard. Alloy, he adds, hardens gold, and renders it less malleable; so that the fraudulent tradesman who should attempt to debase the gold would expose himself to much greater loss in the operation than he could derive of profit from the alloy. From this statement it might be inferred that nothing but fine or perfectly pure gold is used by the gold-beater, whereas, in point of fact, it is variously alloyed, according to the color required. Indeed, it is not uncommonly supposed, among the workmen employed in the business, that fine gold is incapable of being reduced to thin leaves; but this also is an error. It is simply objectionable for commercial purposes, on account of its greater cost, and also on account of the adhesion which takes place when one part of a leaf of fine gold touches another, thus causing a waste of labour, by the leaves being spoiled. For work, however, which is to be exposed to the weather, fine gold is the best, being more durable, and not liable to tarnish or change color.

A London gold-beater, Mr. E. S. MARSHALL, exhibited specimens of gold-leaf at the Great Exhibition of 1851, for which the prize medal was awarded to him. The specimens were twelve in number, and embraced a regular gradation in color from red to nearly white—namely, red, pale red, extra deep, deep, orange, lemon, deep pale, pale, pale pale, deep party, party, and fine gold. The deeper colors were alloyed with from twelve to sixteen grains of copper per ounce, but no silver, since any admixture of this metal with so large a quantity of copper would considerably impair the malleability of the alloy; the medium colors contained from twelve to twenty grains of silver, with from six to eight grains of copper, to the ounce; and, lastly, the paler leaves contained from two to not less than twenty pennyweights of silver to the ounce, but no copper, for the same reason that silver was omitted in the red or deep-colored golds.

The process of gold-beating is purely a mechanical operation, but involving as it does one of the most important applications of this precious metal, it will be necessary to give a short account of it. The first operation is the *casting of the metal into ingots*. For this purpose the gold, either pure or alloyed, according to the color desired, is melted in a crucible at a higher temperature than is simply necessary to fuse it, by which its malleability is improved. It is then poured into moulds previously heated and greased on the inside, and cast into flat oblong ingots, each about three-fourths of an inch wide, and weighing two ounces. The ingots, when taken from the moulds, are annealed in hot ashes, which cleanse them from grease and increase the malleability of the gold. When the ingot is cold, the French gold-beaters hammer it out to the thickness of one-sixth of an inch, and expose it at the same time to repeated annealings; but this operation,

termed the *forging*, is omitted by the English gold-beaters. The next process is the *lamination*, which consists in repeatedly passing the ingot between two rollers of polished steel, gradually brought closer together, until it is formed into a riband of one and a half inch in width, and ten feet in length, to the ounce. By this means the ingot is spread out to a surface of nine hundred and sixty square inches of the thickness of rather more than one-eight-hundredth of an inch. The next operation is the *beating*, for which purpose the riband of gold, after being annealed or softened in the fire, is carefully divided with compasses and cut up into pieces of the size of a square inch, each weighing about six grains; about one hundred and sixty of these are placed by means of wooden pliers between the leaves of a *cutch*, which formerly consisted of a packet of fine calf-skin vellum, but now it is usual to employ a tough paper manufactured in France. A case of strong parchment, open at both ends, is drawn over the cutch, and this is enclosed in a second similar case at right angles to the first, so as to cover the edges which the first had left exposed. The cutch is then beaten with a seventeen-pound hammer, upon a smooth block of black marble, supported on a strong bench, and surrounded on three sides by a wooden ledge, while the front is left open, and has a leathern apron attached to it, to preserve any fragments of gold that may fall out of the packet. The hammer is short-handled, and is wielded by the workman with one hand, while with the other he occasionally turns the packet over, to distribute the force equally. The elasticity of the packet causes the hammer to rebound, and lightens the labor of the operator. At intervals the packet is taken up, and bent or rolled between the hands, to overcome any slight adhesion between the leaves and the interposed paper or vellum; or it is taken to pieces to examine the state of the gold, and to shift the central leaves to the outside, and *vice versa*.

When the gold plates of one inch square are thus spread out into four-inch squares, or to nearly the size of the leaves of the cutch, which generally requires about twenty minutes' beating, the packet is opened, and each leaf of gold is taken out, and cut with a knife into four equal squares, thus increasing the one hundred and fifty pieces to six hundred of nearly the same size as at first. These are put between the leaves of another tool, called a *shoder*, made of *gold-beater's skin*. This substance is the cæcum of the ox, which is first doubled, then prepared with solutions of alum, isinglass, white of egg, *et cetera*, and after being beaten between folds of paper to expel the grease, is finally pressed and dried. The shoder is enclosed in parchment and beaten as before, but with a smaller hammer, about nine or ten pounds weight, till the squares of gold are again extended to nearly the size of the skins. The shoder requires about two hours' beating for this purpose. During this period, the packet must be often folded, to render the gold as loose as possible between the membranes. As all the leaves do not spread quite equally, the shoder is beaten upon after the more expanded leaves have reached the edges, the effect of which is, that these come out of the edges in the shape

of dust, and this allows time for the smaller leaves to reach the full size of the shoder.

The packet is now opened, and the leaves of gold, being spread on a cushion, are again subdivided into fours, by means of two pieces of cane cut to very sharp edges, and fixed down cross-wise on a board. This rectangular cross being applied on each leaf, with slight pressure, divides it into four equal portions, and is preferable to a steel knife, to which the gold, in its now attenuated state, would be liable to adhere. The two thousand four hundred squares thus formed are separated into three parcels of eight hundred each, and the squares of each parcel are placed in another shoder or mould composed of gold-beater's skin, enclosed in the parchment cases, and beaten as before. This is the last and most difficult stage of the process. The mould must be made of the finest skins, about five inches square; and on the fineness of the skin, and the judgment and dexterity of the workman, the perfection and thinness of the leaf of gold depend. A seven-pound hammer is now employed, and after two hours' beating, the gold is reduced to the one hundred and fifty thousandth of an inch in thickness, and begins to transmit the rays of light. When the gold is quite pure, or but slightly alloyed, it transmits the green rays, but in gold highly alloyed with silver, the pale violet rays are transmitted. After being hammered another two hours, the leaves acquire the tenuity of ordinary leaf-gold, and average from three to three and a half inches square. The three beatings and two quarterings expand the gold to an area about one hundred and ninety times greater than it had in the form of a riband, and one hundred square feet of it weigh only an ounce. It is true that an ounce might be hammered to cover an area of one hundred and sixty feet; but in this case the gold would be too much attenuated for common use, and the extra labor and care required would not be compensated by any corresponding advantage. After the last beating, the leaves are lifted one by one with a delicate pair of long pincers, made of white wood, and are spread out on a leathern cushion by blowing them flat with the mouth. Broken or blemished leaves are rejected; the good ones have the ragged edges cut off with a square frame of sharp cane, which reduces them all to a uniform size, and are then placed in a book, the leaves of which have been rubbed with red ochre, to prevent the gold from adhering. Each book is capable of holding twenty-five leaves, and in this form the gold-leaf is sold for gilding picture-frames and books, and for the various ornamental purposes to which it is applied in the arts.

In this country the art of gold-beating was long confined to London, where it has been carried to higher perfection than in any other part of the world; but, of late years, efforts have been made on the Continent, with the aid of English gold-beaters' skin, to emulate the beauty and fineness of the English product; and the art is now practised successfully in different large cities in England, as well as in Scotland and Ireland. Latterly, machinery has been applied to supersede the arduous manual labor of gold-beating with the hammer, and machines for this purpose were sent to the Great Exhibition from France and the United States.

There was also exhibited a specimen of leaf-gold, manufactured in London by means of steam machinery; and there is little doubt that the article, so manufactured, will ultimately supersede the product of manual labor.

GILDING.—This is the art of applying a superficial covering of gold to articles of wood, metal, *et cetera*, chiefly for the purpose of ornament, but sometimes also for utility, as when it is essential that the article should be preserved from tarnishing. Gilding is practised by various methods, the principal of which may be classified under the following heads, namely: 1. Mechanical gilding with gold-leaf for wood, leather, *et cetera*; 2. Chemical gilding, properly so called, which is practised on metallic substances, and includes wash-gilding, or gilding by amalgamation; gilding by immersion and various other processes; 3. Electro-gilding, commonly known as the electrolyte.

1. *Mechanical Gilding*, or gilding on wood with gold-leaf, is of two kinds, distinguished as burnish-gilding and oil-gilding.

In *burnish-gilding*, the process may be exemplified as applied to a picture-frame. In this case the gilder receives from the joiner a bevelled moulding twelve feet in length, which he prepares for gilding by a number of preliminary coatings of size, mixed with different substances. He first gives it a priming of hot size and whiting, this mixture being laid on in a somewhat fluid state, and therefore termed *thin-white*. It is prepared by melting the size in an earthen pipkin, and stirring in the whiting in fine powder by small portions at a time. When this first coating is dry the surface is examined, and all holes and irregularities are filled up with a mixture of whiting and size, made of the consistence of putty, but containing no oil. The moulding then receives four or five layers of a mixture similar to the first, but of greater consistence, and therefore termed *thick-white*, allowing time between each layer for the work to dry. While each of these last coatings is still wet, the fine work of the moulding is kept open by means of chisels, gouges, and other tools for the purpose. Sometimes two thick-whites are laid on successively, without allowing the first to dry, and are then worked into the shape of the moulding by hard stones of the required form. The whiting is now from one-sixteenth to one-twelfth of an inch in thickness, and is trimmed to remove the unevenness at the edges, after which the entire surface of the moulding is smoothed with pumice-stone, formed to fit exactly into the various parts, which are slightly wetted to promote the smoothing effect. The final polish of the whiting is given with glass-paper.

The moulding is now ready to receive the gold-size, which consists of pipe-clay, red chalk, black lead, suet, and bullock's blood. Of this mixture, which is sold to the gilder in a tenacious mass, rather softer than butter, a portion is taken and melted with common clear thin size; and while still slightly warm, is laid on with a brush, and with great nicety of hand.

The next operation is the gilding, for which several tools are required,—a leathern cushion to receive the gold-leaf, a knife for cutting it into different sizes, and a little instrument, termed a *tip*, for laying the leaf on the moulding. This last instrument consists of two

pieces of card glued together, with the ends of a row of camel's hairs fastened between them, and projecting from one inch to one inch and a half. The gilder having moistened with water a few inches of the moulding about to be gilded, and having cut a leaf into stripes suited to the width of the part on which it is to be laid, touches one of these stripes with the tip, to the hairs of which it slightly adheres, and transfers it to the moistened part of the moulding. When the whole of the moulding has been thus covered, it is set aside to dry.

The next process is the burnishing, which is performed by rubbing briskly over the gold a piece of flint or agate. This greatly increases its brilliancy, and does not injure the gold-leaf on account of the foundation of gold-size and whiting which yields under the hand. The parts which are to be in *dead* gold or *matt*, are left unburnished, but over these parts a very thin, clear size is passed, and, when dry, the gold is carefully wiped with soft cotton wool. The work is completed by wetting the matt parts with a pencil dipped in clear finishing size. The moulding is then passed into the hands of the frame-maker, who cuts it up and forms it into a frame of the required size.

When the frame or other article to be gilt is somewhat richly ornamented, *oil-gilding* is used. In this case the moulding is first whitened as before, but is then made up to the required shape, and decorated with composition ornaments before the application of any further primings. In this state the gilder receives the frame, and his first operation is to wash it, in order to free it from oil or other impurities. He then gives it two or three coatings of thin-white, mixed with a little soft clay, and several additional coatings are given to the parts intended to be burnished. Two or three coats of a moderately strong size called *clear-cole* are now spread over the whole, after which the *oil gold-size*, consisting of a mixture of boiled linseed-oil and ochre, is laid on smoothly with a brush. After six or eight hours, when the oil-size has been partially dried, the gold-leaf is applied as before, except that in this case no water is used, the oil serving the same purpose. For deep ornaments, the gold is pressed in with cotton-wool, and in this case the gilding has to be repeated to remove the irregular fractures known by the gilders as *spiders' legs*. The work, which has still a ragged appearance, is now carefully gone over and smoothed with a brush—superfluous gold being removed from some parts and worked into others. This operation is termed *skewing*. The parts to be burnished are then treated as before, and finally the frame, after being dusted, is sized with clear size, and yellowed on the outside.

Another application of gold-leaf is to book-gilding. When the book is bound in leather, the back and sides to be gilt are first covered with a coating of isinglass, or white of egg, dissolved in a large proportion of water, and termed *glaire*. This is allowed to dry, and when the gold-leaf is about to be laid on, a woollen rag, slightly moistened with hog's lard or sweet oil, but so as to feel almost dry to the touch, is rubbed over the leather. This causes the adherence of the gold-leaf, which is laid on over the whole space intended to be covered by the figure; and is then imprinted with a hot brass

block, cut to the required design or letters. For this purpose a blocking-press is employed, and in the upper bed is a cavity containing a row of gas jets for keeping the block at the proper temperature. After the block has been brought down by means of a lever, the gold is readily brushed off from the parts which have not received the impression. Books bound in cloth are treated in the same manner, except that they do not receive the preliminary coating of *glaire*, the place of which is supplied by a portion of the glue under the cloth being raised by the heated block. The edges of the leaves of books are gilded in the bookbinder's press by applying a solution of isinglass or white of egg, moistened with oil, and then laying on the gold-leaf, which is firmly pressed down and burnished with agate, blood-stone, or polished steel. Instead of isinglass or ovalbumen, the serum of bullock's blood is often employed.

2. *Chemical Gilding*.—When metallic surfaces are to be gilded, the gold is applied either in the state of an amalgam, which is termed *wash-gilding*, or is deposited by chemical affinity from its solution.

Water or *Wash gilding* consists in applying evenly an amalgam of gold to the metallic surface to be gilt, and then dissipating the mercury by heat so as to leave on the surface a film of pure gold. Ordinary brass answers very well for gilding on, but the alloy which is now generally preferred is a mixture of copper, nickel, and zinc, which may be so proportioned as nearly to resemble gold in color. To form the amalgam, a small quantity of gold, reduced to grains or thin plates, is heated in a crucible till it becomes faintly red, and then thrown into mercury, also previously heated till it has begun to emit visible vapor. The proportion of mercury to gold is generally as six or eight to one. The mercury is then stirred with an iron rod till all the gold is dissolved. The crucible is now removed from the fire, and the amalgam, when cold, is squeezed in a bag of chamois leather, for the purpose of straining off the superfluous mercury. The true amalgam which remains consists of about thirty-three of gold and fifty-seven of mercury in a hundred parts; it is a yellowish silvery mass, of the consistence of butter.

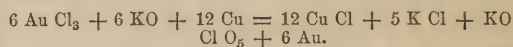
Before applying the amalgam to the metallic surface, the latter is rubbed over with a solution, formed by dissolving a hundred parts of mercury in a hundred and ten parts, by weight, of nitric acid, of specific gravity 1.33, and diluted with about twenty-five times its weight of distilled water. This solution not only cleanses the metal from any rust or tarnish, but in consequence of the stronger affinity of the copper alloy for nitric acid than the mercury has, the latter is precipitated upon its surface in the same manner as a piece of polished iron precipitates copper from a solution of the sulphate of that metal. The amalgam is now spread evenly over the alloy to be gilt by means of a brush, and readily adheres to the metallic surface in consequence of the thin film of mercury already deposited upon it. Sometimes the metal is previously cleaned with sulphuric acid, and the nitrate solution and amalgam are then applied simultaneously. For this purpose a gilder's scratch-brush, made with fine brass-wire, is first dipped into the nitrate of mercury solution, and is then drawn over a lump of amalgam, placed on

the sloping side of an earthen vessel, after which the brush is applied to the surface of the alloy. This process is repeated till the whole is coated with its just proportion of gold. The article is then bathed in water, dried, and exposed to a fire of glowing charcoal to expel the mercury. The heat applied must be just sufficient for this purpose, and the article must be turned about to expose it equally on all sides. From time to time it is withdrawn from the fire, and while the operator holds it in his left hand, protected by a stuffed glove, he spreads the amalgam equally with his right hand by means of a long-haired brush. The piece is then returned to the fire, and the same operations are repeated till the mercury has entirely volatilized. This is known by the surface becoming of a dull yellow color, and by the hissing sound of a drop of water let fall upon it.

The surface, now coated with a film of gold, is still deficient in polish and lustre. To communicate these qualities, it is washed and well rubbed with a scratch-brush in water acidulated with vinegar. It is then covered with a composition called *gilding wax*, which is simply a mixture of bees' wax with some of the following substances, namely, red ochre, verdigris, copper scales, alum, vitriol, and borax. Coated with this composition, it is again exposed to the fire until the wax is burnt off. By this means the gilding is found to be heightened in color, probably in consequence of the complete dissipation of some of the mercury remaining after the former operations. If the article is wrought or chased, the parts intended to be burnished are now rubbed with a steel burnisher, dipped in acidulated water, till a fine metallic lustre is produced. Formerly hæmatite or bloodstone was almost exclusively used for this purpose, but is now generally abandoned for the use of the steel burnisher, which is case-hardened and then carefully polished. The parts intended to be deadened are coated with a mixture of sea-salt, nitre, and alum, fused in the water of crystallization of the last-mentioned salt; the article is then heated till the saline crust with which it is covered enters into fusion, and becomes homogeneous, after which it is withdrawn and suddenly plunged into cold water, which entirely detaches the crust. Lastly, the piece is passed through weak nitric acid, washed in pure water, and dried.

Gilding by immersion is another method by which copper trinkets and stamped articles can be coated with a thin film of gold. This method, which dispenses with the dangerous use of mercury, so detrimental to the health of the workmen, was patented by Mr. ELKINGTON, of Birmingham, in 1836, and has been very extensively practised, more especially in France. In this process the copper or other metallic articles to be gilt, are, after being well cleansed, immersed in a boiling-hot solution of terchloride of gold mixed with a solution of bicarbonate of potassa. The adhesion of the gold to the inferior metal takes place in consequence of a portion of the copper becoming dissolved by the action of the potassa, and the deposition of an equivalent of gold upon the copper article in its stead. The details and rationale of the process are thus described by Dr. MILLER of London:—The gilding-bath is prepared by dissolving one part of fine gold in aqua regia,

and expelling the excess of acid by evaporation. The chloride is dissolved in a small quantity of water. To this solution thirty parts of bicarbonate of potassa are gradually added. This liquid is then mixed with a solution of thirty parts more of the bicarbonate, dissolved in two hundred parts of water, and the liquid is boiled for two hours. During this operation the bicarbonate of potassa is converted into the sesquicarbonate, and the yellow liquid passes into green; after this, the solution is ready for use. The trinkets having been annealed, are cleansed from adhering oxide by a momentary immersion in a mixture of equal parts of sulphuric and nitric acids; to which, when the gold is intended to have a *dead* appearance, a little chloride of sodium is added. The articles are washed in water, and then plunged into the gilding liquid, where they are left for about half a minute, after which they are washed in water and dried in hot sawdust. This bath may be also employed for gilding on German silver, platinum, or silver, by immersing the objects composed of these metals in the liquid, in contact with wires of copper or of zinc. During this process of gilding, a remarkable reaction occurs—the gold imparts a portion of its chlorine to the excess of potassa contained in the bath, forming chlorate of potassa; protochloride of gold is formed, and is decomposed by the copper,—chloride of copper being produced, whilst metallic gold is deposited upon the surface of the trinkets:—



During this operation a black powder is precipitated, which contains hydrated carbonate of copper, mixed with a small proportion of the purple of Cassius derived from the action of the gilding solution upon the tin contained in the solder of the trinkets. The compound termed the purple of Cassius will be described afterwards.

Gilding on iron and steel cannot be well performed directly by the method of amalgamation, as it is difficult to prevent the oxidation of the metal during the volatilization of the mercury, and the temper of sword-blades, daggers, and other such instruments, to which the gilding is usually applied, is liable to be injured in the process. It may be effected, indeed, by previously applying to the polished surface the solution of nitrate of mercury already described, and known as *quicksilver water*; the acid so applied unites with a portion of the iron or steel, and deposits in its place a thin coating of mercury, which combines with the gold amalgam when brushed on. By this method, however, a bright and durable gilding cannot be obtained.

Another not very successful method of gilding on polished iron and steel, is by means of an ethereal solution of terchloride of gold. For this purpose the gold is first dissolved in aqua regia, and about twice the quantity of ether is then cautiously added in a large vessel. The liquids are agitated and allowed to rest, when the ether will separate, and float on the surface of the acid. The whole mixture is now poured into a funnel terminating in a small aperture, and again allowed to settle and separate, after which the acid is run off from below. The ether which remains has taken up all the

gold, and before applying it to the iron or steel, the metal is polished with the finest emery and spirit of wine. The ether is then laid on with a small brush, and as it evaporates it deposits the gold, which can now be heated and polished. This gilding, however, is neither very rich nor durable, in consequence of the affinity between gold and iron being feeble compared to that between gold and copper or silver.

But polished iron and steel, as well as copper, may be effectively gilded with gold-leaf by the application of heat. For this purpose, the metals are heated till the iron assumes a bluish tint, and till the copper has acquired a like temperature. The first coat of leaf-gold is then applied, being pressed gently down with a burnisher, and then exposed to a moderate heat. Several leaves, either single or double, are thus successively applied, and the last is burnished down cold. This is the method usually practised in gilding iron or steel.

Gilding on silver is performed by means of the ashes of a linen rag, which has been dipped in a solution of gold and copper in aqua regia. For this purpose, sixty grains of fine gold and twelve of rose copper are dissolved in two ounces of aqua regia. With this solution a quantity of linen rags sufficient to absorb all the liquid is soaked. The rags are then dried and burned, and the ashes contain the gold in powder. A moistened cork or piece of leather is dipped into this powder, and after the article to be gilt has been well annealed and polished, the ashes are rubbed over it with the cork till the surface appears sufficiently gilded. Large articles are finally burnished with bloodstone, and small ones with steel burnishers, along with soap-water.

Gilding on glass or porcelain is effected with pulverulent gold, or gold precipitated from its chloride solution by means of sulphate of iron. In this state the gold is mixed with one-twelfth of its weight of oxide of bismuth, together with a small quantity of borax and gum-water, and is applied to the parts to be gilt with a camel's hair pencil. The article is then heated in a muffle, and when removed the gold appears of a dingy color, but the lustre is brought out by burnishing with agate or bloodstone. Lastly, it is cleaned with vinegar or white-lead.

Vessels which are not often used, and are not liable to wear, may easily be gilt in a less durable manner, by fixing gold-leaf upon them with copal varnish.

3. *Electro-Gilding*.—This process, which has now almost entirely superseded the method by amalgamation, is applicable not only to metals, but to wood, plaster, or any other substance capable of receiving a coating of plumbago, or of PARKES' patent preparation of phosphorus. Full details of this beautiful process have been given in the article ELECTRO-METALLURGY, to which the reader is referred.

ARTIFICIAL GOLD.—Under the name of Californian gold, and other sounding titles, are sometimes sold alloys which do not contain one grain of the precious metal, but merely resemble it in color and lustre so long as they remain untarnished. It is stated that a good imitation has lately been formed by Messrs. MOURIER and VALLENT, of Paris. The materials and

proportions used by them are—pure copper, 100 parts by weight; zinc, 17; magnesia, 6; sal ammoniac, 3.60; quicklime, 1.80; tartar, 9. The copper is melted in a crucible, in a suitable furnace; the magnesia, sal ammoniac, lime, and tartar, are then added, separately and by degrees, in the form of powder; the whole is stirred for about thirty minutes to thoroughly mix the ingredients, and the zinc is then thrown on the surface, having first been ground into very small grains; the stirring is continued until the fusion is complete. The crucible is now covered, and the fusion continued for about thirty-five minutes, when it is uncovered and skimmed with care, and the contents are run into a mould of moist sand or metal. The material which results may be cast at such a temperature that any ornamental form may be given to it. It is very fine-grained, and is also damascene, malleable, and capable of taking a very brilliant polish. When tarnished by oxidation, its brilliancy can be restored by a little acidulated water. If tin be employed instead of zinc, the alloy will be still more brilliant.

COMPOUNDS OF GOLD.—Apart from the alloys of gold, the only chemical compounds of this metal possessing any importance, are the chlorides, the oxides, and a substance known as the *purple of Cassius*, of which the composition is still somewhat obscure.

Chlorides of Gold.—Gold forms two compounds with chlorine,—a protochloride, AuCl , and a terchloride, AuCl_3 . The latter is the most important chemical compound of the metal, and from it nearly all the other useful preparations of gold are made. It is prepared directly by dissolving gold in nitro-hydrochloric acid. On evaporating the solution, the terchloride may be obtained in ruby-red prismatic crystals, which are very fusible, and deliquesce on exposure to the air. It is very easily decomposed by heat, light, organic substances, and all deoxidizing or reducing agents. Hence the fingers or writing paper, if washed over with the solution, become stained of a violet color when exposed to the sun's light; and hence also its occasional use in photography. It is soluble in water, in alcohol, and in ether; and the latter solution, as already stated, is sometimes used for gilding steel. When heated to about 350° , the terchloride is transformed, by the expulsion of two-thirds of the chlorine, into a pale-yellow sparingly soluble powder, which is the *protochloride*. This is an unstable compound of no importance in the arts. At a red heat it loses its chlorine entirely, and metallic gold remains.

The terchloride is the usual and most convenient form of obtaining a solution of gold, and examining its properties in that state. The different reagents by which pulverulent gold may be precipitated from this solution, have been already mentioned. It is by this means that gold is obtained in a state of chemical purity.

Oxides of Gold.—The oxides of gold correspond to the chlorides, and are obtained from them,—the protoxide, AuO , from the protochloride, and the teroxide, AuO_3 , from the terchloride. The *protoxide* is obtained as a dark green powder by precipitating the protochloride by a dilute cold solution of potassa. It is permanent at ordinary temperatures, but a heat bordering

upon 480° decomposes it into metal and oxygen; kept in contact with a solution of potassa for some time, it alters to metallic gold and the teroxide. When digested with ammonia, it forms fulminating gold. The *teroxide* which possesses acid properties, and is therefore frequently termed *auric acid*, is the only well-known oxide of gold; it is usually prepared by digesting a solution of the terchloride of gold with pure magnesia, washing the precipitate with water, and removing the excess of magnesia by dilute nitric acid; but WAGNER recommends the following process:—Dissolve one part of gold in the usual way, render it quite neutral by evaporation, and re-dissolve in twelve parts of water; add to the solution one part of carbonate of potassa dissolved in twice its weight of water, and digest at about 170° . Carbonic acid gradually escapes, and the hydrated teroxide subsides, of a brownish-red color. After being well washed, it is dissolved in colorless nitric acid of specific gravity 1.4, and the solution decomposed by admixture with water. The hydrated teroxide is thus obtained nearly pure, and is rendered anhydrous by a temperature of 212° . In the state of hydrate it is yellow, but when anhydrous it is nearly black. It is insoluble in water, is very readily reduced by solar light, and at a temperature of about 470° it is resolved into metallic gold and free oxygen. It is quickly dissolved in hydrochloric acid, yielding the common solution of gold; but although it is likewise taken up by strong nitric and sulphuric acids, it forms no true salts or definite compounds with these or with any acids containing oxygen: so slight is the affinity, that the oxide is quickly precipitated by the addition of water. The hydrated teroxide, however, readily combines with the alkalies, apparently forming regular salts, which are termed *aurates*.

FIGUIER gives the following method in preference to the above, in consequence of its yielding a larger product, and at the same time a *purer oxide*. Dissolve one part of gold in four of aqua regia, and evaporate to dryness on the sand-bath at a gentle heat; wash the dry residue with water, till the undecomposed terchloride of gold is removed, and add a further quantity of aqua-regia to the residue, which consists of metallic gold and protochloride; after solution, evaporate and wash as before, and repeat the process till the whole of the metal is obtained as neutral terchloride. Add the various liquors together, and then an excess of potassa, till there is a strongly alkaline reaction manifested on testing with turmeric paper. The menstruum becomes turbid, but before the teroxide of gold precipitates to any appreciable extent, chloride of barium is added. This causes the deposition of a canary-colored aurate of baryta. When the precipitate begins to present a whitish aspect, the addition of the chloride of barium is discontinued; the aurate is washed by decantation till sulphuric acid fails to show that baryta is contained in the washings, after which it is acted upon by dilute nitric acid, with the view of dissolving out the baryta. To effect the latter completely, it is necessary to raise the temperature to ebullition. As in the previous case, the nitrate of baryta is removed by decanting the liquor, and the several succeeding washings, till an acid reaction ceases to be discerned with blue litmus paper.

In drying the precipitate, care is necessary, since at 212° it partly decomposes. FIGUIER recommends the pressing of the matter between folds of bibulous paper, and subsequently exposing it in a dark situation to air, till the last traces of moisture are eliminated.

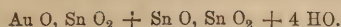
Any gold which may be carried off in the washings of the aurate of baryta, described above, is recovered by adding to them sulphate of iron, after their concentration and the removal of the baryta with sulphuric acid.

The washings and solution from the separated teroxide of gold may likewise be operated upon in a similar way, only that it is necessary to remove the nitric acid before doing so. For this purpose, the liquid is evaporated, and the residue boiled for some time with an excess of hydrochloric acid till nitrous acid ceases to be evolved.

Fulminating gold may be prepared from recently precipitated teroxide, by keeping it in strong ammonia for about a day. A dark olive-brown compound is thus obtained. BERZELIUS assigns to it the composition $\text{Au O}_3 + 2 \text{NH}_3 + \text{HO}$, while DUMAS gives it as $\text{Au N} + \text{NH}_3 + 3 \text{HO}$. The Editor considers the former the more simple and probable view of its proximate composition, that is, regarding it as a diaurate of ammonia, and not a nitride of gold. A similar detonating compound is obtained when the terchloride is digested with an excess of ammonia; this is the ordinary mode of procuring fulminating gold. It subsides in the form of a yellow precipitate, the fulminating ingredient of which appears to be identical with that obtained from the teroxide. This compound may be dried at 212° ; but friction, or a heat suddenly raised to about 290° , produces a violent detonation. The best way is to dry it in the open air, and to make it only in small quantities at a time. Fulminating gold, however, has no application in the arts, in which respect it differs essentially from the following.

Purple of Cassius.—When a mixture of protochloride and bichloride of tin very much diluted, is added drop by drop to a dilute neutral solution of terchloride of gold, a flocculent purple deposit takes place, which has been termed *purple of Cassius*, from the circumstance that the method of preparing it was first described by ANDREAS CASSIUS of Leyden and his son, in 1685, under the name of *gold purple*. It may likewise be prepared by fusing together 150 parts of silver, 20 of gold, and 35.1 of tin, and acting on the alloy with nitric acid, which dissolves out the silver, and leaves a purple residue containing the tin and gold. To prevent the oxidation of the tin during the fusion, the three metals should be projected into a red-hot black-lead crucible, which contains a little melted borax. FUCHS states that the finest purple is produced by mixing a solution of sesquichloride of iron with aqueous protochloride of tin, till the yellow color is converted into pale green, and precipitating the gold solution with the mixture thus formed; he adds that the protochloride of iron in the liquid does not affect the product. This substance, in the moist state, is dark purple-red, and after drying, brown. Its true nature and composition have given rise to much discussion. According to some authorities, it contains metallic gold with hydrated stannic oxide;

according to others, the gold is oxidized. BERZELIUS concluded from the researches of M. FIGUIER, that it consists of a hydrated double stannate of gold and tin, as expressed by the formula,—



it is evident, as TURNER has remarked, both from the color of the compound, and its solubility in ammonia, that it is not a mechanical mixture of metallic gold and binoxide of tin, nor can it well be regarded as a chemical compound of these ingredients, since no definite combinations of that nature are known to chemists. The more probable supposition is, that it is a hydrated double salt, composed of binoxide of tin as the acid, united with protoxide of tin and binoxide of gold as bases, in such proportion that the oxygen of the gold exactly suffices to convert the protoxide into binoxide of tin. On this hypothesis, its composition would be expressed by the formula,—



Purple of Cassius is decomposed by the acids, but is not changed by the action of light. Hence it is somewhat extensively employed in the arts, chiefly for coloring glass and porcelain. When mixed with a little borax or some fusible glass, and applied to the surface of china, it imparts to it a beautiful rose or a rich purple color. Its different applications as a coloring material have already been explained in the articles ENAMELS and GLASS. It is remarkable that the oxide of tin does not appear to be essential, since even finely-divided metallic gold alone will give the same purple hue.

Burgos Lustre.—If finely-divided gold be heated with sulphur in contact with carbonate of potassa, a double sulphide of gold and potassium is formed, which resists a red heat, and is very soluble in water. This sulphur salt is likewise used for gilding porcelain, and produces the color known as *Burgos lustre*.

QUANTITATIVE ESTIMATION OF GOLD ORES AND ALLOYS.—In proceeding to determine the exact amount of gold present in an ore or alloy, it is obviously necessary to exercise the greatest caution in the sampling. Excellent advice on this point is given by Dr. PERCY in his admirable lecture on the metallurgical treatment and assaying of gold ores, delivered at the Museum of Practical Geology. Careless sampling, he remarks, can only mislead; assays of individual specimens may be accurate, but they are worse than useless if the assayer has not operated upon an *average* sample of the ore. He therefore advises the capitalist, to whom prospectuses of gold-mining schemes may be submitted, not to be allured with glittering specimens of gold ore, with assays yielding a high produce, and with the glowing statements of sanguine promoters or enthusiastic adventurers, without having ascertained on good evidence that the samples which are presented to his notice are really *average samples* of the ore, and that something like a continuous supply may reasonably be expected. If such specimens, he adds, do not represent an average, they become what the Cornish miner calls *stocking-stones*, which are at all times enticing and dangerous to the inexperienced and unwary, and never more

so than in the case of auriferous ores. The sampling generally devolves upon the miner, but the assayer and metallurgist should likewise understand the business. Assayers of great experience and high integrity may occasionally, he adds, commit unintentional mistakes. Thus, a few years ago, two small pigs of lead from South America, very rich in silver, were offered for sale. They were assayed by men of very high standing. Portions had been taken from the top and bottom of each pig, with a view to obtain a fair average. Dr. PERCY had occasion to attempt to verify the report of the assayers. Portions were taken from the same parts of each pig as in the first instance; but the results did not agree with the report, nor did Dr. PERCY's assays agree with each other on taking fresh portions. It was therefore certain that the composition was not uniform, and that the portions taken for the purpose of assaying in neither case represented an average. The pigs were accordingly sent again to the same assayers. Each pig was melted separately, and while melted a sample was taken. A second report was given, which differed from the former to the extent of one thousand ounces and upwards to the ton! In the sampling of gold ores most especial care should be taken, as the precious metal exists irregularly diffused through the mass, in particles of very different size, and as minute errors in sampling will necessarily be greatly multiplied when the quantity of gold per ton is calculated from the assaying of, it may be, five hundred or a thousand *grains* of ore.—*Percy*.

The quantitative estimation may be made, more or less correctly, by one of four methods: 1. By determining the specific gravity of the ore or alloy; 2. By the touchstone; 3. By chemical analysis, or the *wet method* of assaying; and 4. By the metallurgical, or *dry method*, in which fire is the principal agent. The first two afford only approximations, and the second is applicable only to alloys of gold; but both may be useful when circumstances render impossible or inconvenient the performance of an exact assay by the wet or dry method.

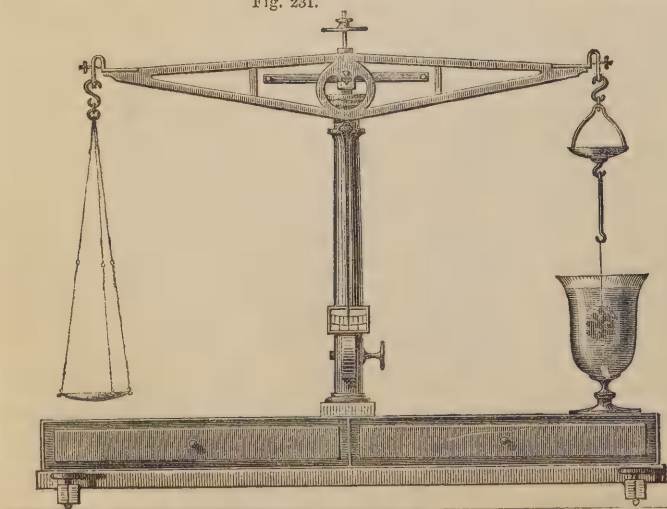
1. *Quantitative Estimation by Specific Gravity.*—It is evident that the high specific gravity of gold, in which it is exceeded only by platinum, not only affords facilities for separating it, by means of washing, from other matters, but also for estimating approximatively the amount in which it is present in any ore or mineral of known composition. The nature of the other ingredients being ascertained, and consequently their weight or specific gravity, the additional weight must be due to the presence of gold, and hence its amount may be calculated. Unfortunately, this quantitative test is rarely applicable to alloys, for experiment proves that an alloy composed of two metals has seldom a density corresponding to the mean which should be obtained by calculation from the relative amounts and specific gravities of its constituents. Thus, it has been found that alloys of gold with zinc, tin, bismuth, antimony, or cobalt, possess a greater specific gravity than the mean of the constituents, while alloys of the same metal with silver, iron, lead, copper, iridium, or nickel, have a specific gravity inferior to that of the mean. It will be seen that in the latter category are included the

metals most usually associated with gold, and hence it may be laid down as a general rule, that the specific gravity of *native gold*, containing an admixture of one or more of those metals, such as silver or copper, is *lower* than it ought to be theoretically. The following experiments by BOUSSINGAULT will show that a very remarkable discrepancy exists between the calculated and true specific gravity of a *native alloy* of gold and silver. In this case, three specimens of native gold were analysed, and their specific gravities, as found by experiment, are subjoined to the results obtained by a simple theoretical calculation:—

	First Specimen.	Second Specimen.	Third Specimen.
Gold,	88.24	73.45	64.93
Silver,	11.76	26.55	35.07
	100.00	100.00	100.00
Calculated specific gravity,	18.22	16.93	16.17
Actual,	14.70	12.66	14.14
Difference,	3.52	4.27	2.03

It is evident, therefore, that an estimate formed from the actual specific gravities of these native alloys of gold, as found by experiment, would have given too low a figure for the amount of gold present. *It is remarkable, however, that these alloys acquire a higher specific gravity after being melted.* Thus, the specific gravity of the first specimen rose, after fusion, to 18.10, or very nearly to what it ought to have been by calculation. Hence it may be assumed, that in artificial alloys, a nearer approximation would be obtained to the true value by this method than with native alloys. At the same time, when, as in the case of Australian gold, the metal is nearly pure, it is evident that the amount of it present in a piece of auriferous quartz, may be deduced with considerable accuracy from its specific gravity, and as the same method is calculated to afford a useful and convenient approximation even in estimating alloys, the *modus operandi* will be explained.

Fig. 231.



Taking for granted, therefore, that the mineral proposed to be submitted to this test is a piece of auriferous quartz—the first point to be determined is its specific

gravity, or its weight as compared with that of an equal bulk of distilled water; because, if this be no higher than that of common quartz, which is found by experiment to average 2.6, it will be unnecessary to proceed further; but if higher, the amount of gold present may be calculated from the difference or excess. Now, the specific gravity of a solid insoluble body, such as quartz, is very readily found by the hydrostatic balance, which in its simplest form is a common pair of scales, with a horse-hair or fine thread attached to the under surface of one of the scale pans. This balance, in its most improved form, is represented in Fig. 231. The substance of which the specific gravity is required is weighed in air, and then, being attached to the hair or thread, is immersed in distilled water at the temperature of 60° Fahr. and again weighed. The difference of the two weights will be that of its own bulk of water, and the specific gravity of the substance is the quotient of its weight in air divided by this difference. This method of ascertaining the specific gravity of irregular solids was one of the great discoveries of ARCHIMEDES, and may be thus explained:—When a body is plunged beneath the surface of a liquid, it obviously displaces a bulk of such liquid equal to itself, and, consequently, it is pressed upward or supported in the liquid with a force exactly equal to that with which the particles of the liquid were supported, when they previously occupied its place; the solid will therefore appear to have lost weight exactly equivalent to that of the bulk or volume of liquid which it occupies. Supposing, therefore, the weight of the auriferous quartz in air to be W , and its weight in water W' , the difference, $W - W'$, will represent the weight of an equal bulk of water, and if S be the specific gravity of the auriferous quartz, or mixture of rock and metal:—

$$S = \frac{W}{W - W'}$$

Having thus obtained the weight and specific gravity of the compound, and knowing the specific gravity of the constituents, it is easy to calculate the amount or weight of gold present. Or, assuming G to represent the weight of the gold, and g the specific gravity of that metal; R the weight of rock or quartz, and r its specific gravity; W the weight of the compound in air, and W' its weight in water, as before; then the weight of gold in the specimen may be found directly by the following formula:—

$$G = \frac{g [W - r (W - W')]}{g - r};$$

and the weight of pure quartz, if required, by this formula:—

$$R = \frac{r [g (W - W') - W]}{g - r}.$$

When the gold ore is in the state of powder or small grains, a somewhat different process must be employed to obtain the weight of a volume of water equal to that of the mineral under examination. In this case, the instrument called the specific gravity bottle, and repre-

sented in Fig. 232, is most conveniently employed. It usually consists of a cylindrical bottle, which may be

Fig. 232.



graduated or not, and the stopper of which, nicely fitted by grinding, is so adjusted that it cannot sink beyond a line marked upon the neck of the phial. When the latter is filled with distilled water, and the stopper inserted, the superfluous liquid escapes by a capillary tube which is formed in the stopper for that purpose, as shown in the figure, and thus the bottle is exactly filled, and all air is expelled. Such bottles are usually made to contain precisely one thousand grains of distilled water at the temperature of 60°, so that when once filled with water at that temperature, the weight of the included liquid is known.

To ascertain the specific gravity of an insoluble powder by this instrument, the powder is first weighed in the air by means of a delicate balance, and its weight noted. It is then introduced into the bottle of distilled water, from which, when the stopper is inserted, a portion of liquid will escape, precisely equal in volume to that of the mineral introduced. The bottle, containing the water and mineral, is now carefully wiped dry, and weighed—a counterpoise equal to the known weight of the bottle having been previously placed in one of the scales. The weight found will evidently be that of the whole water and mineral together, *minus* the weight of a volume of water equal to that of the mineral. If, therefore, *M* be assumed to represent the weight of the mineral in air, *W* the weight of water which exactly fills the bottle, and *W'* the weight of water and mineral in the bottle, it is evident that *M + W - W'* represents the weight of water which has been displaced by the mineral, or in other words, the weight of a volume of water equal to its own bulk. Hence the specific gravity, *S*, of the mineral, or its weight in air, in terms of an equal bulk of distilled water as unity, is found by this formula:—

$$S = \frac{M}{M + W - W'}$$

Suppose, for example, that the substance to be examined resembles gold dust, and that it is found to weigh in air 150 grains. Let the bottle be assumed to contain exactly 1000 grains of distilled water, and when a portion of this is displaced by introducing the heavier mineral, let the weight of the contents of the phial be 1140 grains. In this case, *M* = 150, *W* = 1000, and *W'* = 1140. Hence, *M + W - W'* = 10; and, consequently, by the preceding formula:—

$$S = \frac{150}{10} = 15$$

instead of 19.5, the specific gravity of pure gold; from which it may be inferred that a considerable amount of the precious metal is present, though very far from being in a state of purity. The absolute amount of gold can only be estimated, provided the nature of the substances with which it is associated is known.

The trouble of weighing the contents of the bottle

may be entirely avoided, and thus the operation simplified, by employing a modification of the same vessel provided with a narrow neck graduated to grains of distilled water, which will show at once the amount of liquid displaced. A phial of sufficient capacity to contain not more than from 150 to 200 grains of water, will generally be most convenient for this purpose.

2. *Quantitative Estimation by the Touchstone.*—Another method of estimating approximatively the amount of gold, not in auriferous ores, but in native gold or artificial alloys, is by the use of the touchstone—a method which may be practised with considerable advantage, when the apparatus and reagents necessary for the carrying out of a complete assay cannot be conveniently procured. It is more especially applicable to the estimation of trinkets or other finished articles, which could not be submitted to the assaying processes, either by the wet or dry method, without destroying them.

The touchstone test essentially consists in rubbing some convenient part of the object to be examined on a smooth piece of black basalt or pottery, which for this reason is termed the *touchstone*, and comparing the marks so formed with those produced by one or other of a series of small bars or needles, consisting of alloys of gold with silver or copper in known proportions. The material commonly employed as the touchstone, and generally known by that name, is a species of quartz, colored dark by bituminous matter, and of which large quantities are found in Saxony, Bohemia, and various other localities. Black flint slate will serve the same purpose. The sets of needles or bars may vary from pure gold, through a well-graduated proportion, to equal parts of gold and silver, equal parts of gold and copper, or various mixtures of all three metals in determinate quantities. The fineness of each bar is marked in carats—a mode of valuation which has been already explained.

In proceeding to make an assay by this method, the first streak obtained by rubbing the object to be examined on the touchstone cannot be safely employed to ascertain its composition, if it be a manufactured article, because, by a process previously described, the surface of jewellery is invariably rendered of a higher standard than that of the mass. The object must therefore be passed once or twice over the back or edge of the stone, in order to remove the superficial film of richer metal, before making the streak from which its quality is to be judged. Other streaks are then made successively with two or three of the needles which the assayer, guided by experience, considers to approach nearest in composition to the article under examination. In doing so, he compares not only the color of the streaks made upon the touchstone, but likewise the sensation of roughness, dryness, smoothness, or greasiness which the texture of the rubbed metals excites when abraded by the stone. When he succeeds in obtaining with one of his needles a streak which is perfectly similar in appearance to that produced by the article which forms the subject of experiment, he then moistens both streaks with nitric acid, which will affect them differently if they be not similar compositions. That which has the least gold will be

most affected; on the contrary, if the gold be pure, the streak will remain unaltered. If the actions do not correspond, his experience will enable him to judge in what they differ, and will direct him in selecting another needle to submit to the same comparative test. When one has been found which agrees satisfactorily in all particulars with the metal submitted to examination, the latter is assumed to possess a similar standard of fineness to that which is indicated by the mark on this particular needle.

Nitric acid of specific gravity 1.20 is commonly employed in this operation, with sometimes an addition of about two per cent. of hydrochloric acid. Although the results obtained cannot be relied on where absolute accuracy is required, yet they afford a useful approximation, not only in estimating the value of manufactured articles which cannot be submitted to a regular assaying process, but also in obtaining that preliminary knowledge of the general composition of an alloy, which is so important to the assayer in proceeding to a detailed analysis. The touchstone is therefore of great use in practised hands, but it is of little avail in the hands of an inexperienced operator.

3. Quantitative Estimation by the Wet Method—Analysis.—However useful the approximations obtained from the specific gravity of an auriferous ore, or the application of the touchstone to an alloy of gold, it is evident that more exact methods are required to determine with absolute precision the value of an alloy or ore of this precious metal. Accordingly, there are two methods by which the assaying of gold ores or alloys may be conducted with perfect accuracy, and these are distinguished as the *wet* or *dry* method, according as the agency of liquid solvents or that of fluxes and fire is employed. For practical purposes, in the determination of gold, the latter process is always adopted, although in the final separation of the silver even the dry method, as now practised, involves the application of a liquid solvent.

The principles of the quantitative estimation of gold by the humid method have been already explained in detailing the laboratory process for the preparation of pure gold, and in describing the application of the tests or reagents by which its presence is detected. It is evident that any of the qualitative tests which result in precipitating the gold from its solution in aqua regia, such as protosulphate of iron, may be converted into the means of obtaining a quantitative estimation, by simply weighing the amount of ore or alloy on which the experiment is performed, and then weighing the amount of pure gold, carefully washed and dried, which is obtained in the form of a precipitate. It will therefore be unnecessary to enter into minute details on the chemical principles involved.

It may be stated, however, that if the substance to be examined be a natural or artificial alloy, composed chiefly of the pure metal, such as the gold dust of California or Australia, the quantity taken for the analysis should not exceed fifteen grains. A convenient quantity is twelve and a half grains, as it is then only necessary to multiply the result by eight to obtain the per-centage composition. In performing analyses very small quantities are taken, because it is

easier to operate upon a few grains than upon a large mass; the effect of the reactions is more rapid; there is less waste of materials; and as accurate results can be obtained with a small as with a large quantity, provided sufficient precaution be taken to operate upon an average sample. If the gold be mixed with earthy or quartzose matter, so much of this should be taken as may be judged, from preliminary experiments or other sources of information, to contain the amount of native gold above-mentioned; and this must be triturated in a mortar with great care before subjecting it to the action of the aqua regia—a precaution of less importance in merely testing for gold, but absolutely necessary and essential when it is required to ascertain the exact amount of the precious metal present; for, unless the quartz be reduced to a state of the most minute division, it is evident that much of the gold remaining enveloped in the quartz will escape the action of the acid.

Whatever the precise amount taken, the ore or alloy to be examined must be weighed with extreme accuracy, and then introduced into a Florence flask or any other convenient glass vessel for boiling liquids. Supposing the compound to contain from twelve to fifteen grains of native gold, about an ounce of aqua regia is now poured upon it; the flask is then placed on a retort-stand or sand-bath, and the mixture is allowed to digest at a moderate heat for about half an hour. At the end of that time the gold will be completely dissolved, and the silver, if any be present, will be found in the form of an insoluble chloride, mixed with the silica at the bottom. The heat may then be increased under the flask, and the solution boiled off until it is diminished to about an eighth or tenth of its original quantity. At the same time a little hydrochloric acid should be added occasionally for the purpose of expelling or decomposing the nitric acid, the presence of which is injurious in the after part of the process. The addition of a little carbonate of soda will serve the same purpose. The reader will recollect that the function of the nitric acid is merely to liberate the chlorine, which is the real solvent of gold.

When the evaporation has been carried sufficiently far, three or four ounces of water should be added, after which the contents of the flask must be allowed to remain in perfect rest until the undissolved matter has completely subsided, and the supernatant fluid is quite clear. The latter is then to be carefully decanted or filtered off, and to the residue about an ounce of fresh water must be added, left to stand till clear, again decanted or filtered; and this operation repeated five or six times, always adding the later washings to the first portion of fluid. The solution of gold now obtained will be very dilute. Add to it, therefore, a few drops of hydrochloric acid, and then introduce the protosulphate of iron, which, when the liquid is well stirred, will speedily precipitate the whole of the gold in the form of a brown powder. If oxalic acid be used for the same purpose, the liquid ought to be boiled. When the whole of the precipitate appears to have settled to the bottom, a few drops of the clear supernatant liquid should be taken out on the end of a rod, placed upon a surface of clean white porcelain, and

tested with a drop of the solution of protochloride of tin. If no purple precipitate be formed, it is a proof that the whole of the gold has been thrown down. If a dark brown coloring, but still no subsidence, be produced, this will indicate the presence of platinum. If any precipitate be observed, more of the sulphate of iron or oxalic acid must be added to effect a complete precipitation of the gold contained in the solution.

When the pulverulent gold has entirely deposited, the liquid must be decanted or filtered off with the greatest precaution. Care must be taken that not the smallest particle of the gold powder is allowed to pass away with the liquid. A little hydrochloric acid, which must be quite free from any admixture of nitric acid, is then to be poured upon the precipitate. This will remove any iron or other metallic impurities without dissolving the gold. The latter is then to be washed, at least six times, with successive portions of distilled water; and lastly, it is transferred to a small porcelain or platinum crucible, in which it is heated over a spirit lamp, till the last portions of water are expelled. It ought, in fact, to be raised to a red heat, or even to be fused with a small quantity of borax and nitrate of soda, as formerly recommended, to expel the last traces of chloride of silver.

The pure gold thus obtained is then to be placed in a watch-glass or small capsule, and accurately weighed in a pair of delicate scales, which should be capable of turning with a difference of at least one-hundredth part of a grain. Instead of first counterpoising the dish or capsule, and then adding weights to counterpoise the gold, it is better to begin by placing the capsule *containing the gold* in one pan, and counterpoising both by means of sand, or some other convenient material placed in the other. The gold is then removed from the dish, and weights put in its stead sufficient to restore the equilibrium. The number of grains and fractions of a grain required for this purpose will accurately represent the weight of the gold; and in this method of *weighing by substitution*, as it is termed, any risk of error arising from the possible inequality in length of the two arms of the balance will be entirely avoided.

Supposing the gold to weigh exactly 10·75 grains, and that the amount of alloy submitted to experiment was 12·5 grains, or the eighth part of one hundred, it is evident that $10\cdot75 \times 8 = 86$ is the per-centage of pure gold present.

4. *Quantitative Estimation by the Dry Method—Assaying.*—The fourth and last method of estimating the amount of gold in an ore or alloy, is by the use of fluxes and fire. It is therefore termed the *dry method*, and formerly even the separation of the silver was effected without a liquid solvent, by one or other of the dry processes described in connection with the operation of parting on the large scale; but now the agency of an acid solution is employed in the last part of the process.

This metallurgical method, to which the name of *assaying* is strictly confined, when not otherwise expressed, is that uniformly practised at the Mint, and other regular assaying establishments, being not only more expeditious than the wet method, but admitting

of a greater number of assays being conducted simultaneously. The wet method is useful for special or occasional assays in the laboratory, where assaying furnaces, cupels, *et cetera*, cannot be kept constantly in requisition. On the other hand, the dry method is the best where assaying is practised as a business, and where all the apparatus required is therefore in constant efficiency. This method consists in the following processes: 1. Fusion, to separate earthy and other gross impurities, which may be either performed in a crucible by means of oxide of lead, or by the method of *scorification* with metallic lead. 2. Cupellation, to remove the copper and other base metals by oxidation and absorption. 3. Parting by inquantation, or separation of the silver from the gold, by dissolving the former metal in nitric acid.

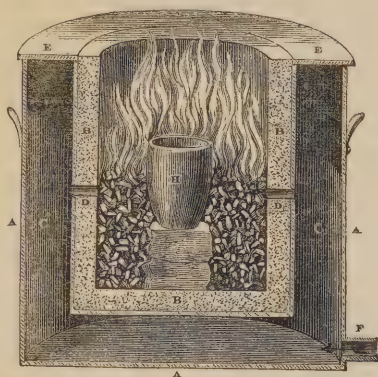
From this enumeration of the different operations which constitute the process of assaying by the dry method, it will be seen that this process is nothing more than a miniature representation of the smelting and refining operations already described. It will therefore be unnecessary to explain the principles on which this important department of the subject is founded, as those already enunciated in reference to the smelting and refining of gold ores, apply equally to the assaying of these ores, as well as of artificial alloys. The principal difference between the two cases consists in the fact, that the assayer operates upon a few grains instead of large quantities, while, at the same time, he must exercise the utmost precaution in attending to the weight and proportions of his materials.

Fusion with Oxide of Lead.—Assuming, as before, that the ore to be assayed is gold quartz, it must first, as in all other cases, be reduced to a fine powder, by triturating in an iron mortar. This operation is much facilitated by heating the quartz to redness, and plunging it in cold water. Having pulverized a few thousand grains, it is usual to make at least two assays of the sample, to test the correctness of the result. For each of these weigh five hundred or a thousand grains, according to the richness of the ore, and mix intimately on a clean surface of glass, or highly-glazed writing paper, with about the same weight of litharge or red lead, half the weight of dry carbonate of soda, and five per cent. of finely-powdered charcoal. The precise quantities are not very important; but it is better that the carbonate of soda should be in excess, than that it should fall short of the above proportion. This mixture is introduced into a Cornish or black-lead crucible, of which it should not fill more than two-thirds the capacity; it may then be covered with a thin layer of borax, and is afterwards fixed solidly in the assay-furnace, by surrounding it with fuel.

Furnaces proper for assaying are of several different kinds, and the required temperature may be obtained in them either by supplying an artificial blast of air by some blowing apparatus, or by connecting the furnace with a chimney sufficiently high to establish a strong natural draught. When the materials for its erection can be obtained, the ordinary wind-furnace is to be preferred. This is represented and fully described, in connection with the assaying of copper ores, at page 498, vol. I., to which the reader is referred. For the

travelling assayer, however, a portable apparatus is required, and in this respect SELFSTRÖM'S blast-furnace offers peculiar advantages. This consists of two cylinders of sheet-iron, placed one within the other, as represented in the annexed drawing, Fig. 233. A represents the outer cylinder, which answers the purpose perfectly well when not larger than a man's hat; and B the inner one, lined with a coating of fire-clay about an inch in thickness. Both cylinders are provided with a bottom, and are fixed together at the top, air-tight, by a horizontal hoop or flat ring of metal, E E, in such a way as to leave an equal space, C C, between their sides and bottoms. The interior cylinder, B B, is pierced at about the middle of its depth with eight holes, D D, which pass through the lining of fire-clay, and all point to the centre of the furnace, where the crucible, H, is placed on a piece of fire-brick, kept in

Fig. 233.

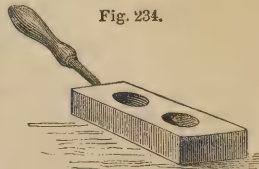


its position by a little fire-clay, and surrounded with fuel. For a small furnace of this kind charcoal must be employed as fuel, and should be broken into pieces about as large as a walnut. The air is blown into the opening, F, by means of a double-action bellows; or a simple rotating fan, like that employed for domestic fires, may be used. By this means the air is compressed into the space C, where it is partially heated, and is thence driven in a steady equable current through the holes D D, into the cavity of the furnace. The heat which may thus be produced with a furnace having an internal diameter of not more than six inches, is so intense as to be capable of melting manganese, or several ounces of cast-iron, with the greatest ease.

To proceed with the fusion. It has been stated that the mixture above-mentioned, when introduced into the crucible, should not fill more than two-thirds of its capacity. This precaution is necessary on account of the effervescence which will take place, owing to the displacement of the carbonic acid from the carbonate of soda by the silica, and the combination of the carbon with the oxygen of the litharge. The heat is continued till perfect fusion is effected, and towards the last the temperature is raised to bright redness, until no further effervescence occurs, and a clear liquid homogeneous slag is obtained. The crucible must then be immediately removed from the fire, otherwise the

unreduced litharge would be liable to cut through the pot; and as dexterously and rapidly as possible, the slag, which constitutes the upper portion of the contents, is poured into one of the two hemispherical cavities of a cast-iron ingot-mould, Fig. 234, and then the lead, with adhering slag, into the other. If any particles of lead are found attached to the slag which is poured into the first cavity, they must be carefully separated by trituration and washing, and added to the button of lead in the other cavity. The latter is then taken out, and struck carefully on the side, on a bright anvil, with a hammer, to detach any portions of slag that may still adhere to it. Sometimes the crucible is broken to extract the button of lead, but this may be avoided by the method above described, if executed with sufficient dexterity. The whole of the gold, with any silver that may be present, remains in the lead, which is then subjected to the process of cupellation.

Fig. 234.



The proportion of oxide of lead to be used in the fusion will necessarily vary with the amount of oxidisable substances present; but this compound should in all cases be added in excess, since, if the slags retain any traces of an alkaline sulphide, these will retain a part of the gold. PHILLIPS states that for the assay of iron pyrites about thirty parts of oxide of lead are necessary, whilst for mispickel, zinc blende, copper pyrites, grey cobalt, and sulphide of antimony, from fifteen to twenty-five times their weight only may be employed. When auriferous pyrites is the subject of examination, it must first be reduced to fine powder, and then roasted in a shallow dish of refractory clay, heated to low redness in a large muffle, until the odor of burning sulphur ceases to be evolved. As the sulphur burns away, the temperature is gradually raised to bright redness. The pyrites is thus converted into oxide of iron. Of this product one thousand grains or more may be taken, and mixed with five hundred of dry carbonate of soda, three hundred to five hundred of litharge or red lead, with five per cent. of charcoal, or the same quantity of granulated metallic lead without charcoal, and lastly, about five hundred of dried borax. This mixture is heated, introduced into the crucible, and fused as for quartz or other common ores. The fuel should be either charcoal, coke, or anthracite. For small portable furnaces, such as SELFSTRÖM'S, charcoal is employed, but anthracite is found to be well adapted for the air-furnace, and is characterised by the power of producing an intense heat in a short time, over a space confined to a few inches above the bars.

The principal objection to this method of assay is the large amount of lead which is produced for cupellation, since pure iron pyrites affords, when thus treated, eight and a half parts of lead, whilst sulphate of antimony and grey copper ore yield from six to seven parts. This inconvenience, as well as the trouble of roasting, may be avoided by the cautious and gradual addition of nitrate of potassa, which effects the partial oxidation of the mineral, and enables the skilful assayer to pro-

cure a metallic button of almost any required weight. The nitre, however, if employed in excess, would determine the oxidation of all the metallic and combustible substances contained in the mineral, except the gold alone, which is never present in sufficient quantity to form a button. The exact amount of nitre to be added must depend on the nature and richness of the ore. As a general rule, it may be stated that two and a half parts of nitre are sufficient to completely oxidise one part of iron pyrites, and that one and a half and two-thirds their weight, in the case of sulphide of antimony and galena, are sufficient to produce the same effect on these ores.

Alloys of gold containing *tin* and *zinc* must likewise be fused, before cupellation, with nitrate of potassa, to oxidise these metals; and by adding about sixteen parts of lead, when the mixture is quite melted, they are separated in the state of slag or scoria, leaving, as before, a button of lead containing the whole of the gold, which is now ready for being cupelled. But before describing this part of the assaying process, the method by scorification, which is often preferred to that of fusion with oxide of lead, will be briefly explained.

Method by Scorification.—Scorification, or, in other words, the conversion of the silica and other impurities into a scoria, is simply another method of fusion, in which, however, metallic lead, instead of its oxides, is employed; and the oxidation of the various substances to be removed is produced by the aid of atmospheric air, whilst the litharge necessary for the fusion of the earthy and silicious matters is formed by the oxidation of a portion of the metallic lead. For this operation, instead of a crucible, a shallow cup-like vessel, termed a *scorifier*, is employed. This vessel, the form of which

Fig. 235.



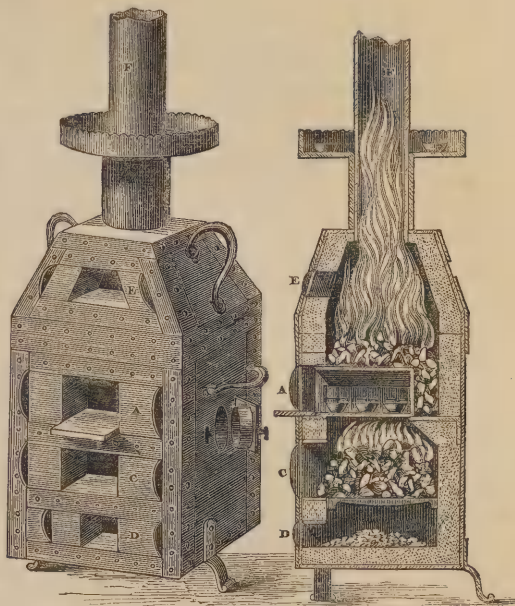
is represented in Fig. 235, should be made of refractory clay, and be as compact in structure as possible, in order to resist the corrosive action of melted litharge. The scorifier with its contents is heated in the muffle of an ordinary assay-furnace, and as many assays may be introduced at one time as there is room for in the muffle.

A very convenient furnace for this purpose, as well as for the subsequent process of cupellation, is shown in elevation and vertical section in Figs. 236 and 237, and the form of the muffle is represented in Fig. 238. This last apparatus is a small arched vessel of fire-clay, closed at one end, and furnished with small holes or perpendicular slits in the sides and closed extremity, to allow of the free circulation of air through the interior. It is introduced by the opening, A, into the furnace, which is made of sheet-iron lined with fire-clay; and when adjusted in its place—as shown in Fig. 237—it is supported at one end by a shelf at the back of the furnace, while the other or open extremity exactly fits the opening, A, to the sides of which it is carefully luted by a little moistened fire-clay. In this position it is surrounded with ignited fuel, by which it is equally and readily heated on all sides; while the openings in its end and sides admit of the passage of a current of air into its interior, and the draught is kept

up by the addition of a long chimney or funnel, F, so that the muffle is constantly traversed by a highly oxidising current. The ledge around the chimney is

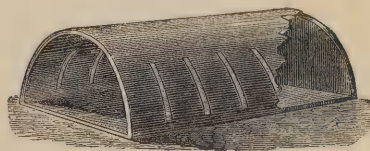
Fig. 236.

Fig. 237.



intended for drying the scorifiers or cupels before introducing them into the muffle. In lighting the furnace, a little ignited charcoal is first introduced by the opening, C, and the body of the furnace above and below

Fig. 238.



the muffle is afterwards well charged with the same fuel, or with good hard coke broken into small pieces. The whole of the openings are then closed by means of their slides or lids, with the exception of the ashpit, D, which is left open to supply the requisite draught.

Before introducing the ore into the scorifiers, it is reduced to powder, and a determined weight of it is intimately mixed with several times its weight of finely-granulated lead, free from silver. The scorifiers charged with this mixture are then placed in the muffle, and the door at the mouth being closed, they are strongly heated in the muffle during a quarter of an hour. By this time the lead will be completely melted, and the mouth of the muffle is again opened. The scorifying process now proceeds in consequence of the current of heated air which passes through the muffle; in other words, the lead is oxidised, and the foreign metals present, whether in combination

with sulphur or oxygen, are attacked and dissolved in the litharge in proportion as this oxide is formed. At first the slags are frequently solid, but gradually become soft, and more and more liquid in proportion as the quantity of oxide of lead increases. Towards the conclusion of the operation, the muffle is for a short time strongly heated to render the slag or scoria completely liquid. When a small iron rod, previously heated to redness and then placed in the mixture, is found, on being withdrawn, covered with a slight film of scoria which runs clean off, the scorification is known to be sufficiently advanced. The scorifiers are then successively withdrawn from the muffle by means of tongs, and the contents are rapidly poured into a circular ingot-mould of the form represented in Fig. 234. When cold, the adherent litharge is detached from the button of lead by a few blows with a hammer. This button contains all the gold and silver which may have been present in the ore, and which are subsequently separated from the lead by cupellation.

If the ore is poor, the whole of the precious metals contained in a large quantity may be concentrated in one small button of lead, by repeating the process on a fresh portion of ore mixed with a suitable quantity of lead, and introducing into this assay the button first obtained. A second button of the same weight as the first, and containing all the precious metals from the two quantities of ore, will thus be procured. The same process may be repeated a third, fourth, or any number of times, till the button of lead last obtained becomes as rich in the precious metals as may be required. It is necessary, however, that a certain amount of lead should be present, with a view to the next process, that of cupellation. In many cases so much as eight times the weight of the ore is employed, but the button may be reduced by a single operation to one-sixth or even to one-eighth of the original lead. Indeed, it is the highest recommendation of this process, as compared with the method by fusion with litharge, that however small may be the proportion of lead, the slags produced never contain any oxy-sulphides at the close of the operation, and, therefore, they seldom retain the slightest trace of either gold or silver. The process of scorification has therefore been justly characterized as one of the most exact methods that can be employed—simple, effective, and applicable to the assay of all kinds of auriferous and argentiferous ores, without exception.

Cupellation of the Assay.—The process of cupellation on the large scale has been already described. When applied to assays the principle is the same; but in this case the whole of the melted litharge and other oxidised matters are removed by absorption into the cupel; whereas it has been shown that, in operating on large quantities, the cupel is soon saturated, and the greater part of the litharge and other oxides are allowed to run away, or are expelled by the current of air which exerts the oxidising action.

The cupels for assaying purposes are formed of the same material as those employed for refining on the large scale, and described at page 284; but they are necessarily much smaller, and are considerably simpler in the manufacture. They are made by pressing the

moistened bone-earth into a mould, which consists of a short, stout cylinder, A—Fig. 239—either of cast-iron or gun-metal, open at both ends, and having the diameter of the cavity somewhat greater at the top than the bottom. Its usual dimensions are as follow:—Interior diameter at top, one and nine-sixteenths of an inch; interior diameter at bottom, one inch and a half; depth, two inches. To make a cupel, the cavity is nearly filled with bone-ash, which is first compressed slightly with the hands, and afterwards by means of the plunger, B, which is formed of the same metal as the mould, and has the lower end turned convex, so as exactly to correspond to the concave surface of the cupel. When the plunger is introduced, it is struck several times with a mallet till the bone-ash is well consolidated. The plunger is then withdrawn, and by inserting at the lower and smaller end of the mould a solid wooden cylinder, which exactly fits the aperture, the cupel is readily forced out, and is then placed to dry on the ledge which surrounds the furnace chimney—Figs. 236 and 237. The diameter of the cupel—Figs. 240 and 241—is about one inch and a half, and its cup-like cavity is very shallow, being not more than three-fourths of an inch deep.

Cupellation, like the process last described, is performed by means of a muffle, Fig. 238. When the muffle has become red-hot, six or eight cupels are successively introduced into it, by a pair of light tongs of the form represented in Fig. 242; and to prevent the

Fig. 239.



Fig. 240.

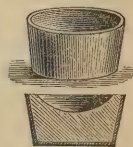


Fig. 241.

Fig. 242.



floor of the muffle being corroded should any of the oxide of lead be spilt on it, it is previously covered with a thin layer of pounded bone-ash. In the furnace of the Mint, the number of assays that can be made at one time is forty-five, and the same number of cupels are put into the muffle. When the cupels are introduced, the door of the opening into the muffle is closed for a few moments, while the draught-hole of the furnace is kept open till the cupels are raised to the temperature of the muffle itself. The slide is then withdrawn, and into each of the cupels is introduced, by a pair of slender tongs, a button of the alloy to be assayed.

By the previous process of fusion with litharge, or that of scorification, if deemed preferable, the earthy impurities have been removed in the form of slag or scoriae, and nothing now remains but the gold, or a mixture of gold and silver, in combination with the lead and any other metals that may be present. The process of cupellation, as previously stated, consists in the oxidation of the lead and other oxidizable metals, and their absorption by the cupel. It is, in fact, a condition essential to the success of the assaying pro-

cess that the whole of the oxides should be imbibed, and thus removed. But the power of absorption in a cupel varies according to its texture, and the care with which the material has been prepared. On an average, it may be calculated that it will absorb about its own weight of fused litharge. This, though not strictly correct, will afford a general guide to the experimenter, as regards the amount of lead which ought to be mixed with the assay. It is evident, on the one hand, that this must not exceed the absorptive power of the cupel. On the other hand, the actual amount, within this limit, must depend on the nature of the compound or alloy upon which the cupellation is to be performed; but supposing that the subject of assay is an alloy of gold and copper, the following table will give the quantity of lead required for the separation of the copper. In treating an alloy of gold and silver with copper, the quantity of lead may be somewhat diminished; but, in cupelling an alloy of copper with gold alone, a small excess of lead is not injurious, as, in consequence of the gold not being volatile, like silver, the heat can be raised and sustained for any required length of time, so as to oxidize the last portions of lead. In this table, which is adapted by Mr. T. W. KEATES, from one given by BERTHIER for the assay of silver—the proportion of lead being altered to render it applicable to the cupellation of gold—the first two columns express respectively the quantities of gold and of copper, and the third column the parts of lead by weight required for one part of the alloy, according to its composition:—

Alloy.		
Quantity of gold.	Quantity of copper.	Proportion of lead required.
1000	0	3-10lbs
950	50	6
900	100	14
800	200	20
700	300	24
600	400	28
500	500	32 to 35
400	600	32 to 35
300	700	32 to 35
200	800	32 to 35
100	900	32 to 35
0	1000	32 to 35

It must be observed that the numbers in the third column indicate multiples of one part of the alloy. It may appear surprising that, at and below the point at which the alloy contains equal parts of gold and copper, the same proportion of lead is required, whatever may be the proportion of the copper. This fact, however, has been fully verified by experience. It requires, in short, as much lead to remove the copper from an alloy of equal parts of that metal and gold as it would to carry off a quantity of copper equal to the weight of the copper and gold together. It may be added, that when the assayer has reason to know pretty nearly the composition of the alloy, it is well to insure the presence of at least two or three times more silver than gold, which is not only useful in the cupellation, to guard against loss of gold, but is necessary, as already stated, for the subsequent operation of parting.

The assays being placed in the cupels, the door is a second time closed during a few minutes, to facili-

tate the fusion of the alloy; and on opening it again, each of the cupels is found to contain a bright convex metallic globule, in which state the assay is said to be *uncovered*. The air is now freely admitted, and rapidly converts the lead into litharge, which, as fast as it is produced, is absorbed by the bone-ash of the cupel. While this operation is going forward, the rounded surface of the liquid button appears to be covered with bright patches and lines of color; these are produced by the thin film of oxide of lead which is constantly forming, and passing off from the centre to the edges of the assay, where it meets with and sinks into the porous matter of the cupel, leaving always a new surface exposed to the current of air which is carried by the draught through the muffle. At the same time there rises, and passes through the openings of the muffle, a white vapor, which is caused by the volatilization and combustion of a portion of lead. When this vapor is very thin, and rises with great rapidity, it is an indication that the heat is too great, and part of the draught must be stopped; on the other hand, when it is thick and heavy, and hangs sluggishly over and around the cupel, the temperature is too low, and the power of the draught must be increased.

As soon as the greater part of the lead has been thus converted into litharge and absorbed, the remaining bead of rich alloy appears to become agitated by a rapid circular movement, and the bands of color with which the surface is covered arise and vanish in quick succession. This is a sign that the process is on the point of completion, and means must now be taken to increase the heat of the furnace for a short time, so as to insure the expulsion of the last remaining portions of lead. But if silver be present in the assay, and if it be desired to estimate also the amount of that metal, the increase of temperature towards the end of the process must be of short duration, otherwise a portion of the silver would soon volatilize. Immediately before the conclusion of the process, the assay becomes somewhat dull, and the movements on its surface can no longer be observed; but after a few moments, it again suddenly lights up with a kind of flash or coruscation, and then becomes permanently brilliant and immovable, —assuming, in short, the fixed metallic lustre of pure melted gold or silver. If the cupellation has been well performed, the gold, or the mixture of the two precious metals, is now in a state of almost chemical purity.

When the phenomenon termed the *flashing*, *brightening*, or *coruscation* of the assay indicates that the cupellation is terminated, the mouth of the muffle ought to be closed for thirty or forty seconds, and then the cupel containing the button of pure metal may be drawn to the front of the muffle, and allowed to cool slowly. The refrigeration must not be too rapid, otherwise there may be very sensible loss by *spitting*, *sprouting*, or *vegetation*—an effect, however, only produced when a large proportion of silver is present, and which has been already explained in connection with the process of cupellation on the large scale. To insure gradual cooling, it is occasionally convenient to invert over the cupel containing the bead another heated cupel.

The button is detached from the cupel after cooling

by a pair of fine steel forceps, and gently squeezed between the jaws of a pair of pliers, to loosen and pulverize any adhering litharge, which is finally cleaned off with a small brush made of brass wire or stout bristles. If the process has succeeded, the button should be round and bright upon its upper surface, but somewhat rough or crystalline on the part by which it was attached to the cupel, from which it ought to be capable of being removed without difficulty.

Even after cupellation, there always remains a trifling admixture of copper in the assay, which is called the *surcharge*, unless there has been present a sufficient proportion of silver. This metal greatly facilitates the separation of the copper, and when it is present in the proportion of three parts of silver to one of gold, the copper can be completely separated. This is one important reason for adding the requisite amount of silver before cupellation. But although silver is not appreciably oxidised or volatilized when melted alone, yet it is so to a certain extent in cupellation, in consequence of the presence of lead. It is, therefore, necessary to make cupellations of the buttons from ores containing silver, at the lowest heat at which the absorption of the litharge can be readily determined. But even when every precaution is used, there is always a loss of silver in cupellation; and the amount of this loss under varying conditions must be known, so as to be able to supply the deficiency in the calculation of the per-centage, as well as with a view to the next process of *parting*. The following table has been calculated for this purpose. The first column gives the weight of silver in one thousand parts of an alloy of silver and copper about to be submitted to cupellation; the second, the actual weight of silver found by cupelling an alloy of silver and copper containing the weight of silver indicated in the corresponding line of the first column; and the third, the actual loss in weight of silver:—

Weight of silver before cupellation.	Weight of silver after cupellation.	Loss of silver
1000	998.97	1.03
975	973.24	1.76
950	947.50	2.50
925	921.75	3.25
900	896.00	4.00
875	870.93	4.07
850	845.85	4.13
825	820.78	4.22
800	795.70	4.30
775	770.59	4.41
750	745.48	4.52
725	720.36	4.64
700	695.25	4.75
675	670.27	4.73
650	645.29	4.71
625	620.30	4.70
600	595.32	4.68
575	570.32	4.68
550	545.32	4.68
525	520.32	4.68
500	495.32	4.68
475	470.50	4.50
450	445.69	4.31
425	420.87	4.13
400	396.05	3.95
375	371.39	3.61
350	346.73	3.27
325	322.06	2.94
300	297.40	2.60
275	272.42	2.58
250	247.44	2.56
225	222.45	2.55

Weight of silver before cupellation.	Weight of silver after cupellation.	Loss of silver.
200	197.47	2.55
175	173.88	2.12
150	148.30	1.70
125	123.71	1.29
100	99.12	.88
75	74.34	.66
50	49.56	.44
25	24.78	.22

In assaying native gold or artificial alloys, the operation usually commences by fusing the alloy in a cupel with about five times its weight of pure lead, and then adding the amount of pure silver necessary to bring the mixture to the proper composition. If the substance be in the ordinary state of the gold of California or Australia, that is, in small grains or dust, it is the best plan to envelop it in a thin sheet of lead; or a suitable quantity of perfectly pure lead may be put into the cupel and melted, and then the assay, wrapped up in a piece of thin sheet assay-lead, may be gently added to the melted lead upon the cupel. Finally, add about three times the weight of the assay in pure silver, and then proceed with the cupellation in the manner above-described. The presence of iron, tin, nickel, or zinc, in the alloy under assay, materially interferes with the success of the operation, as these metals will not pass into the cupel by the aid even of a large quantity of lead; but from their rapid oxidation, will either volatilize, or will accumulate on the surface as a sort of slag, in which particles of precious metal may be entangled. In this case the assay becomes what is technically termed *foul*, the cupel not being able to absorb the metallic oxides as fast as they are formed. To obviate this evil, the preliminary process of scorification should be resorted to, when the presence in the alloy of any of the above metals is known or suspected. A convenient weight of native gold or rich alloy to operate upon is ten to fifteen grains.

Bismuth might be used as a substitute for lead in cupellation, two parts of it being nearly equivalent to three of lead; but its higher price prevents its general use for this purpose. The lead employed must be in all cases entirely free from silver, being such as has been revived from pure litharge, otherwise it would be quite impossible to estimate the true composition of the alloy. The assay of gold furnishes results which are more accurate than those obtained in the cupellation of silver; the loss of gold by volatilization is very much smaller, and scarcely any of the metal is carried into the cupel by an excess of lead.

Parting of the Assay.—After the preceding operations, the button of alloy which remains is composed of gold and silver, not, indeed, absolutely pure, for, whatever precautions may be used, it will still retain a small quantity of lead, and frequently, also, traces of copper. For practical purposes, however, it may be regarded as a pure alloy of the two precious metals, and in this view it now only remains to separate the gold from the silver. It has been stated that, on the Continent, this is effected on the large scale by means of sulphuric acid, which, at its boiling temperature, possesses the property of dissolving silver without acting upon gold. For analytical purposes, however, nitric acid is preferred, and is generally employed in this

country, even for refining operations on the large scale.

It has been stated, also, that when silver and gold are intimately mixed together, as in an alloy, it is necessary that the silver should be present in the proportion of at least two and a half parts of that metal to one part of gold, otherwise its particles will be so enveloped and protected by those of the gold, that the nitric acid will be prevented from exercising its solvent action upon them. If, as is generally the case, the requisite proportion of silver has been introduced before cupellation, or if it is known to exist in the alloy in that proportion, then it will be sufficient to subject the mixture at once to the action of the acid. But if the silver be present in a less or much greater proportion, then, as a preliminary step to the operation of parting, the alloy must be brought to the proper standard, either by the addition of the necessary quantity of pure silver, or by adding more gold, as the case may be; for if the proportion of silver exceed three parts, the gold will be precipitated by the acid as a dark powder, instead of retaining the more convenient form of the alloy subjected to treatment; and thus an accurate estimation of the amount of gold present will be rendered considerably more difficult.

On the whole, the operation of parting is found to succeed best when the alloy contains a little less than three parts of silver to one of gold. Hence, in all cases where much exactness is required, the addition of silver, if necessary, must be so managed as to agree as closely as possible with this proportion; and from the circumstance, that when the relative quantities of the two are so adjusted, the gold is present in the proportion of about one-fourth of the mass, and the silver in the proportion of three-fourths, the operation of bringing the alloy to the proper standard by the requisite addition of the latter metal, is termed *inquantation*. The quantity of silver required can only be known by a previous approximate experiment by the wet method of examination, or by the use of the touchstone.

Assuming that the proper proportion already exists in the button of gold and silver obtained by cupellation, it is first hammered out upon an anvil into a small disc about the size of a sixpence, and annealed by heating it to redness. It is then passed between a pair of laminating rollers, by which its thickness is reduced to that of an ordinary address card, or about one-eightieth of an inch, after which it is a second time annealed. These operations render it sufficiently flexible to allow of its being twisted into a small spiral coil or *cornet*,

Fig. 243.



by rolling between the finger and thumb. The cornet thus obtained is then introduced into a small parting-flask of the form represented in Fig. 243, which contains about an ounce of nitric acid of specific gravity 1.180. The acid must be perfectly *free from chlorine*, and must always be carefully tested to ascertain this point by adding to it a drop of solution of nitrate of

silver, which, if chlorine be present, will instantly render it milky. Instead of the flask represented in Fig. 243, a small bulb-shaped matrass is frequently used, and is now generally adopted by the best assayers of bullion, both on the Continent and in this country. Common Florence oil flasks, or smaller vessels of the forms represented in Figs. 244 and 245, will be found very convenient. When the

cornet has been introduced, the flask with its contents is gently heated to nearly the boiling-point. Effervescence will now take place, with a brisk evolution of nitrous fumes, and the silver will be gradually dissolved, leaving the gold in the form of the original cornet, but porous, very brittle, and of a deep blackish-brown color. When the effervescence has entirely ceased, the flask is removed from the heat, and the solution is carefully decanted off, without letting the cornet of gold fall out. The latter is then washed by pouring distilled water upon it, which, after standing for a couple of minutes, is again poured off. The gold will still retain some traces of silver, and in order to remove these, the cornet is again boiled with stronger nitric acid, of specific gravity 1.280, and this operation may even be repeated a third time, to remove the last portions of silver, which exist as a surcharge. In the second and third boilings, which may each be continued for ten or fifteen minutes, it is well to introduce into the flask a small fragment of charcoal, to prevent the ebullition from taking place with sudden bursts, otherwise the action may be so violent as to break the cornet, which it is desirable to avoid.

The last acid having been poured off, the flask is completely filled with distilled water, and a small, smoothly-finished, porous clay crucible is placed over the mouth of it. The two vessels, thus adjusted, are then inverted, so as to allow the cornet to fall gently through the water into the crucible, and by a dexterous movement of the hand the flask is withdrawn, in such a manner as to prevent the overflow of any liquid from the little crucible. The latter is now carefully decanted into the vessel containing the silver solution, and the crucible containing the cornet is heated to redness in the muffle. Under this final heating it is not fused, but shrinks in bulk, loses its brown appearance, and assumes the peculiar color and lustre of gold; while at the same time it is rendered more compact, less brittle and fragile, and when cold, can now be removed by a pair of forceps to the scales, in which it is weighed with the same precision and care as the original alloy.

The weight of the cornet will indicate very nearly the amount of gold in the alloy if the assay has been properly conducted, but not with absolute exactness. Even when every precaution has been used, the gold contained in the cornet is never chemically pure; it still retains a very small quantity of lead and of silver, and frequently also traces of copper, in consequence of which the weight of the cornet may exceed by one two-thousandth part the true result; and when it is considered that, in assaying alloys, the quantity taken

Fig. 244. Fig. 245.



is usually not more than seven or eight grains, it will be seen that even this small error might lead to serious disappointment in estimating the proportion of gold in large masses of bullion. To ascertain the amount of the error, and thus to arrive at a perfectly correct estimate, it is usual to pass through the muffle, simultaneously with the alloys, a number of what are termed *proofs*, consisting of weighed portions of perfectly pure gold, to each of which is added a proportion of copper equal to that estimated to exist in the alloys under examination. The cornets obtained from these proof-assays are weighed, and the excess of weight over that of the gold which was introduced, indicates the amount of the correction which it becomes necessary to make for the other assays. This correction is liable to variation, according to the temperature of the furnace, and other causes; but it usually ranges from 0.2 to 0.5 in 1000.

If the quantity of silver in the alloy submitted to the operation of parting exceed by more than thrice the weight of the gold, the separation may still be effected by nitric acid, but the gold will be left in a state of powder. It may, however, be washed, ignited, and weighed in the manner described in connection with the quantitative estimation of gold by the wet method, and also in the process of parting with sulphuric acid on the large scale. Should the amount of silver be but small compared with the gold, and the assayer wish to avoid the trouble of inquartation, the alloy may at once be subjected to the action of aqua regia, when the gold will be dissolved, and the silver will be thrown down as an insoluble chloride. The clear solution containing the gold is then decanted, and when the excess of acid has been expelled by evaporation, the gold can be precipitated, as already described, by sulphate of iron.

The silver contained in the solution of the nitrate of that metal obtained in the common process of parting, may readily be recovered by adding an excess of chloride of sodium, which will throw down the whole of the silver as white insoluble chloride. This precipitate, which speedily becomes slate-colored on exposure to light, is collected, and put into a vessel containing water acidulated with hydrochloric acid; some zinc or iron is introduced, and the silver is rapidly restored to the metallic state, in the form of a dark-grey powder. When this powder is washed with water, dried, and fused in a crucible, the silver assumes its natural appearance, but is very brittle. Its malleability is restored, however, by simply re-melting.

PHYSIOLOGICAL EFFECTS, et cetera.—Gold, says PEREIRA, like other metals, has been frequently supposed to be inert while it retains its metallic condition, but in this, as well as in some other instances, the accuracy of the assumption has been denied. Both CHRESTIEN and NIEL, as well as other writers, assert that finely-divided metallic gold—*pulvis auri*—produces the same constitutional effects as those caused by the various preparations of this metal, but in a milder degree, while it excites little or no irritation. It is said to promote the secretions of the skin, kidneys, and salivary glands.

It has been employed as an antivenereal and antiscrofulous remedy, by CHRESTIEN, NIEL, and others,

with considerable success. It is said to be preferable to the other preparations of this metal in delicate and nervous subjects, females and infants. Gold-leaf—*aurum foliatum* seu *lamellatum*—is used by dentists for filling decayed teeth, and was formerly employed by apothecaries for covering pills—*ad inaurandas* seu *obducendas pilulas*. Silver-leaf now takes its place. It has been administered internally in doses of from a quarter of a grain to a grain three or four times a day. CHRESTIEN used it by way of friction on the tongue and gums. NIEL employed it endermically—that is, applied it to the skin deprived of the epidermis—in the form of ointment composed of one grain of gold and thirty grains of lard.

Teroxide of gold is sometimes used internally, in venereal and scrofulous diseases, in doses of from one-tenth of a grain to a grain, made into the form of pills with mezereon.

The terchloride of gold, the preparation of which is described at page 293, acts, according to ORFILA, as a corrosive when introduced into the stomach of animals, but with less energy than the chloride of mercury, and destroys them by the inflammation of the coats of the alimentary canal which it sets up.

On man its effects are analogous to those of chloride of mercury. In *small doses* it acts, according to Dr. CHRESTIEN, more energetically as a stimulant, though less powerfully as a sialogogue, than corrosive sublimate. It promotes the secretions of the skin, the salivary glands, and the kidneys. Taken to the extent of one-tenth of a grain daily, it has occasioned violent fever. CULLERIER has seen one-fifteenth of a grain excite, at the second dose, gastric irritation, dryness of the tongue, redness of the throat, colic, and diarrhoea. When it promotes the secretion of saliva, it does not as mercury affect the teeth and gums. MAGENDIE has seen violent gastritis, accompanied by nervous symptoms—cramps and pains in the limbs, agitation and loss of sleep—and afterwards great heat of skin, and obstinate sleeplessness. In *large doses*, it would probably occasion symptoms similar to those produced by the use of poisonous doses of chloride of mercury.

It has been employed, with variable success, as a substitute for mercury in the secondary symptoms of syphilis. A more extended experience of it is, however, necessary to enable one to speak of its remedial powers with confidence. In the hands of CHRESTIEN, NIEL, CULLERIER, LEGRAND, and others, it has proved most successful.

It has also been used in scrofulous affections, bronchocele, chronic skin diseases, scirrhus tumours, et cetera. DUPORTAL cured with it a case of obstinate ulceration of the face, regarded by him as cancerous and which had resisted all the ordinary methods.

LEGRAND has used terchloride of gold, acidified with nitric acid, as a caustic in syphilitic, scrofulous, and scorbutic ulcers, cancerous growths, and ulcerations of the neck of the uterus.

Internally, it has been given in doses of one-twentieth of a grain, made into pills with starch. But as organic matters decompose it, it is better to use it in distilled water, or to apply it by friction to the mouth, in quantities of from one-sixteenth to one-sixth of a grain.

The whites and yolks of eggs, milk, and a mixture of wheat-flour, oatmeal, or barley, and water, are, as in the case of chloride of mercury, antidotes for an overdose of this auric compound.

The Editor is surprised to find that the above are so little used in medicine. Surely, if physicians would only daily experiment on the action of the different metals and their compounds upon the system, they might soon discover some more very valuable specifics.

STATISTICS.—Gold and silver are frequently confounded in statistical returns under the common designation of the *precious metals*; and even where the two are classed separately, it is still desirable to place them in juxtaposition, since much of the interest attaching to the subject is derived from the relation which they bear to each other. In proceeding, therefore, to state the most important facts connected with the statistics of gold, the Editor will give, at the same time, most of the corresponding facts and figures relating to silver; which will not only save the repetition of a number of tables nearly similar, but will furnish the reader with a clearer and more satisfactory view of the subject, than if the returns relating to each of the metals were tabulated separately in different parts of the work.

Much interesting information relating to the history and statistics of the precious metals is given in a work which was published by Mr. JACOB in 1831, in which he takes up the subject at the earliest period, and continues it to the year above-mentioned. Mr. JACOB shows that, in the days of Roman supremacy, the greater part of the wealth of the world continued to flow into Rome, up to the time of AUGUSTUS, when the production of gold from the Roman mines in Illyria and Spain suddenly ceased; and for a long period the world received no new accession of metallic wealth. With much labor and research, he constructed a table showing the rate of diminution to which the enormous wealth of the Augustan period was subject; and though it includes both gold and silver under one head, while at the same time its accuracy cannot be implicitly relied on, still it is sufficiently correct and instructive to merit a place in these pages:—

QUANTITY OF GOLD AND SILVER IN THE ROMAN EMPIRE.

Year,	
14	£358,000,000
50	322,200,000
86	287,980,000
122	259,182,000
158	233,263,800
194	209,937,420
230	181,943,678
266	163,749,311
302	147,374,380
338	132,636,942
374	119,373,248
410	107,435,924
446	96,692,332
482	87,033,099
518	78,229,700
554	70,406,730
590	63,364,057
626	57,027,652
662	51,324,887
698	46,192,399
734	41,573,160
770	37,415,840
806	33,674,256

From the decline and fall of the Roman empire, the

portion of gold added to that already obtained was, for many centuries, not more than sufficient to supply the annual waste by wear and loss; and except the mines of Hungary and Sweden, which do not appear to have been worked before the eighth or ninth century, no important new sources of gold were opened until the discovery of America by COLUMBUS in 1492. This event was followed, in the course of the next century, by a considerable influx of the precious metals into Europe; yet a very superficial inquiry will suffice to show, that the actual amounts which were imported from Mexico and South America have been greatly exaggerated in the public mind, and sink into very humble figures when compared with the enormous treasures obtained within the last few years from California and Australia. From 1492 to 1500, America, according to HUMBOLDT, furnished to Europe, in gold and silver, not more than fifty-two thousand pounds sterling, and the entire annual amount of gold and silver obtained from America during the sixteenth century was only about half a million sterling; whereas, for the last few years, the value of *gold alone* exported from California and Australia has averaged twenty-four millions per annum. The celebrated *El Dorados* of the sixteenth century sink, therefore, into utter insignificance, compared with the recently-developed auriferous regions.

It is true, that with the discovery of the Brazil mines and other sources, the import of the precious metals from America continued steadily to increase; and from 1600 to 1700, during which period Europe obtained its supply of gold almost exclusively from the New World, the mines of the latter were estimated to have produced an amount of gold and silver equivalent to three hundred and thirty-seven millions, five hundred thousand pounds sterling, or upwards of three millions per annum. In consequence of this continued importation, the value of the coined money in Europe in 1699 has been estimated at two hundred and ninety-seven million pounds sterling. During the eighteenth century, the supply of the precious metals was still chiefly derived from the Americas. The annual produce of the mines of that quarter of the globe, at the commencement of the present century, was estimated by HUMBOLDT at eight millions, seven hundred thousand pounds sterling; and that derived from the European mines of Hungary, Saxony, *et cetera*, and those of Northern Asia, was valued by him at one million pounds sterling more, raising the total produce at that period, exclusive of Africa, to nine million seven hundred thousand pounds sterling. The *quantity* of gold produced in America was to the *quantity* of silver as 1 to 46; in Europe as 1 to 40; and the *values* of equal quantities of gold and silver were then in the proportion of 15 to 1, so that the aggregate value of the gold to that of the silver was nearly as 1 : 3; or, in other words, the annual amount of *gold alone* produced at the beginning of the present century was worth about three million two hundred thousand pounds sterling.

From 1800 to 1810 the yield of the American mines continued still to increase, and, in conjunction with that of the European and Russian mines, is supposed to have amounted in the latter year to upwards of eleven million pounds sterling, in gold and silver. But in that

year began the contest which resulted in the dissolution of the connection between Spain and her American colonies, causing the abandonment of several of the mines, and a consequent decline in the production of the precious metals to such an extent, that, according to JACOB, the total average yield of the American mines, inclusive of Brazil, during the twenty years ending with 1829, might be estimated at little more than four million pounds sterling a year; being less than half their produce in 1800. Some years later, however, they again began to increase; and this, in conjunction with the recent extraordinary development of the Russian

mines, raised the entire amount of gold and silver produced from all the *known* auriferous localities throughout the world, *before the discovery of California and Australia*, to upwards of twelve million pounds sterling per annum; the value of the gold to that of the silver being nearly as 5 : 6. This will appear from the following table, prepared by Mr. BIRKMYRE, showing, by approximate calculation, the annual produce in value of fine gold and silver for 1846 and 1850; the first being two years before the discovery of the rich deposits of gold in California, the latter two years after the discovery:—

Countries.	1846.			1850.		
	Gold.	Silver.	Total.	Gold.	Silver.	Total.
	£	£	£	£	£	£
California,.....	—	—	—	12,000,000	62,088	12,062,088
United States,.....	237,336	1,864	239,230	115,430	11,444	126,874
Mexico,.....	249,753	3,457,020	3,706,773	382,901	5,383,333	5,766,234
New Grenada,.....	252,407	42,929	295,336	252,407	42,929	295,336
Peru,.....	96,241	1,000,583	1,096,824	96,241	1,000,583	1,096,824
Bolivia,.....	60,337	460,191	520,548	60,357	460,191	520,548
Chili,.....	145,585	297,029	442,614	145,585	297,029	442,614
Brazil,.....	259,871	2,003	261,874	289,068	2,227	291,295
Total of North and South America,....	1,301,560	5,261,619	6,563,179	13,341,989	7,259,824	20,601,813
Russia,.....	3,414,427	167,831	3,582,258	4,175,860	171,817	4,347,477
Norway,.....	—	32,346	32,346	—	35,607	35,607
North Germany,.....	357	138,022	138,379	357	138,022	138,379
Saxony,.....	—	198,200	198,200	—	198,200	198,200
Austria,.....	282,750	282,654	565,404	288,708	286,971	575,679
Piedmont,.....	17,841	7,444	25,285	17,841	7,444	25,285
Spain,.....	2,498	227,499	229,997	2,498	440,210	442,708
United Kingdom,.....	—	109,989	109,989	—	160,000	160,000
Africa,.....	203,900	1,056	204,956	203,900	1,056	204,956
Borneo,.....	305,900	1,584	307,484	305,850	1,584	307,484
Ava,.....	100,000	517	100,517	100,000	517	100,517
Malacca,.....	72,240	374	72,614	72,240	374	72,614
Sumatra,.....	63,719	330	64,049	63,719	330	64,049
Annam or Tonquin,.....	30,585	53,460	84,045	30,585	53,460	84,045
Various countries,.....	50,975	33,000	83,975	50,975	33,000	83,975
Total of Europe, Africa, and Asia,....	4,545,192	1,254,306	5,799,498	5,312,533	1,528,592	6,840,975
Total of North and South America,....	1,301,560	5,261,619	6,563,179	13,341,989	7,259,824	20,601,813
Total,.....	5,846,752	6,515,925	12,362,677	18,654,522	8,788,416	27,442,788

The various countries are exclusive of China and Japan, which produce large quantities of gold and silver, the amount of which is quite unknown to Europeans.

It will be seen from the above table, that in 1846 the total value of the gold is estimated at five million, eight hundred and forty-six thousand, seven hundred and fifty-two pounds sterling; in 1850, it rises to eighteen million, six hundred and fifty-four thousand, five hundred and twenty-two pounds sterling. Mr. BIRKMYRE, however, estimates the produce of California alone in the last-mentioned year at twelve million pounds ster-

ling—a figure so high that, notwithstanding the importance attached by MACCULLOCH to his calculations, it seems to have far exceeded the truth. This may be inferred from the following table, extracted from the *Economist* newspaper, which has the credit of deriving its statistical information from the highest official sources:—

TOTAL VALUE OF GOLD EXPORTED FROM AUSTRALIA AND CALIFORNIA IN EACH YEAR FROM 1848 TO 1856 INCLUSIVE.

Year.	New South Wales.	Victoria.	California.	Total.
1848	—	—	£11,700	£11,700
1849	—	—	1,600,000	1,600,000
1850	—	—	5,000,000	5,000,000
1851	£468,336	£438,777	8,250,300	9,157,413
1852	3,600,175	6,135,728	11,700,000	21,435,903
1853	1,781,171	8,664,529	12,500,000	22,945,700
1854	773,209	8,255,550	14,100,000	23,128,759
1855	209,250	11,303,980	13,400,000	24,913,230
1856	97,456	12,643,024	14,000,000	26,740,480
Total,	£6,929,597	£47,441,588	£80,562,000	£134,933,185

To bring down the accounts to the latest date, the following table of imports, also resting on high authority, may be added:—

IMPORTS OF GOLD AND SILVER INTO GREAT BRITAIN FOR THE FIRST SIX MONTHS OF THE YEAR 1857 WERE—

From	
Africa,.....	gold £52,000
United States, including principal imports from California,.....	3,252,000
Australia,.....	5,833,000
Brazils,.....	6,000
Mexico, West Indies, Peru, and a portion from California,.....	gold and silver 3,415,000
Mediterranean,.....	543,000
Russia,.....	119,000
	£13,220,000

It will be observed, however, that these figures include both silver and gold, and indicate merely the amount of the precious metals imported into this country. But when it is considered that nearly the whole of the Australian produce is in gold, and that it is almost exclusively exported to Great Britain, the amount above stated as having been imported from that part of the world during the first six months of the present year, seems to indicate a falling-off as compared with the amount exported in 1856. This decline has been acknowledged by Australian journalists, but is attributed to temporary causes—the employment of larger numbers of the mining population than at any former period in deep sinking and in quartz mining, their consequent withdrawal from the immediate production of gold, and the protracted dryness of the season. The same writers affirm, that when the labor of the deep sinkers has been consummated, and the hoards of the shallow sinkers have passed through the process of washing, the average of the returns of the current year will be brought up to that of last. The steadiness with which the quartz reefs are being opened up at a heavy cost of labor and of money, and the large sums expended in machinery for the extraction of the metal, are deemed sure indications of the faith entertained by practical men in the hidden riches of the Australian gold mines.

On the whole, the present annual supply of gold may be roughly estimated as follows:—

Asiatic Russia,.....	£4,000,000
Rest of Asia—exclusive of Japan and China,.....	500,000
Europe,.....	300,000
Africa,.....	200,000
North and South America—exclusive of California,.....	1,500,000
California,.....	14,000,000
Australia,.....	13,000,000
Total,.....	£33,500,000

The annual consumption of *gold and silver* in the arts, and as coin or currency, is estimated by MACCULLOCH as follows:—

Wear and tear and loss of coin,.....	£5,700,000
Increase of currency,.....	11,400,000
Used in the arts,.....	11,200,000
Total,.....	£28,300,000

In connection with the subject of coinage, it may not be out of place to append the following tables, which would be obviously divested of much of their interest by giving the gold coinage alone:—

I. AMOUNT OF GOLD, SILVER, AND COPPER MONIES COINED AT THE ROYAL MINT, LONDON, FROM 1840 TO 1856.

Years.	Gold.	Silver.	Copper.	Total.
1840 ..	Nil	£216,414 ..	£3,136 ..	£219,550
1841 ..	£378,472 ..	96,175 ..	8,848 ..	483,495
1842 ..	5,977,051 ..	192,852 ..	1,764 ..	6,171,667
1843 ..	6,607,849 ..	276,606 ..	10,080 ..	6,894,535
1844 ..	3,563,949 ..	626,670 ..	7,246 ..	4,197,865
1845 ..	4,244,608 ..	647,658 ..	6,944 ..	4,899,210
1846 ..	4,334,911 ..	559,548 ..	6,496 ..	4,900,955
1847 ..	5,158,440 ..	125,730 ..	8,960 ..	5,293,130
1848 ..	2,451,999 ..	35,442 ..	2,688 ..	2,490,129
1849 ..	2,177,955 ..	119,592 ..	1,792 ..	2,299,339
1850 ..	1,491,836 ..	129,096 ..	448 ..	1,621,380
1851 ..	4,400,411 ..	87,868 ..	3,584 ..	4,491,863
1852 ..	8,742,270 ..	189,596 ..	4,312 ..	8,936,178
1853 ..	11,952,391 ..	701,544 ..	10,190 ..	12,664,125
1854 ..	4,152,183 ..	140,480 ..	61,538 ..	4,354,201
1855 ..	9,008,663 ..	195,510 ..	41,091 ..	9,245,264
1856 ..	6,002,114 ..	462,528 ..	11,418 ..	6,476,061

II. COINAGE OF FRANCE IN EACH YEAR FROM 1846 TO 1856 INCLUSIVE, CONVERTED INTO BRITISH MONEY AT THE RATE OF TWENTY-FIVE FRANCS TO THE POUND STERLING.

Years.	Gold.	Silver.	Total.
1846	£88,000	£1,332,000	£1,420,000
1847	300,000	2,760,000	3,060,000
1848	1,600,000	4,040,000	5,640,000
1849	1,080,000	7,360,000	8,440,000
1850	4,600,000	3,120,000	7,720,000
1851	9,600,000	2,360,000	11,960,000
1852	1,040,000	2,840,000	3,880,000
1853	13,200,000	800,000	14,000,000
1854	20,480,000	80,000	2,056,000
1855	16,417,928	862,800	17,280,728
1856	20,334,076	2,168,888	22,502,964

III. ACCOUNT SHOWING THE AMOUNT OF COINAGE IN THE UNITED STATES IN 1855, CONVERTED INTO BRITISH MONEY AT THE RATE OF FOUR SHILLINGS AND THREE-PENCE TO THE DOLLAR.

Mints.	Gold.	Silver.
Philadelphia,.....	£2,251,321	£301,574
New Orleans,.....	95,731	407,575
San Francisco,.....	3,739,639	34,228
Dahlonega,.....	24,815	—
Charlotte,.....	46,311	—

Total,.....£6,157,817£743,377

IV. BULLION EXPORTED FROM ENGLAND AND THE MEDITERRANEAN PORTS TO THE EAST—1852 TO 1856.

Years.	Gold.	Silver.	Total.
1852	£761,318	£2,494,137	£3,255,455
1853	985,574	5,695,602	6,682,176
1854	1,222,755	4,583,017	5,805,772
1855	1,191,511	7,934,129	9,125,640
1856	478,788	14,108,901	14,587,689

Total,....£4,640,946£34,815,786£39,456,732

Annexed are some of the rates of value of a pound troy of gold at different periods:—

VALUE OF THE TROY POUND OF GOLD.

Years.	
1344	£15 0 0
1345	13 3 4
1347	14 0 0
1412	16 13 4
1464	20 16 8
1526	27 0 0
1549	34 0 0
1605	40 10 0
1626	44 10 0
1718	46 14 6
1817	46 14 6

which is the price at which fine gold still continues, or three pounds seventeen shillings and tenpence half-penny per ounce.

Mr. HUNT states, that for the uses of the arts not less

than one thousand ounces of fine gold are used in Birmingham alone every week, and that in the United Kingdom the weekly consumption of leaf-gold is as follows:—

	Ounces weekly
London,	400
Edinburgh,	35
Birmingham,	70
Manchester,	40
Dublin,	12
Liverpool,	15
Leeds,	6
Glasgow,	6
Total,	584

Of this amount, he states, on the authority of an eminent gold-refiner, that not one-tenth part can be recovered; and he adds, that for gilding metals by the electrotype, and the water or wash-gilding processes, not less than ten thousand ounces of gold are required annually. One establishment in the Potteries employs three thousand five hundred pounds' worth of gold per annum, and nearly two thousand pounds' worth is used by another. The consumption of gold in the Staffordshire Potteries for gilding porcelain and making crimson and rose color, varies from seven thousand to ten thousand ounces per annum.

The Editor has to express his obligations to Mr. GEORGE BLAIR of Glasgow for his valuable aid during the compilation of this article.

GUMS.—*Gommes*, French; *Pflanzenschleimen*, *Gummi*, German; *Gummi*, Latin.—Under the term gum, says BRANDE, are included several modifications of a distinct proximate principle of vegetables, which are of extremely common and almost universal occurrence. To some of these, the term *mucilage* is occasionally applied.

They are characterised by forming a viscid, mucilaginous, or adhesive solution with water, and by insolubility in alcohol, so that the addition of the latter to a moderately strong aqueous solution of gum occasions the separation of a white precipitate or magma. Another characteristic of gum is its convertibility into mucic or sacclactic acid by the action of nitric acid.—*Brande*.

Gum is found upon the bark of certain trees as an exudation, which gradually concretes in transparent or translucent amorphous drops. It may also be detected, in greater or less quantity, in the juices of most plants and fruits.

The several species of gums are distinguished by their behavior with water. Some dissolve in that liquid, and form *mucilages*, as gum-arabic; while others soften and intumescence, as tragacanth. But there is also an intermediate kind, represented by cherry-tree gum, which is only partially dissolved in water. These different classifications of gums have been denominated *arabin*, *tragacanthin*, and *cerasin*—from the Latin *cerasus*, a cherry-tree.

GUM-ARABIC—*Gomme Arabique*, French; *Arabischegummi*, German; *Gummi Acacia*, Latin—is the produce of the *Acacia Vera Arabica*, and other varieties. Many have supposed the *shittah* tree, mentioned in many parts of the Old Testament, especially in connection with the building of the tabernacle, to have been an acacia; some have regarded it as the *A. Vera*,

while others have thought it to have been the *A. Horrida*.

Dr. ADAM CLARKE, in his comment on Exodus, xxv. 5, says:—The *Acacia Nilotica*, or *A. Arabica*, is known to have been plentiful in Egypt, and it abounds in Arabia Deserta, the very place in which MOSES was when he built the tabernacle; and hence it is reasonable to suppose that he built it of that wood, which was every way proper for his purpose, being solid, light, and very beautiful.

HIPPOCRATES mentions *Egyptian acacia*, and the *white acacia*, by which, it is supposed, he meant the *acacia vera*. DIERBACH, however, thinks that the *Acacia Senegal* is referred to, from the fact that the wood, bark, and flowers of the latter are white. Gum is also named by HIPPOCRATES as being employed in medicine.

PRODUCTION.—The gum of the acacia trees flows, in the liquid state, from the trunk and branches, and hardens by exposure to the air. It usually exudes spontaneously, but, in some instances, the discharge is facilitated by incisions. In Barbary, the largest quantity of gum is procured during the hot and parching months of July and August. The more sickly the tree appears, the more gum it yields; and the hotter the weather, the more prolific is it. A wet winter and a cool or mild summer are unfavorable to the production of gum. In Senegal the gum begins to flow when the tree first opens its flowers, and it continues during the rainy season till the month of December, when it is collected for the first time. Another gathering of the gum is made in the month of March from incisions in the bark, which the extreme dryness of the atmosphere at that time is said to render necessary.—*Pereira*.

DESCRIPTION.—Gum-arabic occurs in globular pieces or *tears*, which are colorless or light yellow, more or less transparent, inodorous, and somewhat brittle. The following description of the most important varieties of acacia gum, is extracted from PEREIRA'S *Materia Medica*:—

Turkey or *Arabic Gum* is imported from Leghorn, Malta, Trieste, Gibraltar, Smyrna, Alexandria, Constantinople, *et cetera*, and is the produce of the *Acacia Vera*, and probably of other species, especially *A. Arabica*. It occurs in rounded tears, or amorphous or angular fragments, varying from the size of a pea to that of a walnut, or even still larger; some of the pieces being transparent, others more or less opaque, from innumerable cracks extending through them. It has a glassy lustre, is white, yellow, or sherry colored, and has no odor, or, if any, an acid one. Its specific gravity varies from 1.316 to 1.482. It is entirely soluble in water, the solution having the property of reddening litmus, and being feebly opalescent. The latter characteristic is said by GUERIN to be owing to the presence of a small quantity of insoluble nitrogenous matter.

Barbary or *Morocco Gum* is imported from Mogadore and Mazagan. It is probably the produce of *Acacia Gummifera*. Dr. PEREIRA had two varieties of Barbary gum; one in roundish or irregular tears, mixed with many impurities, imperfectly transparent, and of a dull yellowish color, with a faint tint of green. It

was not wholly soluble in water. The other kind, called Mogadore gum, is in small, irregular, broken, mostly yellow pieces, which resemble fragments of Turkey gum.

Gum-senegal is imported from St. Louis, St. Mary's, the river Gambia, Senegal, and Bathurst, and is probably obtained from several species of acacia; but especially *A. Senegal*, *A. Vera*, *A. Serjal*, and *A. Adansonii*, are said to produce it in part. It occurs in larger tears than those of Turkey or Arabic gum, and large air cavities are frequently found in their centres on breaking them. Whitish pieces are occasionally met with, but for the most part they are yellow, reddish-yellow, or brownish-red. More difficulty is experienced in breaking or pulverizing this gum than gum-arabic, and its fracture is more conchoidal. GUIBOUT distinguishes two varieties of this gum: the first, gum-senegal, properly so called, probably the produce of *Acacia Senegal*; while the second, gum-galam, is yielded by *A. Vera*. There is but little difference between them, yet the latter has a greater resemblance to Turkey gum than the former. The pieces of gum-galam are more broken, and therefore more brilliant than those of gum-senegal. Those tears or fragments which have on some part of them a yellowish opaque skin or pellicle, constitute the *Gomme pelliculée* of GUIBOUT. The *Marrons de Gomme*, or *Gomme lignirode* of the same pharmacologist, is also found in the Senegal gum of commerce; it consists of yellowish or dark-brownish pieces, which are difficult to break, opaque, and rough. Treated with water, it is only partially dissolved. GUIBOUT states, that in most of the *marrons* he found a large ovoid cell, which had evidently been the habitation of some larvæ, whence he concludes that this substance is the work of an insect.

East India Gum is imported principally from Bombay, and is most likely the produce of various species. Many pieces—yellow East India gum—agree in their physical and chemical characters with Turkey gum, and are probably the produce of *Acacia Arabica*, or some allied species. Others, however, are larger, red, or brown—brown East India gum—and more difficult to pulverize than Turkey or Arabic gum.

Cape Gum is imported from the Cape of Good Hope; BURCHELL states that it is obtained from a species of acacia, closely resembling *A. Vera*, and which he denominates *A. capensis*. Notwithstanding that the last-named authority asserts, that the Cape gum is in no way inferior to that from *A. Vera*, it is considered by English dealers as a very inferior kind. It is pale yellow, and apparently resembles Mogadore gum mentioned previously, or small fragments of Turkey gum. It is collected by the Caffres.

PROPERTIES AND COMPOSITION.—Gum-arabic dissolves both in cold and hot water. If this solution be allowed to evaporate spontaneously, the gum is left apparently dry, but, in reality, in a hydrated state, retaining about seventeen per cent. of moisture. If heated slightly above 212° , the color of the gum becomes yellow, and it has an acid taste. When distilled destructively, the products are empyreumatic oil, acid water, carbide of hydrogen, carbonic acid, and a charred mass; the latter leaving, upon ignition, about three per

cent. of inorganic matter, composed of carbonates of potassa and lime, with minute portions of chloride of potassium, oxide of iron, aluminum, magnesia, and silicic acid.

Gum is thrown down from its aqueous solution by alcohol as a white magma. Tribasic acetate of lead—but not the neutral acetate—occasions a white precipitate, which BERZELIUS denominated *gummiæ of lead*. A concentrated solution of sesquichloride of iron causes, when dropped into a gummy menstruum, a brownish translucent gelatinization. Silicate of potassa and oxalate of ammonia produce white deposits, the reaction with the latter being caused by the lime present. Caustic potassa, according to BERZELIUS, first causes in strong solutions of gum a coagulum, which gradually liquefies. A solution of borax occasions in that of gum-arabic, a coagulation which dissolves in free acid. Gum, in this instance, gives a reaction similar to that afforded by starch.

On the trituration of powdered acacia gum with a sufficient quantity of sulphuric acid to form a pasty mass, the mixture soon acquires a brown color; and if it is allowed to stand for about twenty-four hours, then liquefied with water, and carbonate of lime added to unite with the acid, the gum which remains dissolved is considerably changed in character and properties. If, on the contrary, sulphuric acid and gum be mixed, the latter is decomposed with evolution of sulphurous acid, and the production of artificial tannin and a scarcely appreciable amount of acetic acid. Upon adding water after this reaction, about thirty per cent. of carbon is deposited. The ebullition of gum with *very attenuated* sulphuric acid, gives rise to the formation of glucose or grape sugar.

Gum is decomposed by nitric acid, and, on the application of heat, nitric oxide is set free, and *muic acid* deposits as the temperature of the mass becomes reduced. On carrying the decomposition further, malic and oxalic acids may be detected.

According to VAUQUELIN, when a solution of gum is subjected to the action of a stream of chlorine gas, citric acid is formed; but this statement is very questionable. Chlorine is absorbed by powdered gum, causing the latter to soften and become brown. Hydrochloric acid is also absorbed by gum; the latter becomes brown and glutinous; and, on the addition of sulphuric acid to the magma, hydrochloric acid gas is evolved.

Gum has been analysed by BERZELIUS, PROUT, GUERIN, MULDER, and many others. The following are some of the results of the examination of gum-arabic:—

	Centesimally represented.		
	Berzelius.	Prout.	Mulder.
Carbon,	41.906	41.4	45.10
Hydrogen,	6.788	6.5	6.10
Oxygen,	51.306	52.1	48.80
	100.000	100.0	100.00

The analyses of BERZELIUS and PROUT give rise to the formula, $C_{13}H_{13}O_{12}$. That deduced from the results of MULDER is $C_{12}H_{10}O_{10}$. But LIEBIG adopts the formula, $C_{12}H_{11}O_{11}$, and represents it as a hydrate of carbon, C_{12} , 11 HO, and these views are supported

by the composition of the compound of gum with oxide of lead, as ascertained by BERZELIUS:—

	At. weight	Theory.	Centesimally.
1 Eq. Oxide of lead, { 1 Eq. Lead, 104 } { 1 Eq. Oxygen, 8 }	112	39.58	38.25
1 Eq. Gum, { 12 Eqs. Carbon, 72 } { 11 Eqs. Hydrogen, 11 } { 11 Eqs. Oxygen, 88 }	171	60.42	61.75
1 Eq. Gummiæ of lead,	283	100.00	100.00

Fine gum-arabic consists almost entirely of *arabin*, the other constituents being the inorganic matter and moisture.

Pure arabin may be obtained by making a clear aqueous solution of gum, and adding alcohol, when the arabin is thrown down. It is an uncrystallizable amorphous solid, devoid of color, taste, or smell; soluble in water, whether cold or hot, but not taken up by ether or oils. It unites with alkalies. According to GUERIN, arabin consists of—

	Centesimally.
Carbon,	43.81
Hydrogen,	6.20
Oxygen,	49.85
Nitrogen,	0.14
	100.00

But it is clear that this analysis must be wrong, since gum itself contains no nitrogen, and no substances containing this element are required in the preparation of arabin. According to the same authority, gum-arabic contains 79.4 per cent. of arabin.

USES.—Gum-arabic is employed in medicine as an emollient and demulcent, but more frequently as a vehicle for the exhibition of other medicines. It is sometimes slowly dissolved in the mouth to allay troublesome cough, and to diminish irritation of the fauces, by diluting the acid secretions, and sheathing the part from the action of the atmosphere. In inflammatory affections of the intestinal tube, as well as of the respiratory and urinary organs, gum is employed as a demulcent and emollient. A solution of gum may be used as a sheathing substance in cases of acrid poisoning; but its efficacy is believed to be owing to mechanical properties merely. In the state of powder, gum is occasionally employed to check hemorrhage from leech bites. As a vehicle for the administration of other medicines, it is used either in powder or mucilage—in the former condition to give bulk to active and heavy powders, as subchloride of mercury, tartrate of antimony and potassa, *et cetera*, and in the preparation of lozenges; in solution, to suspend insoluble powders—as oxide of zinc or musk—in water; or to diffuse oily and resinous substances through aqueous fluids, and to give form and tenacity to pills. Furthermore, adds PEREIRA, it is exceedingly useful for various other pharmaceutical purposes, although it is now generally superseded by dextrin.

Its property of suspending fine powders or precipitates in solution, has caused its use in the manufacture of inks; and its clamminess when moist, and firmness when dry, have given rise to its application for cementing or pasting paper or other light articles which are not to be exposed to moisture.

ADULTERATION.—Gum-arabic, says NORMANDY, is

often adulterated with gum-senegal, which has almost the same appearance, and altogether the same qualities as the former; the latter being considerably cheaper, those pieces which are small, light-colored, dry, easily broken, and which, in fact, most resemble gum-arabic, are mixed with it, and sold as such.

It is sometimes also mixed with common cherry-tree gum; but this is generally in dark-brown irregular masses, difficult to break, and when thrown into water they swell and separate from the homogeneous mucilage afforded by the genuine gum in gelatinous clots. This is equally effective as a test, whether the gum is or is not pulverized.

Gum-arabic when ground is in the state of a white powder, and is consequently sophisticated with starch and flour, and the gum generally is altogether replaced by gum-senegal, or partly by cherry-tree gum.

Gum-senegal itself is often mixed, both when in tears and when ground, with cherry-tree gum.

The presence of starch and flour may be readily detected by boiling a small quantity of the suspected gum in water, and testing the mucilage, when it has become cold, with iodine, which imparts to starch an intense blue or violet hue.

PURIFICATION.—A patent was granted, in the year 1848, to M. H. PICCIOTTO, for two several methods of purifying and decoloring all varieties of gum-arabic. The first of these is as follows:—

A rather strong solution of pure sulphurous acid gas is prepared by one of the ordinary methods, and protected as much as possible from the contact of atmospheric air. In each six to twelve parts of this solution, one part by weight of gum, either in its natural state or in powder, is introduced. When it has dissolved, it will be found that the greater portion of its coloring matter will have been destroyed, or has chemically combined with the sulphurous acid, forming a colorless compound.

The sulphurous acid may be brought into contact with the gum by other methods than the one just described, as by passing a current of the gas into a concentrated solution of gum, or by introducing the gas into a close receiver, surrounded with a refrigerating substance or mixture; in which case, by the action of the cold and the pressure of the gas itself, it will be condensed into a fluid, and in this state may be commingled with a solution of gum.

Various processes may be resorted to for the removal from the solution of gum, of the free acid, or the acid combined with the coloring matter; but the patentee prefers the following:—

Heat is applied to the close vessel containing the menstruum, during which time the portion of gas evolved may pass through a tube into another receiver containing water, and thus be recovered for another operation. The hot mixture is then run off in small portions into a larger and open vessel, containing a slight excess of some salifiable base, which, in its combination with sulphurous acid, will form an insoluble salt. For this purpose, carbonate of baryta is to be preferred, as both the sulphite and sulphate of baryta are insoluble. The combination is aided by agitation, and when the whole of the disengaged car-

bonic acid gas has been driven off, and the solution has become neutral, it is allowed to rest for some hours—the vessel being covered—so that the coarser parts of the solid matter may be deposited. The neutralization of the acid may also be effected without previously heating the liquid; but then the patentee recommends that it should be heated after the combination has taken place, so that the whole of the carbonic acid, which might retain in solution a small portion of undecomposed carbonate of baryta, may be evolved.

The menstruum is now to be filtered, in order to remove the sulphite of baryta and other insoluble impurities. The filter employed by the patentee is a thin layer of pure gelatinous hydrate of alumina laid on cloth; but the liquid may also be forced through unglazed earthen or stone ware. After the solution has percolated either of these media, it will be found that all ligneous fibre, silicious and earthy matters, and all particles of insoluble gum have been separated and deposited on the vessels and filter employed, and very little color will remain in the depurated solution; but when a very white gum is required, the process of acidulation must be repeated. By evaporating the filtered menstruum, a colorless, tasteless, and pure gum is obtained, the natural properties of which have not been in the least degree altered.

The sulphurous acid gas may be separated from the solution of gum, without neutralizing it by means of a base, by boiling the mixture in a close air-tight vessel, and conducting the evolved gas into a receiver containing water. If required, the bleaching process may be repeated, by introducing a current of pure sulphurous acid gas into the vessel containing the solution, and then removing it by ebullition. When the menstruum has become cool, it will be found that all the impurities originally united with the gum are deposited at the bottom of the vessel, and the pure solution may be drawn off; or the whole contents of the vessel may be emptied into cloth bags, when the fluid portion will percolate.

The second process is given underneath:—

The gum is dissolved in from six to fifteen parts of hot or cold water, and the solution filtered through cloth. A quantity of pure gelatinous hydrate of alumina is then thoroughly incorporated with the menstruum so as to form a thin homogeneous paste, and this being placed on cloth, a pure and greatly decolorized liquid of gum will percolate. Instead of making the mixture just described, the simple solution of gum may be passed through a bed of alumina alone, or the latter with other substances; and, more time being allowed for the filtration, the decoloration will be quite as well effected. If a perfectly white gum is required, it will be essential that the process be again repeated; but as the second and third portions of alumina, after being used, contain very little tinctorial matter, they may serve again for the first decoloration of another quantity of gum. When the hydrate of alumina becomes highly tinged, it is washed with hot water on a filter, to separate the gum from it; after which it is edulcorated with a cold limpid solution of chlorine or chloride of calcium, filtered, and then repeatedly subjected to the action of a stream of hot water.

By these means, not only its original whiteness and purity, but also its chemical affinity for tinctorial matter, are restored.

STATISTICS.—Gum-arabic is imported either direct from Alexandria, Smyrna, Tripoli, Mogadore, Tangiers, *et cetera*; or second-hand from those places through Gibraltar, Malta, and the Italian ports.

Previously to the year 1842, the duty on gum-arabic from *British colonies* was six shillings per hundredweight; from other parts twelve shillings; but the duty was then fixed at twelve shillings per hundredweight upon all gums, of whatever origin, and this was subsequently reduced to one shilling upon the same quantity. Of twenty-five thousand, two hundred and eighty-nine hundredweight imported in 1839, Tripoli, Barbary, and Morocco furnished four thousand five hundred and eighty-seven; Turkey, four hundred and thirteen; and the Cape of Good Hope, two thousand seven hundred and thirteen, while fifteen thousand four hundred and thirty-one hundredweight were from the East Indies.

The trade in gum-senegal is principally in the hands of the French.

AUSTRALIAN GUM.—In 1848, Dr. HOFFF received a gum, purporting to be from Australia, which consisted of reddish-brown and brownish-yellow pieces, mostly semiglobular, tear-shaped, and moderately transparent, to which the bark was partly adhering. Internally this gum was much cracked. It was not hygroscopic, was easily pulverized, glittered like glass, and furnished a slightly colored powder. Its aqueous solution had no peculiar taste; when diluted to such an extent that it could be filtered, it gave the following reactions:—

Basic acetate of lead caused a brownish turbidity; subnitrate of mercury produced a greyish opalescence; nitrate of mercury gave a similar, but less decisive reaction; chloride of mercury occasioned no change; iodine scarcely tinged the menstruum.—*Pharmaceutical Journal*.

From the above characteristics it will be seen, as Dr. PEREIRA has remarked, that the Australian gum bears more resemblance to that of the cherry-tree than that of the acacia.

GUM-BASSORA, though described by continental pharmacologists, seems to be new, of nearly so, in British commerce. According to Dr. PEREIRA, it occurs in variable-sized pieces, which are whitish or yellowish, and opaque. It appears to belong to the Bassorine class, as when put into water, it swells up, but dissolves only in part. Its origin is unknown.

BRITISH GUM.—*Artificial Gum—Torrefied Starch—Dextrin*.—Under these names a modification of starch is known, which is often prepared in the following manner:—

Well-dried starch is heated to 300° in sheet-iron trays, when it intumesces, giving off vapors and the odor of highly-baked bread, and forming yellowish-brown masses. This, when ground, is employed as a substitute for tragacanth, senegal, and similar gums, in the dressing, stiffening, glazing, sizing, dyeing, printing and finishing calicos, nets, crapes, laces, silks, papers, and all goods of a similar kind.

Starch, when submitted to the above process, is converted into a gummy substance, which, having lost all gelatinous properties, is soluble in either cold or hot water; and iodine, instead of causing a blue color, as with unaltered starch, communicates to it a dingy purple tint.

It possesses the characteristic property of turning the plane of polarization to the right when acting on polarized light, and is consequently sold in Paris under the name of *dextrin*.

British gum or dextrin is now met with in commerce in three distinct forms; namely, as a white, brilliant, and pearly powder; as a sirupy solution; and in the form of exotic gum, in greater or less perfection, either broken into small fragments, or made into rolls of various sizes.

Formerly, it was only produced in the first condition, that of powder; and if some manufacturers have attempted to impart to it the appearance of the product for which it is so much substituted, they may have been induced to do so from the conviction, that the only way to supersede the old plan was by humoring and even deceiving its consumers with the outward appearance of the old product.

It has since been discovered, that many advantages, not primarily expected, are attendant on the communication to dextrin of the form and appearance of natural gum. It is easily dissolved, and makes a clear solution; in the state of powder it possesses the superiority over dextrin of being more readily packed; and over liquid gum, the advantage of not fermenting.

A misapprehension seems to have been entertained, that, taking advantage of the resemblance, the exotic would be adulterated with the artificial product. Fortunately this is impracticable, as the smell and taste of potato oil, which always accompany artificial gum, are sufficient to betray its presence; and thus, if the purchaser suspects fraud, the most ready means for its detection are in his possession, and may be at once applied.

British gum may be prepared by many other processes than the one just described. Besides being procured by torrefaction, it is also obtainable, either by the use of acids, or by means of diastase.

PAYEN discovered a method which furnishes a whiter and more soluble product than can be obtained by torrefaction. It consists in moistening one thousand parts of *dry* starch—potato-starch is generally used—with very dilute nitric acid, consisting of two parts of the concentrated acid to three hundred of water. The mass is then divided into small blocks, which, when exsiccated in the air, are rubbed down, and exposed in a proper stove to a current of air heated to about 150° or 160°. The powder is ultimately well dried at a temperature not exceeding 230°. When well made, it dissolves in cold or slightly warmed water, with the same facility as gum. The modified starch obtained by this mode has been also called *leiocom*.—*Brande*.

A patent was granted in May, 1845, to J. F. PINEL, for improvements in the method of treating farinaceous matters for the production of British gum. The *modus operandi* is as follows:—

Half a gallon of nitric and half a pint of hydrochloric acid are mixed with one hundred gallons of spring water, and as much flour or fecula being then added as is sufficient to form a paste, the whole is well worked together, and left for two hours to settle. After the expiration of this time, the paste is carefully removed into buckets properly prepared for allowing the water to drain off. When this has been effected to the required extent, the mass is divided into small lumps, which are placed on shelves in a drying-room, and allowed to remain until fully desiccated. They are then reduced to powder, and placed on the shelves of a stove, the temperature of which is raised, on the first day to 100°; on the second to 150°; and on the third day to 190°. After this process, the powder is allowed to cool, and is then passed through a sieve. It is next placed in an oven, heated to from 300° to 350°, and when thoroughly baked it is ready for use.

The operator can ascertain if the process has been correctly carried out, by mixing a small quantity of the powder with filtered water, in which it should readily dissolve without leaving any sediment.

It will require little discrimination in the reader to see that this process, though there is some slight variation in the quantity and kind of acid, is yet essentially the same process with that of PAYEN given above.

If the flour or fecula be grey—that is, if it has been badly prepared, and adulterated or damaged—the patentee substitutes half a pint of sulphuric for the hydrochloric acid, by the agency of which, he states, the heterogeneous matters are separated from the good flour.

This patent also extends to the production of the gum in lumps, so as to resemble natural gum both in color and transparency; and for this purpose the powder is mixed, after it has gone through the stove and been sifted, with as much water as will bring it to the consistence of a paste, adding one part of nitric acid to each four hundred parts of water. When well mixed, the paste is spread upon copper dishes, in layers three-fourths of an inch deep, and subjected, in an oven, to a heat of 240° to 300°. As soon as it has become sufficiently hard, it is removed from the oven into the open air, and when cool, is ready for use.

Since the discovery, by PAYEN and PERSOZ, of diastase—described at page 71, Vol. I.—another method for the fabrication of artificial gum has been devised.

This process seems to be the most worthy of attention, and by accepting the modifications of M. EMILE THOMAS, it will be found to give more perfect results than any other. THOMAS' improvements with the original method of operation are thus described in the *Bulletin de la Société d'Encouragement*:—

The fecula must be rendered soluble in vats, heated by steam in such a manner that the temperature can be lowered or heightened with ease. The fecula is first mixed with four times its weight of water, previously brought to the temperature of 120°; and, for this purpose, is gradually introduced into the boiler or other vessel containing the hot water. M. THOMAS employed double-bottomed copper boilers, capable of containing four hundred gallons, and at one operation, six hundred pounds of fecula, mixed with one thousand

two hundred quarts of water were decomposed. The temperature must be kept at about 140°, until the whole mass is converted into starch. Two per cent. by weight of very fine white malt, and the mucilage obtainable from one per cent. of linseed, are then added. The latter imparts tenacity to the gum. If a greater proportion of malt than that just mentioned were employed, the decomposition would, doubtless, be effected more rapidly; but much more glucose would be formed, and the gum would be, to a greater or less extent, colored.

The temperature of the mixture must be maintained at 120° or 140° until all the starch is redissolved, when it should be suddenly elevated to 167°, as nearly as possible, in order to cause the most powerful action of which the diastase is capable. The thorough agitation of the mixture is then requisite, until the decomposition is almost complete; this may be ascertained by the deep blue tint which the mixture acquires, and also by the action of iodine, which will communicate to the dextrin a purple or violet tint.

The operation lasts about an hour and a quarter; fifteen minutes are required for the formation of the paste, the same period for its dissolution, and the remaining time for rendering it soluble.

M. THOMAS prefers this method of forming the paste to adding the malt, as the reagent spreads much more uniformly throughout the mass, and does not subside to the bottom of the vessel.

The liquor must now be removed from the decomposing vats, and left in pans to settle. This may require from six to eighteen hours, according to the external temperature. During this period, a slight fermentation will be perceived, but it must be checked by the addition of one hundred and forty-five grains of alum for each twenty-five gallons of the liquid. It is essential that sufficient time be allowed for subsidence of the menstruum, as by this means two serious evils are avoided—the coloring of the gum during the baking; and a singular phenomenon so often observed in evaporating viscous liquids, namely, their being quite *still*, which, THOMAS states, is caused by the accumulation of a thick crust on the sides of the evaporating vessels.

The liquor, when drawn off after subsiding, is concentrated by raising it *very slowly* to the boiling point, which precaution is indispensable, for the perfect clarification is effected without any foreign agent, by the coagulation of the vegetal albumen contained in the malt and the linseed mucilage, and is best attained by checking the first boiling. The scum which rises while the heat is maintained, must be carefully removed, and if the boiling is too much accelerated, the gum will first become thick, and afterwards will be colored. When a solid pellicle forms on the surface of the sirup, the baking will be completed.

If it be desirable to preserve the gum in a liquid form, the boiling must be stopped when the menstruum has acquired a sufficient density, and it must then be poured into well-closed vessels previously smeared with oil of turpentine, and the surface of the gum should be covered with a thin layer of the same. This method prevents, tolerably well, the fermentation of the fluid gum.

When the dextrin is to be solidified, the boiling sirup is poured into small, shallow tin vessels, placed upon a hot air stove, maintained at a temperature of from 100° to 120°. At the end of twenty-four hours the gum acquires the consistency of jujube paste, and it is then cut up, with a pair of shears, into small oblong pieces, which are rolled out upon a polished surface, with a wooden cylinder; dusted with pulverized artificial gum; and afterwards placed upon wooden frames, where it is allowed to remain drying for three or four days. THOMAS suggests that the gum would be much better desiccated by permitting it to run upon a cylinder heated to 230° or 250°, but he adds that the economy of this method is questionable.

The last-named authority has remarked with reference to British gum prepared by sulphuric acid, that it possesses the disadvantageous property of being deliquescent. This method is, therefore, never employed, as besides this, the products are often colored. He also states that when nitric acid is employed in the preparation of dextrin, *it must be perfectly pure*. Commercial nitric acid, as obtained by the action of oil of vitriol upon nitrate of soda, always contains a small amount of chlorine; and although this element is contained in diminished proportion in the dextrin, it is nevertheless sufficient to considerably lessen the brilliancy of the colors prepared with the dextrin. Several printers upon paper and vegetal tissues have observed this, but have been unable to account for it otherwise than by attributing it to the inferior quality of the gum.

GUM-BUTEA is the produce of the *Butea Frondosa*, a middling-sized tree, common in Bengal and the mountainous portions of India. Dr. PEREIRA found this gum to be identical with a substance he had previously obtained in the warehouse of an old drug firm in London, under the name of *gummi rubrum astringens*. It occurs, according to the last-named authority, in small, elongated tears, which are blackish externally, and have fragments of bark adhering to them. Small fragments examined by transmitted light are ruby-red. It has an astringent taste, and contains from fifteen to twenty-five per cent. of impurities, consisting of wood, bark, small pebbles, and sand. According to SOLLY, the gum, when purified by water, so as to separate the extraneous matters, is composed of—

	Centesimally.
Gum, with gallic acid and other soluble substances, ..	73.26
Tannic acid,	21.67
Soluble extractive,	5.07
	100.00

It is employed by the natives of North-western India for precipitating their indigo, and in tanning. English tanners, however, object to its use on account of the disagreeable color it communicates to the leather.

CHERRY-TREE GUM, *Gomme de cerisier*, French; *Kirschgummi*, German; *Gummi cerasi*, Latin; which is also procured from the trunks of plum, peach, apricot, and other rosaceous trees, is similar in appearance to the poorer qualities of gum-arabic. By the action of water, in which it is only soluble to a partial extent, it is divisible into two portions, that which is dissolved being *arabin*, while the insoluble matter is *cerasin*.

It has not been analysed, but its composition is probably the same with that of gum-arabic. Cherry-tree gum is not thrown down either by silicate of potassa or by nitrate of mercury. It does not gelatinise with sesquichloride of iron, but a precipitate is produced on the addition of chloride of tin.

It does not seem to have been employed for any purpose whatever in this country. Dr. PEREIRA has suggested its substitution for gum-tragacanth in medicine.

GUM-KINO.—*Gomme Kino*, French; *Gummi Kino*, German; *Gummi Kino*, Latin. Of this so-called gum there are two varieties, Botany Bay and East Indian kino, the former being the inspissated juice of the *Eucalyptus Resinifera*, or *Iron bark*, a native of Australia and Van Diemen's Land; while the latter kind is the produce of *Pterocarpus Erinaceus* or *P. Marsupium*. According to GRAY, when an incision is made in the trunk and branches of the tree, the juice exudes, at first, of an extremely pale-red color, and in a very liquid state; but it soon coagulates, becoming of a deep blood-red hue, and so remarkably brittle, that its collection is attended with some difficulty. East Indian kino, Dr. PEREIRA remarks, is presumed to be the substance referred to in the British pharmacopœias, as it is always regarded in commerce as *genuine gum-kino*. It is imported in boxes from Bombay or Tellicherry.

PROPERTIES.—East Indian kino occurs in small, angular, glistening fragments, the larger of which appear almost black; the smaller being ruddy. When entire, they are opaque, but in thin laminæ are transparent and ruby-red. They are brittle between the fingers, soften in the mouth, adhere to the teeth, tinge the saliva red, and, though inodorous, have a very astringent taste. Kino imparts both to alcohol and to water a deep-red color; the aqueous decoction, on cooling, becomes turbid. In the latter solution, gelatin, tartrate of antimony and potassa, acetate of lead, sesquichloride of iron, and nitrate of silver, produce precipitates.

Botany Bay kino is met with in irregular masses, many of them in the form of tears, somewhat resembling those of cherry-tree gum in outline, and as large as those of gum-senegal. The purer pieces are vitreous, almost black in the mass; but when in small and thin fragments, transparent, and of a beautiful ruby-red. Some of the pieces, however, from the intermixture of wood and other impurities, are dull. When chewed, it sticks to the teeth, and has an astringent taste, but is devoid of odor. Digested in cold water, it swells, becomes soft and gelatinous, and yields a red liquid, which gives an acid reaction with litmus paper, and yields precipitates with lime-water, gelatin, acetate of lead, sesquichloride of iron, and—if a little caustic potassa or ammonia be previously added—with chloride of calcium. Tartrate of antimony and potassa occasions no deposit. Digested in rectified spirit, Botany Bay kino becomes gelatinous, as with water, and affords a similar red solution, in which water causes no subsidence, but which reddens litmus, and deposits a copious precipitate when potassa, ammonia, or lime-water is added.—*Pereira*.

In 1852, Dr. CHRISTISON received from a merchant of Moulmein, a specimen of kino produced in that locality, possessing the physical and apparently the chemical properties of the ordinary kino. Though a small quantity of it was once shipped to England, it is yet, as an article of commerce, unknown.

The pharmacologist last named thus describes it:—

This product consists partly of little angular fragments; but there are larger masses which seem to be portions of cylinders, about half an inch in diameter, apparently moulded by collecting the juice in reeds. These have externally a greyish, striated surface, most unlike that of the broken fragments of commercial kino. They are easily frangible, the broken pieces possessing the exact appearance of ordinary kino, except that they are blacker and more glassy by reflected light; and though opaque, by transmitted light, when of very moderate thickness, yet in very thin fragments, they are of a splendid cherry-red color. They are easily reduced to fine powder, which has a dark, dirty, lake tint. Their taste is very slightly bitter, and intensely astringent.

Cold water acts more quickly on this kino than on that of commerce, gradually dissolving a very large proportion of it, forming a deep cherry-red astringent solution, and leaving a residue of greyish flocculent matter, which is soluble to a great extent in boiling water, and which appears to be analogous to the insoluble variety of gum called bassorin. Boiling water dissolves this kino almost entirely, and the menstruum, when cold, continues nearly transparent for at least an hour; it afterwards becomes slightly turbid, and a scanty flocculent precipitate slowly subsides. Both the hot and cold solutions yield, when much diluted, a deep olive-green precipitate with sesquichloride of iron; when the menstruum is concentrated, a dirty-grey precipitate is formed so abundantly, that the whole fluid becomes a thick, pulpy mass. A solution of one part of the kino in twenty-five of boiling water forms, with the iron-test, a magma too thick to flow. Even a solution in seventy-five parts of cold water has a beautiful intense cherry-red color, and forms with sesquichloride of iron, in the course of an hour, a pulp so thick as to flow only sluggishly.

On comparing these characters with a fine specimen of kino of home trade, and also with a sample from the neighborhood of Goomsoor, Dr. CHRISTISON found the last two to be identical, with the single exception, that the Goomsoor product is somewhat redder when seen in bulk, and that the Moulmein kino is blacker, more vitreous in lustre, rather more easily soluble in cold water, and with rather less residue; and when the cold solution is diluted to the strength of one in seventy-five, it requires rather more sesquichloride of iron to throw down all its tannin, and, consequently, the precipitate forms with the water a somewhat firmer pulp. This kino dissolves, with only a trace of flaky residue, in rectified spirit, which forms an intense cherry-red tincture of very pure astringent taste. Its physical characters, the action of water, and the properties of the aqueous solution, are enough to prove that the Moulmein kino is identical with the kino of commerce, and, in point of quality, is somewhat superior. There is no

doubt, from its taste, and the action of the iron-test, that analysis will prove the presence of a larger proportion of tannin.

It does not absolutely follow, even from the exact coincidences now mentioned, that the Moulmein kino is derived from the same botanical source with the present official kino. The latter has been accurately referred, by the separate researches of GIBSON, PEREIRA, and ROYLE, to the *Pterocarpus marsupium* of ROXBURGH. But the *Butea frondosa* also yields a fine kino, which is scarcely distinguishable in chemical properties from the official kind.—*Pharmaceutical Journal*.

COMPOSITION.—Gum-kino was first analysed by VAUQUELIN, in whose days the resources of chemistry were very much limited, causing a deviation from the truth in many cases, and occasioning, with regard to all investigations of the period, a great amount of doubt as to their correctness.

The comparatively simple tabulation of VAUQUELIN'S results is as under:—

	Centesimally.
Tannic acid and peculiar extractive,	75
Red gum,	24
Insoluble matter,	1
	100

The presence of catechuic acid has subsequently been proved by A. W. BUCHNER.

USES.—For medical purposes only; it is administered in cases of obstinate diarrhoea; it has occasionally been applied to flabby ulcers as a local astringent.

STATISTICS.—Gum-kino is imported from Rangoon and Madagascar into London and Liverpool, in chests and boxes containing each from one to three hundred-weight. It varies in value from fifty to seventy shillings per hundredweight. Duty-free.

GUM-KUTEERA bears considerable resemblance to flaky tragacanth, for which it has occasionally been attempted to be substituted. GUIBOUT considered it as identical with gum-bassora, but PEREIRA states that it is very distinct. It is supposed to be produced by the *Sterculia Urens*, a plant of the family *Byttneriaceae*, and is unknown in British commerce.

GUM-MEZGNITE, known synonymously as *muckeet*, *mezgneet*, or *musgnit*, has been described by MORFIT, who was led to submit it to a chemical examination, on account of the facility with which it may be obtained in large quantities, and its very probable prospective value as an article of commerce.

It is said to be the product of a tree flourishing extensively in the high and dry regions of the plains of Western Texas, New Mexico, and the adjacent Indian territory. It is a spontaneous semifluid exudation, concreting by exposure into tears and lumps of variable size and form. A portion of the sample obtained by Dr. SHUMARD—who first brought it into public notice in 1854—consisted of small irregular pieces and rounded balls about the size of a hazel-nut; semi-transparent, and shading in color from a lemon-white to a dark amber. When broken, the fractured surfaces were brilliant, and the gum was easily reduced to a dull white powder. One of the balls was enveloped with an outer pellicle of gum, about one-sixteenth of

an inch in thickness. Its specific gravity was 1.5, but MORFIT remarks that this determination may admit of correction upon purer samples than were obtainable.

Its proximate composition was found to be:—

	Centesimally.
Arabin,	84.967
Bassorin,	0.206
Water,	11.640
Inorganic matter,	3.000
Impurities,	0.236
	100.049

Its elementary composition is represented by MORFIT as—

	Centesimally.
Carbon,	44.706
Hydrogen,	6.500
Oxygen,	48.794
	100.000

which approaches very closely to that of gums arabic and senegal, as represented by GUERIN and MULDER. The general appearance of the gum, continues its describer, is similar to that of gum-senegal and the dark inferior qualities of gum-arabic; while in chemical properties it is also allied to them, being insoluble in absolute alcohol, partially soluble in alcohol of the ordinary strength, and readily forming with hot or cold water a very adhesive mucilage. It is, in fine, a true gum, and promises, in its physical and chemical behavior, much of the advantage expected by its discoverer, as an economical substitute for gum-arabic or senegal.

MUCILAGE.—*Mucilage*, French; *Schleim*, German; *Mucilago*, Latin.—Many seeds, roots, &c. *cetera*, when infused in water heated to 160° or 170°, impart to it a substance, which, when purified by percolation and evaporation, bears considerable resemblance to gum.

QUINCE MUCILAGE.—One part of quince seed, Dr. PEREIRA states, forms, with forty parts of water, a thick mucilage, which yields with acetate and subacetate of lead, protochloride of tin, nitrate of mercury, and sesquichloride of iron, gelatinous coagula or precipitates. Rectified spirit produces at first scarcely any effect; after some time partial concretion occurs. Sulphuric acid communicates a pinkish tint, and causes the separation of a frothy coagulum, which floats on the mixture. Silicate of potassa, infusion of galls, and oxalate of ammonia produce no change in the mucilage. Quince mucilage is distinguished from arabin, by the effect on it of alcohol, silicate of potassa, oxalate of ammonia, and sulphuric acid; from bassorin and cerasin by its solubility, both in cold and hot water; from tragacanthin, by the reactions caused by alcohol, oxalate of ammonia, and sulphate of iron; from *carrageenin*—see carrageen mucilage below—by the effect of silicate of potassa and acetate of lead. From these and other peculiarities, Dr. PEREIRA proposed to call it *cydonin*—derived from the name of the quince-tree, *Cydonia Vulgaris*.

CARRAGEEN MUCILAGE.—The mucilaginous constituent of Carrageen or Irish moss—*chondrus crispus*—termed by some writers vegetal jelly, or vegetal mucilage, was, from its appearing to have peculiar characteristics, designated by Dr. PEREIRA *carrageenin*. Its

properties, according to that distinguished pharmacologist, are as follow :—

Carrageenin is soluble in boiling water; the menstrum gives precipitates with subacetate of lead and silicate of potassa, and, if sufficiently concentrated, gelatinizes on cooling. It is distinguished from ordinary gum by its aqueous solution not producing a precipitate on the addition of alcohol; from starch by its not assuming a blue color on the addition of iodine; from animal jelly by tincture of galls producing no precipitate; from pectin by the absence of any reaction with acetate of lead, as also by the formation of no mucic acid on the addition of nitric acid.—*Pereira's Materia Medica.*

LINSEED MUCILAGE is extracted from the seeds of the flax-plant, *Linum Usitatissimum*, by the agency of hot water. Alcohol causes the formation in it of white mucilaginous flocks. It is also precipitated by protochloride of tin, and by acetate and subacetate of lead. It possesses an acid reaction, and is not changed by chlorine or iodine. On evaporation, a substance similar in appearance to gum-arabic is obtained, which, when digested in water, intumescs, and partially dissolves.

There are many other mucilages, but as they possess characters in common with those described, a notice of them would be unwarrantable.

GUM-TRAGACANTH, or *Gum-dragon*—*Gomme tragacante*, French; *Gummi tragant*, German; *Gummi tragacantha*, Latin—is a natural exudation from different varieties of the *Astragalus*, or milk-vetch. OLIVIER states that the tragacanth of Asia Minor, Armenia, and northern Persia, is yielded by the *A. Versus*. Mr. BRANT, English consul at Erzeroum, forwarded to Dr. LINDLEY a specimen of *A. Gummiifer*, which was stated to be the tragacanth plant of Koordistan, and producing the white or best kind of gum. It was accompanied with a plant of *A. Strobiliferus*, which was said by the same authority to be the shrub from which the red or inferior species of tragacanth is produced.

According to TOURNEFORT, the *Astragalus Creticus* also yields the gum.

DESCRIPTION.—Gum-tragacanth is white, yellowish, or yellowish-brown, and occurs either in moderately large, broad, thin pieces, marked with arched or concentric elevations—*flaky tragacanth*,—or in small, twisted, filiform, spiral fragments—*vermiform tragacanth*. The former is the kind usually found in this country, while the latter is common on the Continent.

COLLECTION AND ASSORTMENT.—According to S. H. MALTASS, the following is the manner in which gum-tragacanth is collected :—In July and August the peasants clear away the earth from the lower part of the shrub, and make several longitudinal incisions in the bark; the gum exudes the whole length of the incision, and dries in flakes; three or four days are sufficient for this purpose, and the product is then collected. In some places the peasants also puncture the bark with the point of the knife. If the weather be hot and dry, the gum is white and clean; but if the atmosphere be damp, and the temperature but moderate, a longer time is required for inspissation, and the gum assumes a yellow or brownish tinge.

High winds are favorable for drying, but they cause the contamination of the gum with earthy and silicious matters. While engaged in this labor, the peasants pick off from the shrubs the gum which exudes naturally, and this constitutes the variety known in Britain as *common* or *sorts*. The whole of the tragacanth gathered is mixed and sold to native merchants, who send it to Smyrna for re-sale, in bags containing about two hundredweight each. In this state it is termed *rough gum*, and contains as follows :—

	Per Cent.
Flaky or leaf gum, perfectly white, . . .	40 to 50
Flaky or leaf gum, discolored or brown, . . .	15 to 25
Vermicelli gum,	10 to 15
Common or sorts,	35 to 10

The finest parcels, continues this authority, contain the most *vermicelli*, which is nothing more than the siftings of the *leaf* gum which is broken by carriage from the interior, and by removing from one place to another, together with the small vermicular masses termed *Sesame seed*, which are collected with the leaf gum.

When gum-tragacanth is purchased for shipment to Europe, it undergoes the following assortment :—The large, white, flaky, or leaf gum, termed *French quality*, is first picked out, and the residue is sifted. The coarser portion is returned to the pickers, who remove the *discolored leaf*, which is termed *English quality*. The remainder is then examined, and any stones, or dirty, very black pieces are thrown aside as refuse; the rest, composed of naturally exuded gum and brown leaf, is denominated *common* or *sorts*.

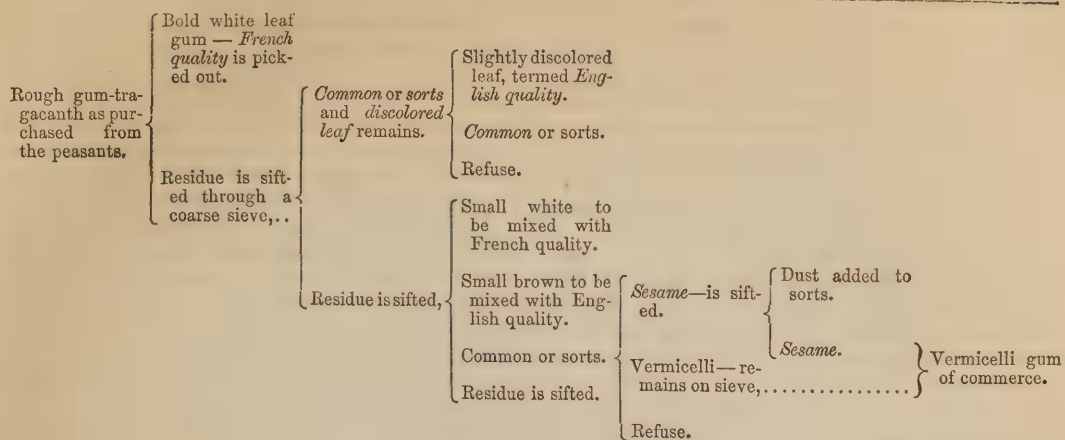
The head-man or master-picker then subjects the gum which passed through the first sieve, to the action of a second and finer one, occasionally throwing out any straw or other light extraneous substance which may rest at the top. The gum remaining after this second sifting is given to the women to assort at their own houses. The *white* is separated from the *brown*, and the latter from the *common*. The first is mixed with the French, the second with the English quality.

A third, and still finer sifting now takes place. The gum which passes through is termed *Sesame seed*; the coarse, which remains upon the sieve, is *vermicelli*. Both qualities are carefully picked by women. When cleaned, the *Sesame seed* is again sifted, and the dust and minute particles are added to the *sorts* or *common* gum. The *Vermicelli* and *Sesame seed* are then commingled, forming the *vermicelli tragacanth* of commerce.

When the gums are intended for the French market, the fine white leaf only is shipped; the *vermicelli* is sold for Trieste, and the discolored leaf and *sorts* for England.

If, however, the whole parcel be worked for Britain, and be required *good*, the French and English qualities are mixed, and the brown leaf which had been left in the *sorts* is also picked out and added. This procedure reduces the value of the *common* or *sorts*.

The various siftings and pickings to which gum-tragacanth is subjected at Smyrna, may be thus tabulated :—

—*Pharmaceutical Journal*.

PROPERTIES AND COMPOSITION.—Gum-tragacanth is the type of the *Bassorin* class of gums. It is destitute both of taste and odor. Its toughness is so great as to prevent its pulverization until it has been exsiccated at 212°, when it becomes tolerably brittle. Instead of dissolving in water like gum-arabic, it intumesces, forming a mucilaginous magma. On subjecting this to ebullition with water, it gradually acquires the appearance of a solution of gum-arabic, in consequence, *BRANDE* supposes, of its transmutation into arabin.

The soluble portion of gum-tragacanth—tragacanthin or adragantin—is generally regarded as identical with gum-arabic, but differs from it in being unchanged by sesquichloride of iron, or silicate of potassa, and also by the flocculency of the precipitate occasioned by alcohol. Subacetate of lead, protochloride of tin, and protonitrate of mercury, produce deposits similar to those caused in a solution of gum-arabic. The presence of lime is shown by the subsidence occasioned by oxalate of ammonia.

The insoluble part of gum-tragacanth—*bassorin*—is similar to that of gum-bassora. Starch globules may be seen in it, with the aid of a good microscope, and the blue coloration produced in it by iodine is a proof of the presence in it of that principle.

DE CANDOLLE has suggested that the intumescence of tragacanth may be caused by the gummy matter being enclosed in cells.

GUIBOUT states that neither arabin nor bassorin are present in gum-tragacanth, but that it is composed of an organised gelatiniform matter, very diverse, both chemically and physically, from gum-arabic, and which swells and divides in water, so as partially to traverse a filter. The same chemist considers the insoluble portion of tragacanth to be a compound of starch and lignin, and to have, in no respect, the same properties with bassorin.

GUERIN-VARRY estimated the proximate principles of tragacanth as under:—

	Centesimally.
Tragacanthin or arabin,.....	53.3
Bassorin and starch,.....	33.1
Water,.....	11.1
Inorganic matter,.....	2.5
	100.0

The ultimate constituents of gum-tragacanth have been determined by *HERMANN*, and by *GUERIN-VARRY*:—

	At. weight.	Centesimally represented.	
		Theory.	Hermann.
10 Eqs. Carbon,.....	60	40.00	40.50
10 Eqs. Hydrogen,.....	10	6.66	6.61
10 Eqs. Oxygen,.....	80	53.34	52.89
1 Eq. Gum-tragacanth, 150		100.00	100.00

GUERIN-VARRY's results are as follow:—

	Centesimally.	
	Soluble part.	Insoluble part.
Carbon,.....	42.01	35.79
Hydrogen,.....	6.42	7.11
Oxygen,.....	54.47	57.10
	102.90	100.00

USES.—Gum-tragacanth is occasionally employed in medicine as a sheathing or demulcent agent in irritation of the mucous membranes; and also as a vehicle for the administration of active and heavy medicines.

Shoemakers use the inferior varieties, in the form of mucilage, for imparting a gloss to the heels of boots.

ADULTERATION.—According to *S. H. MALTASS*, gum-tragacanth is adulterated with two inferior gums. These, he says, are collected in Armenia and Caramania from various trees, principally wild almond and plum. That from the former locality is sent to Constantinople from Moussul, whence it takes the name of *Moussouli*. The Caramanian product is sent direct to Smyrna, and is termed *Caraman*.

Both these gums, continues he, are almost worthless, but fetch high prices for the purpose of mixing with gum-tragacanth. By some they are considered to be an inferior kind of the same gum. As neither Caramania nor Moussul gum occurs in flat pieces like tragacanth, and as they are of a dark color—particularly the former—they would be easily detected if mixed with leaf gum without previous preparation. The Jews, therefore, who adulterate all the drugs of Turkey, have found means of deceiving the eye by breaking up the spurious article into small irregular pieces, which are then coated with *white-lead*. The leaf gum is sophisticated with this at the rate of fifty

per cent. For mixing with the Vermicelli gum, the adulterant is broken into smaller fragments, and added only to the extent of twenty-five to thirty per cent. The pieces are left largest for the sorts or common gum, which often receives even a hundred per cent. of this vile trash.—*Pharmaceutical Journal*.

When pulverized, gum-tragacanth is very often mixed with a multitude of other cheaper powders, more especially with gum-senegal.

A mixture of gums tragacanth and senegal always forms with water a thinner mucilage than the same quantity of either of them alone. The following process is indicated by PLANCHE for the detection of this fraud:—Make a mucilage of the suspected gum, and add to it a few drops of alcoholic tincture of guaiacum, taking care to agitate the menstruum all the while. If the gum under examination contain any gum-arabic, the mixture, in the course of a few minutes, assumes a fine blue color, whilst if the gum-tragacanth be pure, the tint is unaltered. One-twentieth of gum-arabic can thus be detected. It should be remarked, that only

four or five drops of tincture of guaiacum should be employed for two drachms of mucilage, and that when the quantity of gum-arabic is very small, three or four hours must often elapse before the change of color can be observed. When rectified alcohol is poured in a clear and filtered mucilage of gum-tragacanth, it produces only a few flakes, which float in the menstruum, but do not impair its transparency; whilst, if gum-arabic be present, either a precipitate occurs in the liquid, or it becomes opalescent, according to the proportion of gum-arabic which it contains.—*Normandy*.

STATISTICS.—Gum-tragacanth is imported in cases of one hundredweight each into London and Liverpool. Its value, picked, is from ten to fourteen pounds sterling per hundredweight; sorts, from four to eight shillings per pound. Duty-free.—*Poole*.

Subjoined are particulars of the imports and exports of gums—Arabic, Senegal, Kino, and Tragacanth, those being the only gums noticed in the Returns of the Board of Trade—during the years mentioned:—

IMPORTS.						
	1850.		1851.		1852.	
	Cwt.		Cwt.		Cwt.	
Gum-arabic,	41,949	.....	46,032	.....	48,484	.....
Gum-senegal,	2,035	.....	2,738	.....	4,267	.....
Gum-kino,	107	.....	435	.....	159	.....
Gum-tragacanth,	526	.....	791	.....	1,151	.....
					61,614	.....
					6,150	.....
					101	.....
					1,390	.....
					582	.....
						43,960
						2,164
						611
						300

EXPORTS.						
	1850.		1851.		1852.	
	Cwt.		Cwt.		Cwt.	
Gum-arabic,	14,425	.....	10,025	.....	12,265	.....
Gum-senegal,	5	.....	—	.....	39	.....
Gum-kino,	118	.....	46	.....	169	.....
Gum-tragacanth,	128	.....	109	.....	167	.....
					14,559	.....
					80	.....
					93	.....
					473	.....
					123	.....
						20,607
						388
						22
						131

GUM-RESINS.—*Gommes-résines*, French; *Schleimharze*, German; *Gummi-resina*, Latin.—This class of vegetal products has long been recognised in pharmacy, and the various substances forming it certainly possess a sufficient number of peculiar properties to entitle them to be ranked apart. Their nature is not expressed by the term *gum-resin*, and the designation has consequently been condemned as improper; but it has been long sanctioned by use, and seems likely to be retained. They are the inspissated juices which exude either spontaneously, or by means of incisions, from the stems, branches, and roots of certain plants; and consist of resin, gum, essential oil, with other vegetal substances, as starch, and a small amount of inorganic matter. Their general properties are, that they are solid, most commonly brittle, usually opaque, or at least their translucence is not so great as that of the resins; they have almost always a strong smell, and often an acrid taste. Water partially dissolves them, but the resulting menstruum is opaque, and in general, lacteous. Alcohol takes up a portion of them, forming a transparent solution, which is rendered milky by the addition of water. They are principally used in medicine, having little application in the arts and manufactures.

AMMONIAC.—*Gomme Ammoniaque*, French; *Ammoniak-gummi*, German; *Ammoniacum*, Latin.—This substance is the product of the *Dorema Ammoniacum*,

a glaucous green plant, about seven feet high, the stem being about four inches in circumference at the base; a native of Persia. The whole plant, according to PEREIRA, is abundantly pervaded with a milky juice, which exudes upon the slightest puncture being made even at the ends of the leaves. This sap, when hardened, is the commercial ammoniac or ammoniacum of the present day.

The last-named authority states that this term has also been applied to a gum-resin, the produce of the *Ferula Tingitana*, which constitutes the ammoniacum of HIPPOCRATES, DIOSCORIDES, and PLINY. The second of these writers says, that ammoniacum is obtained from a species of *Ferula*, growing near Cyrene, in Africa. PLINY terms the plant *Metopion*, and states that it grows in that part of Africa which is subject to Ethiopia, near the temple of JUPITER AMMON, and received its name, as also did the gum-resin which it produced, from a Greek word signifying *sand*, in allusion to the arenaceous nature of the soil of the country. Two kinds of ammoniac are mentioned both by DIOSCORIDES and PLINY; the best resembled olibanum, and had a bitter taste, and an odor like castoreum; the commonest had a resinous appearance, and was commingled with earth and stones. DR. LINDLEY assured DR. PEREIRA, that African ammoniac was certainly the produce of *Ferula Tingitana*.

As the Greeks and Romans made no mention of

Persian ammoniac, the product of the *Dorema Ammoniacum*, they were, probably, unacquainted with it. AVICENNA notices ammoniac, but says nothing of its origin. That of ABU MANSUR MOWAFIK, a Persian physician who wrote about A.D. 1055, and of BEVA BEN KHUAS KHAN, A.D. 1512, was, doubtless, of the Persian kind. The Arabic terms by which the three last-mentioned authors designate ammoniac, resemble the name by which the plant is now known in Persia; hence it may be concluded that they all referred to the same object.—*Pereira*.

DESCRIPTION AND PROPERTIES.—Ammoniac is found in tears and drops, sometimes distinct, but more generally in agglutinated masses. Externally the tears are yellow, with a tinge of brown, with a waxy lustre; internally they are white or cream-colored, and opaque. It is moderately hard, and at ordinary temperatures brittle, but softens like wax with the heat of the hand. It has a faint and somewhat unpleasant, but very peculiar odor, best detected by subjecting it to heat; its taste is bitter and nauseous.

M. PICARD, in 1852, discovered by accident a very characteristic reaction of chloroxide of sodium—usually known as hypochlorite of soda—upon gum-ammoniacum. The addition of a few drops of a solution of the former to an alcoholic menstruum containing ammoniacum dissolved, causes the immediate development of a very distinct coloration. As this chemist was operating at the time with the commercial alkaline salt, which consists not only of chloroxide, but also of chloride of sodium and carbonate of soda, he thought it proper to inquire which of these compounds caused the reaction, and he soon found that it was due wholly to the chloroxide. Another question presented itself:—Is it the resinous or the gummy part of the ammoniacum which acts in this phenomenon? To find an answer to this, he attempted the complete separation of the two principles by the following method:—An alcoholic solution of ammoniacum, evaporated to the consistence of a sirup, was precipitated by distilled water. The resulting resin, well edulcorated, was redissolved in alcohol, evaporated, and reprecipitated. This treatment was repeated until nothing more was removed by the water, when the resin might be considered as pure. Its alcoholic solution behaved with chloroxide of sodium, like the gum-resin from which it was derived.

The evaporated menstruum obtained in isolating the resin was treated with alcohol, which precipitated the gum, and this manipulation was successively repeated until the gum, which had a brownish cast, dissolved easily and completely in water. This menstruum giving no reaction whatever with the chloroxide, warranted PICARD in asserting that the coloration was due exclusively to the resin. To attain to more precision, he acted on the method prescribed by PELLETIER and BONASTRE for the separation of the resins, which, since their researches, have been termed *resins* and *sub-resins*, according to their solubility in ether; and found that the ethereal solution, which was of a fine amber tint, at once gave the reaction with the alkaline chloroxide; while the small blackish globule of insoluble matter, when affused with ether and dis-

solved in alcohol, was unaltered by the reagent in question.

The sensibility of the reaction of chloroxide of sodium upon ammoniacum is very intense; a mere trace of the former in a menstruum containing the latter is sufficient to produce the phenomenon. This coloration, however, is not persistent; it disappears in contact with the air. If but little chloroxide has produced the reaction, it will reappear on a further addition; but if the reagent be in excess, the presence of another quantity will not induce a return of the tint. A large excess of chloroxide causes it to vanish, especially with the addition of an acid which disengages chlorine. To study the reaction satisfactorily, PICARD proposes three questions:—

1. Of all the resins and gum-resins, is ammoniacum the only one which thus comports itself with chloroxide of sodium, so that this reaction would serve as a distinctive characteristic of it?

2. Is this reaction peculiar to the chloroxides, and have the oxidising agents which most nearly resemble them no analogous result?

3. Is it possible by means of this reagent to detect gum ammoniacum in a pharmaceutical preparation, when it is mixed with other substances?

There are so many characters, continues the distinguished French pharmacologist, common to all resins, that gum-ammoniacum could scarcely be expected to possess exclusively the property of being influenced by chloroxide of sodium. If the resin of guaiacum, however, be excepted, which gives with this reagent a bluish-green coloration, none were influenced. The principles furnished by vegetals of the same family offer a remarkable analogy of chemical and therapeutical properties. Galbanum, sagapenum, opoponax, asafetida, furnished by the *Umbellifere*, a natural family from one of the species of which gum-ammoniacum proceeds, have, however, shown no change when treated with chloroxide of sodium. It is the same with myrrh, olibanum, mastic, sandarac, resins of jalap, scammony and elemi, liquid and calamite storax, benzoin, balsam of tolu, dragon's blood, euphorbium, colophony, resin pitch, white pitch, and turpentine. A distinctive characteristic of gum-ammoniacum is, therefore, its property of assuming a red color with chloroxide of sodium. It should, however, be mentioned that these experiments were made with the alcoholic tinctures, and not with the isolated resins.

The chloroxides of potassium and calcium have the property, in common with that of sodium, of developing the tint; but chlorine does not possess it. If a little carbonate of soda is previously added to chlorine water, the coloration is readily effected, in consequence of the formation of a small amount of chloroxide. Chloric, iodic, chromic, nitrous and nitric acids, and sesquichloride of iron, offer nothing remarkable.

In these investigations, the very powerful vinous color communicated to aloes by the alkalies must be borne in mind. Chloroxide of sodium from its alkalinity, reacts in a similar manner.—*The Chemist*.

A specimen of African ammoniac sent from Tangiers in 1839, is thus described by Dr. PEREIRA, to whom it was presented by Dr. LINDLEY:—It is an oblong

piece, about three inches long, and one and a half inch thick and broad. Its weight is about eight hundred and thirty grains. Externally it is irregular and uneven, and has a dirty appearance, similar to that which ammoniac would present after repeated handling and long exposure to the air in a dusty situation. It is partially covered with paper. A few pieces of reddish chalky earth, effervescing with acids, are found adhering to it, though the proportion of this on the specimen in question is not sufficient to affect in any way its saleability. It appears to be made up like Persian ammoniac, of agglutinated tears; the internal appearance is also much the same as that of the ordinary gum-resin, except that it is not so white, having a brownish, reddish, and in some places a faint bluish hue. Its odor is very faint, and when it is heated, obviously very distinct from that of Persian ammoniac. Its taste is also much slighter.

COMPOSITION.—Ammoniacum has been analysed by several chemists, with various results. BRACONNOT found it to yield the following:—

	Centesimally.
Resin,	70.0
Gum,	18.4
Gluteniform matter, insoluble in water and alcohol,	4.4
Water,	6.0
Loss,	1.2
	100.0

HAGEN's analysis gave:—

	Centesimally.
Resin,	68.6
Gum,	19.3
Gluten,	5.4
Extractive,	1.6
Silicious matter,	2.3
Volatile oil and water,	2.8
	100.0

But these statements of the composition of ammoniacum, from the limited means of analysing organic substances at the time they were deduced, are very unsatisfactory; and there is no doubt that an investigation of the subject, now that organic chemistry has become so fully developed, would show their erroneousess. Of the volatile oil of ammoniacum, little, indeed nothing, is known; Dr. PEREIRA giving as a description of it, the simple statement that *it is transparent and lighter than water*.

JOHNSTON obtained the resin of ammoniacum by digesting the gum-resin in alcohol, whereby he obtained a pale yellow solution, which, on evaporation at 150°, gave a transparent, nearly colorless resin, having the characteristic odor of the natural product. This resin is soluble in alcohol and the alkalis; partially so in ether, and in fixed and volatile oils. Heated to 212° for some time, it assumes a yellow color, which gradually deepens, while at the same time the peculiar odor becomes less intense. It is easily fusible, and decomposes at a continued heat of 270°; the volatile matter which is evolved containing more oxygen in proportion to the hydrogen than exists in the resin itself. JOHNSTON has expressed its composition, after slow but complete desiccation, by the formula, $C_{40}H_{25}O_9$.

USES.—Ammoniacum is principally employed in medicine; internally, its chief, almost sole use, is in chronic pulmonary affections, and even in these cases, it is unsuitable if there be irritation or inflammation of the bronchial membrane. Externally, it is applied in the form of plaster to glandular enlargements and indolent affections of the joints, as a discutient or resolvent.—*Pereira*.

Its only use in the arts, says URE, is in the formation of a cement for joining broken china and glass, and which is prepared as follows:—Take isinglass, one ounce; distilled water, six ounces; boil these together down to three ounces; add half that quantity of strong alcohol, seethe the mixture for two or three minutes, and then strain it; next add, while hot, first, half an ounce of milky emulsion of ammoniacum, and then five drachms of an alcoholic solution of resin mastic. This resembles an article sold as *diamond cement*.

ASAFETIDA—*Assa fetida*, French; *Asafetida*, *Teufelsdrück*, German; *Asafetida*, Latin—is obtained from the *Ferula Asafetida*, an umbelliferous plant found in Afghanistan, Saristan, and the Punjab. The footstalks of the leaves, and the fibres of the root, being previously removed, incisions are made in the latter, and the gum-resin then exudes, and is removed. This procedure commences about the middle of April, and is repeated towards the latter end of May, and the beginning of June and July in each year.

According to Dr. PEREIRA, the root of the *Ferula Asafetida* is perennial, tapering, ponderous, increasing to the size of a man's arm or leg, covered with a blackish-colored bark, and beset near the top with many strong rigid fibres; its internal substance is white, fleshy, abounding with a thick milky juice, which has an excessively strong, fetid, alliaceous odor. The stem is two or three yards high, six or seven inches in circumference at the base, and smooth. The radical leaves attain the length of nearly two feet, and have been compared by KÆMPFER as resembling in shape those of the pæony, but in color and other respects those of common lovage. The fruit is flat, thin, reddish-brown, like that of parsnip, but rather larger and darker.

This is now considered, continues the last-named authority, to be the genuine asafetida plant; but there is reason to believe that a gum-resin like asafetida has been procured from other species of ferula. *Ferula Persica* has been described by Dr. POPE as the true asafetida plant, and the Edinburgh College of Physicians admitted it as being probably one source of the gum-resin. That it really does yield asafetida seems likely, moreover, from the strong odor of the drug which pervades the entire plant.—*Pereira*.

HISTORICAL NOTICE.—For the historical notice of asafetida, the Editor is also indebted to Dr. PEREIRA, who has collected from many sources the following:—It is uncertain at what period asafetida was first known or described. The difficulty in determining its history arises from the confusion which has existed with respect to the *Succus Cyrenaiacus* and asafetida. By many writers the two substances were considered to be identical; but this opinion seems now to have been satisfactorily disproved by the discovery of the plant

which yields the Cyrenaic juice, and which agrees tolerably well with the rude figures struck on the Cyrenian coins. It would appear, however, that the Cyrenaic juice becoming scarce, the ancients employed some other substance of similar, though inferior, properties as a substitute, and to both of these they applied the term *laser*. For many years, says PLINY, this plant has not been found in Cyrenaica, because the publicans—or farmers of the taxes—who rent the pastures, finding it more profitable, destroy it as food for cattle. One stalk only, found in these days, was sent to the Emperor NERO. It may be known when cattle meet with young shoots of it, by the sleeping of the sheep, and the sneezing of the goats, when they have eaten of it. For a long time past the only laser brought is that which is produced abundantly in Persia, Media, and America, but it is far inferior to the Cyrenaic. It is not at all improbable, continues Dr. PEREIRA, that the laser of Persia may have been the asafetida of the present day. MURRAY says the word *asafetida* seems to have been introduced by the monks into the school of Salerno. But it appears to have been of oriental origin, and may be, as some have suspected, derived from the word *laser*. There are two kinds of *assa*, says AVICENNA, one *fetid*, the other *odoriferous*.—*Materia Medica*.

DESCRIPTION.—Asafetida is found in irregular yellowish or pinkish-brown fragments, of different sizes. The newly-fractured surface is whitish or cream-colored, semi-transparent, and possesses a waxy lustre; but on being subjected for a few hours to the combined influence of air and light, it becomes violet-red, and after the lapse of some days, yellowish or pinkish-brown. Dr. PEREIRA has described three varieties:—

1. *Asafetida in the tear*, which occurs in distinct, roundish, flattened, or oval drops, and also in irregular pieces, varying from the size of a pea to that of a walnut, of a yellow or brownish-yellow externally, but white internally. It is not at all improbable that this variety is obtained from a source different from that whence the lump asafetida is procured; for its color, externally, is more yellow, its odor is much feebler, and its freshly-fractured surface becomes more slowly and less intensely red by exposure to the atmosphere. As it has considerable resemblance to *ammoniacum in the tear*—with which, indeed, except by its odor, it might readily be confounded—may it not be the substance which OLIVIER calls ammoniacum, and which, he says, is produced by *Ferula Persica*?

2. *Lump asafetida*, which is the variety usually found in the shops. It occurs in variable-sized masses, of irregular forms, and having a reddish or brownish-yellow tinge. Frequently these masses are observed to be made up of tears, agglutinated by a reddish-brown substance; these form that kind of asafetida sometimes designated *amygdaloid*.

3. *Stony asafetida*. Dr. PEREIRA never met with this in English commerce, but has described samples which he received from Dr. MARTINY: It occurs in irregular, more or less angular, pieces, which have the odor of asafetida, and a yellowish-brown color, and present numerous small shining points or plates. It slightly effervesces in hydrochloric acid. By incine-

ration it yields a white ash, which strongly effervesces on the addition of acids. ANGELINI found in stony asafetida 51.9 per cent. of sulphate of lime.—Dr. Pereira.

PROPERTIES AND COMPOSITION.—Asafetida is very easily known by its peculiar alliaceous odor. This is the more readily appreciable when the gum-resin is subjected to heat. Exposed to light and air, its recently broken surface soon acquires a red color, which gradually passes into yellowish or pinkish-brown. Its taste is acrid and bitter. With sulphuric acid and heat it blackens; a dark, blood-red fluid is produced, and sulphurous acid is evolved. On diluting the menstruum, and adding an excess of caustic potassa, a beautiful blue color may be seen by reflected light, more especially on the surface.

Asafetida consists principally of resin, gum, and volatile oil. BRANDES analysed it with the following results:—

	Centesimaly.
Resin,.....	48.5
Gum, with traces of saline matters,.....	19.0
Bassorin,.....	6.4
Volatile oil,.....	4.5
Extractive, with saline matters,.....	1.4
Sulphate and carbonate of lime,.....	9.3
Oxide of iron and alumina,.....	0.4
Sand and lignin,.....	4.5
Water,.....	6.0
	100.0

The volatile oil of asafetida is prepared by distillation, either with water or alcohol, and passes over colorless, though by a brief exposure to the atmosphere it becomes yellow. It possesses first a mild, and subsequently a bitter taste; its odor is remarkably powerful, and as it is very volatile, the atmosphere of any apartment where it may be exposed is soon impregnated with it. It is very soluble in alcohol and ether, but two thousand times its weight of water are required to dissolve it. It contains sulphur, which may be known by its blackening silver, and Dr. PEREIRA thinks it probable that phosphorus is likewise present. According to some, the oil is composed of two sulphides of the hydrocarbon, $C_{12}H_{11}$, and when freshly distilled, like the essential oils of black mustard and horseradish, it contains no oxygen. It acquires an acid reaction from continued contact with the air, and on boiling it, sulphide of hydrogen is disengaged.

The resinous matter of asafetida may be isolated by digesting the gum-resin in alcohol, and evaporating the solution; by this simple process, however, it cannot be considered as pure, and it is better obtained in this state by adopting the method described by M. PICARD for the preparation of the resin of ammoniacum, and given at page 321. It is soluble in alcohol, oil of turpentine, and oil of almonds. It has the characteristic odor of the gum-resin, and the property which the natural product possesses of becoming violet-red by exposure to the sun's rays. BRANDES states that ether divides it into two portions, resin and sub-resin, which he has described; but JOHNSTON affirms that it is *readily and completely soluble in ether*. Like many other resins, it must be heated for a length of time before it becomes hard and brittle, and reaches its normal condition.

By this prolonged heating, it acquires a darker and brownish color, and is easily decomposed if the heat be carried much beyond 212° . As the temperature rises, the resin froths up very much for some time, giving off a strong alliaceous odor; it then flows quietly till the heat is again increased.

Its elementary composition, according to JOHNSTON, is represented by the formula, $C_{40}H_{26}O_{10}$, which differs from that of the resin of ammoniacum in containing the elements of an additional equivalent of water.

USES.—In Europe solely as a medical agent; it is found highly useful in spasmodic or convulsive diseases not dependent on the nervous centres; as a stimulating expectorant and antispasmodic in chronic catarrh; in affections of the alimentary canal; as an emmenagogue in uterine obstructions. In some oriental nations, as mentioned in the historical notice of asafoetida, it is employed as a condiment.

BDELLIUM.—By this term two gum-resins are understood; one, obtained from *Amyris Commiphora*, the bdellium of Holy Writ, known as *Indian bdellium*, or *false myrrh*; the other, derived from *Heudolatia Africana*, is called *African bdellium*. It is called by the natives, *niottout*. It occurs in commerce in translucent tears, often of considerable size. These vary in tint, some of them being of a brown color, more or less dark. By age they become opaque, and covered with a white or yellowish dust. Their fracture is dull and ceriferous. Bdellium has a feeble, peculiar odor, and a bitter taste. PELLETIER states that it consists of—

	Centesimally.
Resin,	59.0
Soluble gum,	9.2
Bassorin,	30.6
Volatile oil and loss,	1.2
	100.0

JOHNSTON represents the composition of the *resin* of bdellium, by the formula $C_{40}H_{31}O_5$, or $C_{60}H_{62}O_{10}$.

EUPHORBIIUM is the produce of different species of *euphorbia*, a plant growing in the interior of Africa. It exudes in the form of a milky juice, so acrid as to excoriate the fingers, and which hardens by the heat of the sun into irregular yellowish tears. It is nearly inodorous, but its dust excites incessant sneezing. Its taste, at first slight, is afterwards acrimonious and burning; when swallowed, it produces vomiting and purging, and acts as an acrid poison; the persons who grind it suffer from headache and giddiness, and often from delirium. It principally consists of resin and a waxy matter, and a considerable quantity of malate of lime is also present. ROSÉ, in his researches, found euphorbium to contain two distinct resins: one, easily soluble in cold, the other, only soluble in hot alcohol, and, under certain circumstances, susceptible of crystallization. JOHNSTON has also examined these resins, but there is some doubt as to the results of the analysis. ROSÉ assigns the formula $C_{40}H_{35}O_4$ to the crystallizable resin. Euphorbium has also been examined by BUCHNER and HERBERGER, who regard one of the resins as basic, the other acid.

GALBANUM.—Much uncertainty exists with regard to the plant whence this gum-resin is derived. The Dublin College of Physicians have described galbanum,

on the authority of LINDLEY, as the exudation of the *Opöidia Galbanifera*. DON found an umbelliferous fruit in the galbanum of commerce, which he believed to be that of the plant yielding the gum-resin; and, as it constituted a new genus, he called it *Galbanum Officinale*. But though it is not at all improbable, says Dr. PEREIRA, that these fruits are the produce of the galbanum plant, yet no proof of this has been hitherto adduced, and Dr. LINDLEY, therefore, very properly asks, *Did the fruit found upon the gum really belong to it?*

It has not yet been precisely ascertained where galbanum is produced. DIOSCORIDES says it is obtained in Syria; a statement which is, perhaps, correct, though hitherto no evidence of this has been acquired. It is not improbable that it is also procured in Persia, or even in Arabia, as suggested by Dr. ROYLE. *Opöidia Galbanifera* grows in the province of Khorasan, near Durrood. The German pharmacologists distinguish two varieties—*Galbanum Levanticum* and *Galbanum Persicum*. The names indicate the localities whence they are supposed to be derived.—*Pereira*.

DESCRIPTION.—Galbanum generally occurs in brownish, or dark brownish-yellow, irregular masses of large size, apparently composed of agglutinated tears. Some of these, when broken, appear translucent, and of a bluish, or pearl-white color. Fragments of the stem and other similar impurities often pervade the tears; and, to remove these, the galbanum is generally subjected to fusion and strained.

Another variety of galbanum is known, but it is comparatively rare. It is in distinct, globular, yellowish tears of about the size of a pea, possessing a feebly resinous and yellow fracture.

PROPERTIES AND COMPOSITION.—Galbanum has a hot, acrid, and bitter taste, and a peculiar, balsamic odor. When subjected to cold, it is rendered brittle, and may be easily pulverized.

It has been analyzed by several chemists. PELLETIER's results are as under:—

	Centesimally.
Resin,	66.86
Gum,	19.28
Volatile oil and loss,	6.34
Ligneous matters and impurities,	7.52
Bimalate of lime,	traces.
	100.00

MEISSNER's results, appended, seem much more accurate:—

	Centesimally.
Resin,	65.8
Gum,	22.6
Bassorin,	1.8
Volatile oil,	3.4
Bitter matter, with malic acid,	0.2
Vegetal remains,	2.8
Water,	2.0
Loss,	1.4
	100.0

The volatile oil of galbanum is obtained by submitting the gum-resin, with water, to distillation. It is colorless and limpid. Its odor is like that of galbanum and camphor; its taste is hot, afterwards cooling and bitterish. It is soluble in alcohol, ether, and fixed oils.

The resin of galbanum is dark yellowish-brown, transparent, brittle, and tasteless; soluble in alcohol and ether; scarcely so in spirit containing fifty per cent. of water, or in almond oil; very slightly soluble in oil of turpentine, even when aided by heat. It dissolves in sulphuric acid, forming a dark yellowish-brown liquid.

PELLETIER states that galbanum resin has the remarkable property of yielding an indigo-blue oil when heated to from 248° to 266°. JOHNSTON assigns the formula $C_{40}H_{27}O_7$, as representing the composition of the resin.

USES.—Galbanum is principally employed in medicine; it is administered internally in catarrhs, sometimes in amenorrhœa and chronic rheumatism. Externally, it is applied as a mild stimulant, resolvent, or suppurant, in indolent swellings.

GAMBOGE—*Gomme gutte*, French; *Gutti*, German; *Cambogia*, Latin—is, according to GRAHAM, the produce of *Hebradendron Cambogioides*, a native of Ceylon. Gamboge appears to have been first noticed in 1605 by CLUSIUS, who received some of it in 1603 from PETER GARET of Amsterdam. Admiral VAN NECK had brought this from China, and, according to him, its oriental name was *Ghittaiemou*. In Siam it is obtained, says KONIG, by fracturing the branchlets and leaves, when a yellow milky juice exudes, which is collected either upon the leaves of the tree, or in cocoa-nut shells, from which it is transferred to flat earthen vessels, and allowed to inspissate in the atmosphere; it is finally enveloped with leaves. The cylindrical kind of gamboge is resolved into this form by being deposited, while semi-fluid, in joints of the bamboo.

MURRAY states that gamboge is obtained in Ceylon by wounding the bark of the tree, at the time of flowering, with a sharp stone.

DESCRIPTION.—For the delineation of the different varieties of gamboge, the Editor has to resort to the *Materia Medica* of Dr. PEREIRA as the best source of information on the subject. That eminent authority says:—Two kinds of gamboge are described by pharmacological writers—the Siam and the Ceylon. Of these the first only is known in commerce.

1. *Siam Gamboge*.—This is the gamboge of the shops. It is brought to this country sometimes direct from Siam; at other times indirectly by way of Singapore, Penang, or Canton. It presents itself in commerce in three forms:—1, in rolls, or *solid* cylinders; 2, in pipes, or *hollow* cylinders; 3, in cakes or amorphous masses. The first two varieties are known commercially as *pipe* gamboge. The commonest pieces of the above are called *coarse* gamboge.

a. Pipe gamboge consists of cylindrical pieces, varying in size from one to three inches in diameter. Some of them appear to have been formed by rolling; but many of them are striated, from the impression of the bamboo into which the gamboge juice has been run, and, not unfrequently, portions of the stem are still adherent. The gamboge cylinders are sometimes distinct, and covered externally with a dirty greenish-yellow dust; at other times agglutinated, or even folded so as to form masses of varying sizes and shapes.

Pipe gamboge occurs in all qualities, the finest and the worst specimens having this form. *Fine gamboge* is brittle and devoid of odor. It has very little taste at first; but, after some time, it causes an acrid sensation in the throat. Its fracture is conchoidal, and the resulting surfaces are opaque reddish-yellow, with a glimmering lustre. It is completely dissolved by the successive action of ether and water. With a sufficient quantity of the latter fluid, it forms a yellow emulsion, the films of which are good microscopic objects for the observation of *active molecules*. The powder of fine gamboge is bright yellow.

Inferior qualities of this gum-resin are harder, more earthy in fracture. The fresh surfaces are brownish or greyish-yellow, frequently with black spots from the intermixture of foreign bodies. Ether and water successively employed do not completely dissolve it. Iodine readily detects starch in the cooled decoction by the green color which it gives rise to.

b. Lump or cake gamboge occurs in masses of several pounds' weight. Its quality is inferior to the finest pipe kind. Internally, fragments of wood, twigs, and air-cells may be observed. In most of its characters it agrees with the inferior qualities of pipe gamboge, and, like these, contains starch.

2. *Ceylon or Cingalese Gamboge*.—Dr. PEREIRA was unacquainted with this kind of gamboge, which is unknown in English commerce. According to Dr. CHRISTISON, it is usually in small, irregular fragments; but, as originally collected, is in flattish round masses—as if moulded in shallow bowls—weighing about a pound or upwards, and it appears to be composed of aggregated irregular tears, with interspaces and cavities, which are lined with a dark pulverulent matter, or with a powder of an earthy appearance. Altogether it seems a very coarse article. It forms, with great ease, an emulsion nowise inferior in smoothness, and very little, if at all, in brightness of tint, to that of the very best pipe gamboge of Siam.

PROPERTIES AND COMPOSITION.—The properties of gamboge have been, to some extent, treated of in the foregoing description. The following are additional reactions:—

Gamboge affords orange-red tinctures with ether and alcohol, which, when dropped on water, yield, on the evaporation of the solvent, thin, bright yellow, opaque films, which readily dissolve in caustic potassa. The resinous portion of gamboge, of which these films are constituted, has been termed by JOHNSTON gambogic acid. The potassa salt, obtained as just noted by the solvent power of the alkali, gives with acids a yellow precipitate of gambogic acid; with acetate of lead, yellow; with sulphate of copper, brown; and with the salts of iron, dark brown deposits.

* Should it be necessary, as it sometimes has been in medico-legal cases, to detect the presence of gamboge amongst other vegetal products, as in pills, *et cetera*, the following simple, but sure, course of procedure may be adopted:—

Digest one portion of the suspected substance in alcohol, and another in ether, and subject the tinctures to the above-mentioned tests. Though the yellow resin of New Holland, the produce of the *Xanthorrhœa*

Hastilis, has a similar appearance, yet its chemical reactions with the tests above-mentioned are very different. Should the yellow coloring matter of turmeric, saffron, or rhubarb be taken, at first sight, for that of gamboge, the examination with acids, acetate of lead, sulphate of copper, and salts of iron successively, may be accepted as positive.

Dr. CHRISTISON gives the following as the centesimal composition of gamboge:—

Siam Gamboge.			
	Pipe.	Cake or Lump.	Coars.
Resin,.....	72.5	64.7	48.2
Soluble gum,.....	22.7	20.3	15.2
Woody fibre,.....	trace	5.3	13.3
Pecula,.....	—	5.6	14.5
Moisture,.....	4.8	4.1	8.8
	100.0	100.0	100.0

Ceylon Gamboge.	
Resin,.....	71.2
Soluble gum,.....	19.9
Woody fibre,.....	5.7
Water,.....	3.2
	100.0

GAMBOGIC ACID.—Syn. Gambodic acid—Resin.—It has a deep orange color, and communicates a yellow tint to ten thousand times its weight of alcohol. It is soluble in this menstruum, and still more so in ether. Water does not take up any of it. When subjected to a heat of about 400° it is partially decomposed, so that while one portion is soluble in alcohol, as the original resin, the other is insoluble. Gamboge resin forms numerous salts. Its composition has been represented by the above chemist as $C_{40}H_{22}O_9$. The gum of gamboge seems to be identical with arabin, and like it readily dissolves in water.

The fecula found in the inferior kinds of gamboge is probably an adulterant.

To a small extent gamboge is employed as a water-color; but its principal application is in medicine. It is seldom administered *per se*, owing to its tendency to create nausea and vomiting; but, when combined with milder purgatives, it has been found to be a valuable remedy in constipation; in cerebral affections, as apoplexy; in dropsy; and as an anthelmintic. The full dose of it is said to be from ten to fifteen grains. In excessive quantity it acts as an acrid poison. Dr. PEREIRA records that a drachm administered to a human subject, caused horrible vomiting and purging, followed by syncope and death. No effective antidote is known. HAHNEMANN has, indeed, recommended carbonate of potassa as a means of diminishing the violence of the topical action of gamboge.

MYRRH.—*Myrrhe*, French; *Myrrha*, German; *Myrrha*, Latin. This well-known gum-resin is the spontaneous exudation of the *Balsamodendron Myrrha*. It is repeatedly mentioned in the Old Testament, the earliest allusion being in Genesis, from which it appears that 1729 B.C. it was an article of Eastern commerce. It seems to have been made use of by DEMOCRATES. DIOSCORIDES enumerates several varieties of it; one named the *Troglodytica* being the best. According to some ancient writers, this gum-resin received its

appellation from MYRRHA, the daughter of CIMFRAS, king of Cyprus, who, after committing criminal acts, absconded to Arabia, and was transformed into a tree, which ever afterwards bore her name.

The myrrh tree was not fully known until EHRENBURG, in 1825, returned from his travels with HEMPRICH in Asia and Africa, bringing with him a specimen, which has been delineated and depicted by NEES VON ESENBECK.

DESCRIPTION.—Myrrh, says Dr. PEREIRA, is imported from the East Indies in chests containing from one to two hundredweight each. Formerly the finest kind was brought from Turkey, and an inferior one from the East Indies; but, at the present time, nearly the whole comes from India. Sometimes the same chest contains myrrh of all qualities, which is then termed *myrrh in sorts*; but commonly it is imported more or less assorted.

Myrrh of first quality.—Turkey myrrh occurs in pieces of irregular forms and of variable sizes, consisting of tears—either distinct or agglomerated—usually covered with a fine powder or dust. The color varies, being pale reddish-yellow, red, or reddish-brown. The pieces are fragile, semi-transparent, with a dull, and in part splintery, fatty kind of fracture. In consequence of imperfect desiccation, the largest and finest pieces often present internally, opaque, whitish, or yellow striæ, or veins, which have been compared by DIOSCORIDES, PLINY, and many others, to the white marks on the nails. The purest, palest, and most odorous pieces are sold as *picked myrrh*.

Myrrh of second quality consists of distinct tears or grains, which are rounded or irregular, and vary in size from that of a pin's head to a peppercorn, none of them in Dr. PEREIRA's specimens being so large as a small pea. They are somewhat shiny, more or less transparent, and vary in color from pale or whitish-yellow to reddish-brown. It consists of tears of myrrh, intermixed with fragments of gum-arabic, and of some resin very like mastic or juniper. Many druggists regard it as merely the siftings of the finest kind, but Dr. PEREIRA does not agree with this opinion.

Myrrh of third quality.—Formerly this was the only kind imported from the East Indies. It occurs in pieces, which are darker-colored than those of the so-called Turkey myrrh, and the average size of which does not exceed that of a walnut. It is often mixed with other matters, particularly with *Indian bdellium*, and with a substance of similar appearance to dark-red colored Senegal gum.—*Pereira*.

PROPERTIES AND COMPOSITION.—The odor of myrrh is peculiar, but balsamic and fragrant; the taste is bitter, aromatic, and somewhat pungent. Water dissolves the gum principally, while alcohol and ether take up the volatile oil and resin. Myrrh is readily dissolved by the alkalis. When it is subjected to the action of nitric acid, a vinous hue is produced. According to PELLETIER it consists of thirty-four per cent. of resin and sixty-six of gum. RUICKHOLDT states that it contains, when of the best quality, between forty-four and forty-five per cent. of resin. BRANDES and BRACONNOT have also analysed it, with the following results:—

	Centesimally represented	
	Brandes.	Braconnot.
Volatile oil,.....	2.60	2.5
Resin,.....	27.80	23.0
Gum { Soluble,.....	54.38	46.0
Insoluble,.....	9.32	12.0
Salts—benzoates, malates, phosphates, sulphates, and acetates of potassa and lime,.....	1.36	—
Impurities,.....	1.60	16.5
Loss,.....	2.94	
	100.00	100.0

According to BRANDES, the 27.80 per cent. of resin found by his analysis, consisted of 22.24 soft, and 5.56 of hard resin, the two soluble in alcohol. The former he distinguishes as odorous, and insoluble in ether. UNVERDORBEN regards it as a compound of hard resin and volatile oil. The hard resin is characterised as inodorous, soluble in the caustic alkalies, but not taken up by ether. The resin prepared by RUCKHOLDT was of a brown color, fused at a temperature below 212°, and slightly retained the taste and odor of the gum-resin. By subjecting it to heat, he obtained a modified resin, which he has termed myrrhic acid.

The volatile oil of myrrh has the odor and taste of myrrh; it is soluble in alcohol, ether, and the fixed oils; it is thin, but has a specific gravity higher than that of water. It is devoid of color, but becomes yellowish by keeping, probably from the absorption of oxygen. It forms red menstrua, with sulphuric, nitric, and hydrochloric acids. When exposed to the atmosphere, partial evaporation occurs, and a glutinous, varnish-like magma remains.

The Editor learns that myrrh is often mixed with Indian bdellium—the produce of the *Amyris commiphora*. *Bdellium*, in appearance and taste, is often very similar to myrrh, but differs in odor, and is characterized by its great amount of bassorin. Besides this, it is often mixed with another substance, for the detection of which BLEY and DIESEL give directions as follows:—

Pseudo-myrrh, which has been frequently found incorporated with the genuine myrrh, consists of large pieces of different forms, the majority of them seeming to be fragments of a cylindrical body; they are coated externally with dust, and have a dirty reddish-brown color; the surface of fracture is tolerably even, of vitreous lustre, brownish-yellow color, and nearly as transparent as Senegal gum. It has a faint myrrh-like odor, and a disagreeable, bitter, somewhat balsamic taste. Nitric acid dissolves it, yielding a bright yellowish liquid, from which water separates small yellowish particles. Genuine myrrh yields with nitric acid a transparent dirty-yellow liquid. *Bdellium indicum* is not dissolved by nitric acid; it softens, becomes whitish and opaque. Bibulous paper, moistened with the alcoholic extract of myrrh, and then with nitric acid, acquires the blood-red color first observed by BONASTRE; *bdellium* and pseudo-myrrh exhibit only a yellow or brownish coloring. *Bdellium indicum* is, moreover, distinguished by its greenish-brown hue, its more terebinthinate odor, and bitter and somewhat acrid taste. It becomes viscous when held for some time between the fingers. Myrrh yields a bright

golden-yellow tincture, and an opaque whitish residue; pseudo-myrrh, a high yellow one, and a semi-transparent residue; *myrrha indica*, a dark-yellow tincture, and an opaque residue. An addition of water produces in the first and last a milky turbidness, and in the second no change. Nitric acid—six drops to twenty of the tincture—yields with *myrrha electa* a yellowish-white opacity, upon which, after a time, the periphery of the liquid acquires a bright violet color, while the centre remains yellow. *Myrrha indica* behaves similarly, only that the tint is darker; pseudo-myrrh does not exhibit this reaction. Fuming nitric acid produces with the tincture of *myrrha electa* an amber-brown, and finally a dark violet color; on evaporation, a dark gamboge-looking residue is left; *myrrha indica* exhibits the same reaction; pseudo-myrrh experiences no change. *Bdellium indicum* and *africanum* are distinguished by their not assuming a violet hue on their treatment with nitric acid. About two grains of myrrh, shaken with an ounce of water and filtered, yield with solutions of salts of the oxide of lead a considerable precipitate. *Bdellium indicum*, treated in the same manner, exhibits scarcely any opacity.

USES.—Like most of the other gum-resins, myrrh is employed only in medicine; it is useful in disordered conditions of the digestive organs; in excessive secretions from the mucous membrane; and, externally, as a dentifrice, and as a gargle for ulceration of the throat in the form of tincture.

OLIBANUM.—*Oliban*, French; *Oelbaumharz*, German; *Olibanum*, Latin. This gum-resin, employed by the ancients in their religious rites under the name of *frankincense*, and first mentioned by MOSES, is derived from the *Boswellia Thurifera*, a terebinthaceous tree, inhabiting the mountainous parts of Coromandel.

DESCRIPTION.—Dr. PEREIRA describes it as consisting of round, oblong or ovate, pale-yellowish, semi-opaque, fragile tears, having a balsamic resinous odor. JOHNSTON is of opinion that it is a mixture of two distinct gum-resins. The one he delineates as consisting of opaque, dull, hard, brittle pieces, which, when introduced into alcohol, become almost immediately white and opaque, from a white powdery coating or crust left on their surface as the soluble portion is taken up. This variety constitutes the larger portion of the olibanum of commerce, and is the more fragrant when burned. It contains an acid resin and volatile oil.

The second variety is characterised as being in clearer, more yellow, less brittle, opaque pieces, generally in long tears as they have flowed from the tree, containing less gum than the other kind, and becoming clear and transparent when immersed in alcohol. All the tears of olibanum experimented upon by Dr. PEREIRA became opaque when introduced into alcohol.

COMPOSITION.—Olibanum has been examined by BRACONNOT, who gives the following as its centesimal composition:—

	Per cent.
Resin,.....	56.0
Gum,.....	30.0
Volatile oil,.....	8.0
Matter like gum, insoluble in water and alcohol,.....	5.2
Loss,.....	0.8
	100.0

Dr. STENHOUSE, who examined the volatile oil of olibanum, found it to be colorless, and similar to turpentine, but possessed of a more agreeable odor. Its composition is represented by the formula $C_{35}H_{28}O$.

JOHNSTON has distinguished two distinct resins, produced by both varieties of the gum-resin before-mentioned. The resin from the first of these gave the composition $C_{40}H_{32}O_6$. That from the second, consisting of the clearer, yellower, elongated tears, resembles colophony, and its formula is $C_{40}H_{32}O_4$.

USES.—Olibanum is, to a great extent, disused for medical purposes. It was formerly administered in chronic diarrhoea, old catarrhs, and in affections of the chest. It is sometimes employed for fumigation, and enters into the incense employed in the services of the Roman church.

OPOPONAX.—*Opopanax*, French, German, and Latin.—This gum-resin is the inspissated juice of the *Opopanax Chironium*, a plant flourishing in Greece, Italy, Sicily, and in the South of France, and bearing a great similarity to parsnip. It was employed by HIPPOCRATES, and is mentioned both by DIOSCORIDES and by THEOPHRASTUS.

Opopanax occurs in reddish tears and lumps, tasting acrid and bitter, and possessing a mouldy, disagreeable odor. The following is its constituents, as ascertained by PELLETIER:—

	Centesimally.
Resin,	42·0
Gum,	33·4
Lignin,	9·8
Starch,	4·2
Wax,	0·3
Extractive,	1·6
Malic acid,	2·8
Volatile oil, traces of caoutchouc, and loss,	5·9
	100·0

On evaporating the spiritous solution of opopanax, a transparent brown resin, having a peculiar odor, is obtained. It readily fuses at 212° , and, after remaining for a short time at that temperature, becomes brittle upon cooling. It dissolves in alcohol and ether, and in the caustic alkalies. The alkaline solution is reddish, and parts with the resin, on the addition of hydrochloric acid, in yellow flocculi. Its composition, as it exists in the natural gum-resin, is as under:—

	At weight.	Centesimally.	
		Theory.	Johnston.
40 Eqs. Carbon,	240	63·67	64·01
25 Eqs. Hydrogen,	25	6·63	6·75
14 Eqs. Oxygen,	112	29·70	29·24
1 Eq. Opopanax resin, ..	377	100·00	100·00

USES.—Opopanax was formerly employed in medicine, but it is now banished from the *Materia Medica* as enumerated in the British Pharmacopeias. It is adapted to the same cases as the other gum-resins of this class. Dr. PEREIRA is of opinion, that it is more allied to ammoniacum than to any other of these substances.

SAGAPENUM.—*Sagapenum*, French and German; *Sagapenum*, Latin.—Sagapenum is mentioned, says Dr. PEREIRA, by HIPPOCRATES, DIOSCORIDES, and PLINY. The latter calls it *sacopenium*. DIOSCO-

RIDES says it is a liquor obtained from a ferulaceous plant growing in Media. Nothing is known with respect to the plant yielding sagapenum. WILLDENOW considered it to be *Ferula Persica*, and he has been followed by SPRENGEL and others; but there is no evidence to prove that sagapenum is obtained from a *Ferula*, for the statement of DIOSCORIDES cannot be admitted as having much weight.

BRANDES' analysis of sagapenum gave the following results:—

	Centesimally.
Resin,	50·0
Gum, with calcareous salts,	32·5
Volatile oil,	3·5
Bassorin,	4·2
Malate and phosphate of lime,	1·1
Impurities,	4·2
Water,	4·5
	100·0

Sagapenum of the finest kind consists of masses made up of agglutinated, brownish-yellow, semi-transparent tears, resembling galbanum, but having a darker color and a more alliaceous odor. A more common sort occurs in soft, tough masses, in which no distinct tears are to be seen. Its taste is hot and acrid, and, when heated, it evolves a much more aromatic and agreeable odor than galbanum. It is imported from the Levant.

The oil of sagapenum has a mild bitter, alliaceous taste, subsequently becoming hot; its odor is also garlicky. It is of a pale yellow color, dissolves in alcohol and ether, and is reddened by sulphuric acid. Its specific gravity is greater than that of water.

The resin of sagapenum has been examined by JOHNSTON, who gives, as the representative of its composition, the formula $C_{40}H_{32}O_6$. It possesses a strong garlic odor, and easily fuses, becoming fluid at 212° . Ether resolves it into two resins:—

1. The resin *insoluble in ether* is devoid of taste and odor, and is of a brownish-yellow tint. It is soluble in alcohol and the alkalies, but is not taken up by oils of turpentine and almonds.

2. The resin *soluble in ether* possesses the odor of sagapenum in a slight degree; its taste is mild, subsequently bitter; its color, reddish-yellow. It is soluble in alcohol, and partially so in oils of turpentine and almonds. Sulphuric acid dissolves it, forming a blood-red menstruum, from which a violet-tinged matter is separated by the addition of water.

USES.—The medicinal effects and uses of sagapenum are similar to those of asafetida,—see page 322. It is now very little employed.

The Editor thinks it most remarkable that so little is really known with respect to the previously-cited compounds. There is now a great field open to young chemists to investigate their nature and true composition, *et cetera*, so as to remove many of the inaccuracies regarding them.

STATISTICS.—The Returns of the Board of Trade for 1850 to 1855 only enumerate Ammoniacum, Asafetida, Euphorbium, Gamboge, Myrrh, and Olibanum. Annexed are the imports and exports of these for the years 1850, 1851, 1852, 1853, 1854, and 1855:—

IMPORTS.						
Years ending 5th January, 1850.	1851.	1852.	1853.	1854.	1855.	
Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	
Ammoniacum,	832	391	304	60	19	—
Asafetida,	820	1,922	1,167	2,170	1,555	1,251
Euphorbium,	17	12	14	—	—	99
Gamboge,	561	1,490	701	455	173	259
Myrrh,	545	620	844	282	579	689
Olibanum,	4,539	11,450	8,837	9,029	13,383	10,817

EXPORTS.						
Years ending 5th January, 1850.	1851.	1852.	1853.	1854.	1855.	
Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	
Ammoniacum,	705	222	319	246	168	79
Asafetida,	507	1,049	1,176	904	731	795
Euphorbium,	—	—	—	—	—	4
Gamboge,	426	153	335	1,056	235	373
Myrrh,	113	263	535	341	272	180
Olibanum,	4,798	11,990	8,739	8,892	12,756	11,757

GUN-COTTON.—*Coton-poudre*, French.—Some years ago this substance created quite a *furor* in the scientific world; but the expense of gun-cotton is considerably higher than that of gunpowder, and this with other drawbacks has been a great obstacle to its being extensively used. Ordinary cotton is one of the almost innumerable forms of lignin, a compound of carbon, oxygen, and hydrogen; but, by subjecting cotton to the action of nitric acid, a new element enters into the composition—namely, nitrogen, which is found in nearly all explosive bodies.

The action of nitric acid on vegetal matter had long attracted the attention of chemists before the discovery of the remarkable detonating compound now under notice. In 1813, BRACONNET gave an account of a new substance obtained by the action of concentrated nitric acid on starch, sawdust, linen, and cotton wool. He named this xyloidin, from the Greek word signifying wood, and described it as being white, pulverulent, neutral, and very inflammable. It is easily formed by boiling starch for a few moments in concentrated nitric acid, until solution takes place; on pouring the resultant into cold water, the xyloidin is precipitated, and may be collected and exsiccated. In 1838, PELOUZE called the attention of the Academy of Sciences to the properties of xyloidin, which he observes is very combustible, taking fire at 365°, burning with great rapidity, and almost without residue. This property led him to an experiment which he thought susceptible of some applications, especially in artillery. By plunging paper in nitric acid, specific gravity 1·5, leaving it there the requisite time for the acid to permeate the paper, which is usually accomplished in two or three minutes, then withdrawing it, and, lastly, washing it in water, a kind of parchment impermeable to moisture, and extremely combustible, is obtained. DUMAS proposed to name the compound *nitramidine*, and mentions the application of paper and pasteboard prepared by nitric acid for fireworks.

At a meeting of the British Association at Southampton, in 1846, it was stated that Professor SCHÖNBEIN had discovered a mode of rendering cotton so detonating as to form an excellent substitute for gunpowder. Soon after this announcement, Professor OTTO of Brunswick published an account of an explosive cotton, as did also MOREL of Paris, and BÖTTGER of Frankfort. SCHÖNBEIN undoubtedly, as

DUMAS admits, deserves the honor of having been the first to show that the products of the action of nitric acid upon lignin are superior in explosive energy to gunpowder; but it must be recorded that, as far back as 1832, ROBIQUET produced an insoluble powder, explosive when heated, by the addition of water to a solution of sawdust in strong nitric acid. In April, 1847, SCHÖNBEIN's patent was enrolled; the specification states, that in preparing the cotton the patentee uses nitric acid of specific gravity 1·45 to 1·50, and sulphuric acid of specific gravity 1·85. These acids are to be mixed in the proportion of three parts of the latter to one of the former; the mixture is allowed to cool down to between 50° and 60°, and then rough cotton, free from all extraneous matter, is immersed in the liquid, in as open a state as possible, in a porcelain vessel. When thoroughly soaked, the excess of acid is to be drawn or poured off, and the cotton squeezed lightly with an earthen presser to separate the principal part of the acid. The cotton is covered over and left for an hour, then pressed, and well washed in running water, to get rid of all free acid; it is next to be partially exsiccated by pressure, and to insure its freedom from acid, it is to be washed in a dilute solution of carbonate of potassa, made by dissolving one ounce of this salt in a gallon of water; it is then put in a press, and the excess of alkaline solution squeezed out, leaving the cotton nearly dry. It is next washed in a solution consisting of one ounce of pure nitrate of potassa in one gallon of water, and when again pressed is dried in a room heated by steam or hot water to the temperature of from 150° to 170°. The saltpetre appears to increase the explosive force of the cotton, but it is not absolutely necessary. Of the cotton thus prepared, three parts are said to be equal in force to eight parts of Tower-proof gunpowder.

A simpler method of preparing gun-cotton in small quantities was proposed by Mr. THOMAS TAYLOR in 1846, which is to mix in any convenient glass vessel an ounce and a half, by measure, of nitric acid—specific gravity 1·45 to 1·50—with an equal quantity of sulphuric acid—specific gravity 1·80. When the mixture has cooled, place one hundred grains of fine cotton wool in a mortar, pour the acid over it, and with a glass rod imbue the cotton as quickly as possible with the acid. As soon as the cotton is completely satu-

rated, remove the acid, and, with the aid of a pestle, quickly squeeze out as much liquid as possible. Throw the mass into a basinful of water, and thoroughly wash it, either in successive portions of water or under a tap, until the cotton has not the slightest acid taste. Finally, squeeze it in a linen cloth, and dry it in a water-bath. Nitric acid of the specific gravity of 1.50 answers better than that of 1.45, the cotton being much less acted upon by the strong acid. Nitric acid of the specific gravity 1.36 converts the cotton into a gelatinous mass.

Gun-cotton is considerably heavier than unprepared cotton, and may be distinguished therefrom by its harshness, and by the crepitating sound produced when pressed by the hand. When well made, there is scarcely any change in color or general appearance. It may also be known from common cotton by its electric condition; for if a portion be pulled briskly between the finger and thumb of a dry hand, the fibres will adhere with great tenacity. If a strip of prepared paper be thus treated, it will, on presenting one end to the knuckle, be alternately attracted and repelled, and thus part with its electricity. Gun-cotton is also perfectly soluble in ether, and if the solution be poured on the surface of cold water, the xyloidin yields an opaque film thereon, which, when collected and dried, forms a remarkably explosive paper.

The detonating character of gun-cotton appears to be due to the formation of xyloidin in the tubes and upon the exterior of the cotton fibre, under the action of the nitric acid. Gun-cotton explodes with very great rapidity at from 350° to 400°. If a little gunpowder be placed on a sheet of writing paper, and a small piece of gun-cotton be laid lightly upon it, and the whole held about a foot above the flame of a lamp or candle, the heat will soon be sufficient to ignite the cotton, but the powder will not be kindled; and, although the cotton explodes in contact with the powder, its action is so rapid that there is not time enough to raise the gunpowder to the temperature required for its explosion. This great rapidity of action is opposed to its utility for propulsive purposes. It is well known to practical men that a tardily-exploding material is the best for artillery practice. Thus, when a slow powder is used, the ball acquires a slight degree of motion, which is imparted to the air in front of it, before the full power of the detonation is exerted; and that motion is gradually increased during the remainder of the explosion. But if the action takes place too quickly, the full force of the propelling power comes into play before the ball is in motion, and the bursting of the gun is the probable consequence. This is the reason why the fulminates of mercury and silver have not been more extensively used in warfare.

When gun-cotton has been carefully prepared, the products of its combustion are carbonic acid, aqueous vapor, and free nitrogen. In some cases nitrous acid is produced, owing to defective washing; and when nitrate of potassa has been employed, or, in fact, a solution of any salts, a dense white vapor accompanies the explosion. The quantity of water produced during the decomposition of the cotton by heat is so great, as to constitute an objection to its use

in fire-arms. Its hygrometric condition also impedes its utility; for if a quantity be exposed for an hour or two to a damp atmosphere, it absorbs nearly its own weight of water, and requires re-drying before it can be employed; it cannot be protected from atmospheric moisture by compression into cartridges, as in that state it does not explode with certainty. The idea of using the fulminating cotton as a substitute for gunpowder for artillery purposes, seems to be completely abandoned; but on account of the small quantity of smoke given off, as well as on account of its enormous force, it is much used for mining purposes, the proportionate quantity employed being a fourth of that of powder.—*Tomlinson*.

In the explosion of gun-cotton there appear to be found very decided quantities of nitrous and of hydrocyanic acid. The former corrodes fire-arms, and the latter vitiates the surrounding air in a mine.

The most recent and best information on gun-cotton and its substitution-compounds is given in a paper by Mr. EDWARD HADOW, from which the following interesting details are transcribed.

Analyses of gun-cotton have been published by PELOUZE, PELIGOT, GLADSTONE, PORRETT, RANSOME, and likewise by SCHÖNBEIN; they exhibit, however, a remarkable want of agreement with each other, both in the formulæ to which they give rise, and in the per-centage increase of weight which they would represent the cotton to have obtained on its transformation into gun-cotton.

PELOUZE states that cotton constantly gains from seventy-four to seventy-six per cent., giving the formula $C_{24} H_{17} O_{17}, 5 NO_5$, corresponding to an increase of seventy-five per cent. exactly. PELIGOT's formula is $C_{12} H_9 O_9, 3 NO_5$, according to which the gain must be 94.4 per cent. RANSOME obtained $C_{12} H_8 O_{10}, 2 NO_5$, which represents an increase of 65.4. Dr. GREGORY states it to be 69.5, which corresponds with that required by the formula which GLADSTONE ascribes to the most explosive gun-cotton, $C_{24} \left\{ \begin{matrix} H_{15} \\ 5 NO_4 \end{matrix} \right\} O_{20}$,

while the formula of PORRETT and TESCHEMACHER, $C_{12} H_8 O_8, 4 NO_5$, would double the original weight of the cotton. SCHÖNBEIN merely gives the per-centage of carbon, nitrogen, hydrogen, and oxygen, from which the lowest formula that can be calculated corresponds nearly to $C_{47} H_{31} O_{68} N_{10}$. In consequence of this disagreement between the formulæ, giving rise to so marked a difference in the per-centage increase of weight deduced from them, it was evident that a careful determination of the weight actually acquired by cotton, after immersion in acids, could alone throw much light on the matter, by pointing out the formula upon which most reliance was to be placed, and from which the composition of the soluble variety might be determined, provided that it were indicated by a definite and constant increase of weight. While ascertaining this point, HADOW was anxious likewise to discover what strength and what proportions of acids were capable of producing the soluble gun-cotton, as well as whether there were more than one such compound; expecting that, if such were the case, there would be always an augmentation of weight closely correspond-

ing to two or more numbers from which formulæ might be calculated, or by which at least the results of analyses might be controlled.

In the preparation of these compounds, nitric acid was not used alone, since a very slight difference in strength produced a great difference in the result. HO, NO_5 gives an insoluble product, while $\text{HO}, \text{NO}_5 + \text{HO}$ destroys the texture of the cotton; and having ascertained that when sulphuric acid is used, no trace of it exists in any of the compounds, a mixture of the two was always used; the latter acid being advantageous for the purpose of increasing the bulk of the mixture, retaining the water abstracted from the cotton, and preventing the solution of the compound, which takes place to a greater or less extent in nitric acid *per se*. The mixtures were likewise made in atomic proportions, that their formulæ might be easily retained in the memory, and similar mixtures be prepared from acids of various strengths. After some trials, those which contained one equivalent of monohydrated nitric acid with two equivalents of monohydrated sulphuric acid, proved to be best; and mixtures being made with the acids in this proportion, and from one to five additional equivalents of water, the fifth was found to disintegrate the cotton. The results obtained from one hundred of cotton were as follow:—

$\left. \begin{array}{l} \text{HO}, \text{NO}_5 \\ 2 (\text{HO}, \text{SO}_3) \end{array} \right\}$	$2 \text{ HO} = 177$	} Insoluble in ether + one-eighth alcohol except the last, which is slightly attacked.
$\left. \begin{array}{l} \text{HO}, \text{NO}_5 \\ 2 (\text{HO}, \text{SO}_3) \end{array} \right\}$	$2 \text{ HO} = 176$	
$\left. \begin{array}{l} \text{HO}, \text{NO}_5 \\ 2 (\text{HO}, \text{SO}_3) \end{array} \right\}$	$3 \text{ HO} = 171.7$	
$\left. \begin{array}{l} \text{HO}, \text{NO}_5 \\ 2 (\text{HO}, \text{SO}_3) \end{array} \right\}$	$4 \text{ HO} = 157$	} Very soluble.
$\left. \begin{array}{l} \text{HO}, \text{NO}_5 \\ 2 (\text{HO}, \text{SO}_3) \end{array} \right\}$	$5 \text{ HO} = \frac{\text{about}}{140}$	
		} Soluble in great measure.

The interval between the third and fourth appeared in some degree to correspond to what had been expected. That between the fourth and fifth was doubtful, from the loss of the latter, and from its apparently containing an admixture of unchanged cotton; but on trying fractional additions of water, a corresponding intermediate increase of weight was likewise produced in the cotton: for example,

$\left. \begin{array}{l} \text{HO}, \text{NO}_5 \\ 2 (\text{HO}, \text{SO}_3) \end{array} \right\} 3\frac{1}{2} \text{ HO} = 166.4$ $\left\{ \begin{array}{l} \text{HO}, \text{NO}_5 \\ 2 (\text{HO}, \text{SO}_3) \end{array} \right\} 3\frac{2}{3} \text{ HO} = 160.5$
both compounds proving perfectly soluble. It was likewise found on repeating these experiments, that it was difficult to obtain the same increase of weight unless the mixture corresponded accurately in composition. The cotton in these researches was thor-

oughly exsiccated in a current of dry air at 212° , and in consequence of its hygroscopic properties, was weighed in the same tube in which the desiccation took place. At first the gun-cottons were likewise carefully dried at low temperatures, after thorough washing in distilled water; but the results not being found quite accurate, and a gradual loss of weight being observed at temperatures below 212° , the drying was effected by placing them *in vacuo* over sulphuric acid for twenty-four hours, after which they were found not to sustain the slightest diminution in weight. The acids were also used in large proportion to the quantity of cotton, that the water abstracted might have no appreciable effect in diluting the mixture; and as a precaution, the immersion was continued for several hours, although the full effect appears to be produced in a very short space of time. It was, however, found that, notwithstanding these advantageous conditions for the production of definite compounds, very variable increments of weight were acquired by the cotton, ranging from about forty per cent. upwards.

Immersion in acids previously warmed was then tried, but as the cotton was found to lose weight in proportion to its duration, owing to a slow solution even at 120° , nothing could be learnt from the weighing of the compound; in other respects, however, the result of the experiment with hot acids proved curious and interesting, from the fact that

$\left. \begin{array}{l} \text{HO}, \text{NO}_5 \\ 2 (\text{HO}, \text{SO}_3) \end{array} \right\} 3 \text{ HO}$, which at 60° gave rise to an almost insoluble compound, produced at 130° one perfectly soluble in ether + $\frac{1}{5}$ alcohol: the other acid mixtures, containing more than three equivalents of water, produced soluble compounds, both at 60° and 130° , but their solutions differed remarkably in one respect; for all soluble products formed at ordinary temperatures, when dissolved in the proportion of six grains to the ounce, yield thick glutinous solutions, while all those which are the result of acids at the temperature of 130° , give perfectly fluid ones, which produce, on drying, membranes far exceeding the former in strength and toughness, and much better adapted to photographic or surgical purposes. By far the best mixture for producing collodion-wool is that represented by the formula $\left. \begin{array}{l} \text{HO}, \text{NO}_5 \\ 2 (\text{HO}, \text{SO}_3) \end{array} \right\} + 3.5 \text{ HO}$, which is obtained by mixing eighty parts by weight of nitric acid, specific gravity = 1.424, with one hundred parts by weight of sulphuric acid, specific gravity = 1.833; as—

Sulphuric acid, specific gravity, 1.833,	=	$2 (\text{HO}, \text{SO}_3 + 0.33 \text{ HO})$	=	103.9
Nitric acid, specific gravity, 1.424,	=	$(\text{HO}, \text{NO}_5 + 2.84 \text{ HO})$	=	88.5
$\text{HO}, \text{NO}_5 + 2 (\text{HO}, \text{SO}_3) + 3.5 \text{ HO} = 192.4$				

These specific gravities are especially referred to, from their being those of the acids most frequently met with in commerce. Good collodion-wool is also produced by stronger acids, if there be *not less* water than that required by the formula $\left\{ \begin{array}{l} \text{HO}, \text{NO}_5 \\ 2 (\text{HO}, \text{SO}_3) \end{array} \right\} + 3 \text{ HO}$, and the temperature is raised to 130° ; however, the stronger the acids, the more liable is the collodion-wool to be-

come partially insoluble after drying. If there be less than three additional equivalents of water, the products are equally insoluble whether the acids are employed hot or cold.

Finding that the weighing of the product resulting from the action of warm acids could be of no service in proving the existence of definite compounds, Mr. HARDWICK's suggestion was tried—the effect of reim-

mersing the cotton in a portion of the same cold acid mixture with which it had been previously treated, noting at the same time whether any second increase of weight was obtained. The results were highly satisfactory. For the preparation of the highest compound, a mixture was made of two volumes of the strongest sulphuric and one volume of colorless nitric acid, specific gravity = 1.521.

27.5 grains of cotton, after some hours' immersion, weighed after washing and drying *in vacuo*, 49.88 grains, corresponding to a gain of 81.34 per cent. In this case, it was hardly expected that a second immersion would cause an increase; by experiment it was found to have sustained a slight loss, as it now weighed 49.62, showing that acids have a slight solvent power, even at ordinary temperatures. This increase of 81.34 per cent. in weight does not correspond with any of the analyses hitherto published, although the greatest care was taken to avoid error, on account of the important aid it would afford in deducing a formula for this and other compounds.

Another mixture agreeing with $\left\{ \begin{array}{l} \text{HO, NO}_3 \\ 2 \text{ (HO, SO}_3 \end{array} \right\} + 4 \text{ HO}$, gave at the first immersion an increase of 58.7 per cent.; by a second it was found to have increased to 62.9 per cent., thus fully answering expectations. A third immersion brought it to sixty-four per cent.

On account of the great difference observed between the products of $\left\{ \begin{array}{l} \text{HO, NO}_3 \\ 2 \text{ (HO, SO}_3 \end{array} \right\} + 3 \text{ HO}$, and the same $+ 4 \text{ HO}$, an intermediate mixture was made. The first submersion gave an increase of 67.3 per cent.; a second, 70 per cent.; a third, 71.4 per cent. Hence it was concluded that there were at least three compounds, of which, from one hundred of cotton, there would be obtained quantities approximating to one hundred and sixty-four, one hundred and seventy-two, and one hundred and eighty-two; and it is probable that any acid mixture would produce such a definite compound, were it not diluted at the same time by the water it abstracts, which, when the dilution exceeds a certain point, gives rise to a second compound, the great mass of the liquid probably having but little influence, in consequence of the imperfect diffusion arising from the want of perfect fluidity, and the adhesion to the fibres of the cotton; the washing and *thorough* drying then enable the original acid mixture to raise the second compound to that which would have resulted in the first instance had no dilution occurred. It is evident, also, that the number of immersions required must vary, according as the acid mixture is much within or approaches near to that state of dilution which limits its power of producing a certain compound, a given quantity of water having much more effect in one case than in the other.

In trying the effect of various reagents on gun-cotton, HADOW ascertained that it could be perfectly restored to the original cotton, without loss of form, by means of hydrosulphide of potassium, KS, HS. At Dr. MILLER's suggestion, this was made use of, to effect the analysis of the compounds, and to confirm the previous results. An aqueous solution was first tried,

but found to occasion loss of weight, on account of the long boiling required; an alcoholic solution was, therefore, prepared, by *thoroughly saturating* a strong alcoholic solution of sulphide of potassium and hydrogen, by transmitting the gas until it would absorb no more, and ceased to give a precipitate in sulphate of magnesia. As, however, the reduction was found to proceed easily at ordinary temperatures, it proved better to effect the change by continuing the immersion for twenty-four hours, and thus to avoid the risk of decomposition and loss which prolonged seething occasioned. That the cotton so obtained was free from nitrogen-compounds was proved by strongly heating it with caustic potassa, and conducting the gases evolved into a solution of litmus very faintly reddened, when the color remained unchanged; by the close correspondence in the quantity obtained from gun-cotton with that originally used, or the restoration back to the original weight; and by its possessing all the physical characters of common cotton, which differs from all products obtained from it by the action of acids in its depolarising action on light, and in its far greater softness and compressibility when wet, and also by the action of $\text{HO, SO}_3 + \text{HO}$, which dissolves the nitro-compounds, producing a solution which is not blackened below 212° , while common and reduced cotton are completely carbonised below that temperature.

Two combustions of the reduced cotton were made; one, in which the determination of hydrogen failed in consequence of an accident, gave, in one hundred parts, 44.4 of carbon; another, made by Mr. HARDWICK, yielded—

	Found.	Calculated.
Carbon,.....	44.86	44.44 = 12 C.
Hydrogen,.....	6.64	6.17 = 10 H.
Oxygen,.....	48.50	49.39 = 10 O.
	100.00	100.00

The other products of the equivalents of KS, HS are nitrate of potassa—KO, NO₃—and a little ammonia. No trace of nitrate could be discovered in the solution, which was evaporated to dryness with excess of acetic acid, to expel the nitrous acid. An attempt was made to turn the reaction of KS, HS upon gun-cotton to account in effecting the determination of the nitrogen by this means; but the results were unsatisfactory, in consequence of the co-existence of ammonia and nitrous acid in the liquid. The solution could not be heated to expel the former without risk of loss in the weight of the reduced cotton, neither could the ammonia be retained by addition of an acid, without escape of NO₂, from the action of sulphide of hydrogen and nitrous acid on each other.

A mode altogether different was, therefore, adopted, which consisted in making a solution of the compound in pure sulphuric acid, and, after conversion of the oxides of nitrogen into nitric acid, by means of some oxidating agent, estimating its amount by the method of PELOUZE, depending on its property of converting proto into sesquichloride of iron, and from the amount of the latter calculating the former. Before performing this, the properties of a solution of gun-cotton in sulphuric acid were examined. A portion immersed in cold concentrated sulphuric acid soon dissolves, with-

out evolution of any gas, producing a clear, colorless liquid; if this be poured at once into five or six times its bulk of water, so that the temperature does not rise before dilution takes place, the clear menstruum obtained gives no evidence whatever of nitric acid, or any oxide of nitrogen, even though raised subsequently to the boiling point; neither does it discolor a solution of permanganate or chromate of potassa. If, however, the original liquid in concentrated acid be diluted with only once, or even twice its bulk of water, a violent effervescence ensues, with abundant evolution of nitrous acid— NO_2 —or peroxide of nitrogen— NO_4 —together with carbonic acid. If, again, the solution in strong acid be heated before dilution, carbonic acid is evolved, while the oxides of nitrogen are retained, provided that the sulphuric acid is in different excess; if it now be diluted with water, nitric oxide— NO —escapes with effervescence. It became necessary, therefore, to effect the complete conversion of the nitrogen oxides into nitric acid. After trial of various oxidising agents, the object was successfully attained by the bichromate of potassa, which immediately peroxidises NO_2 and NO , but is without action on NO_4 : hence it was necessary to use a solution of gun-cotton in pure sulphuric acid made *in the cold*, which was then added to a strong solution of bichromate contained in a retort; the mixture—which immediately acquired a dark-green tint, from reduction of the chromic acid—was carefully distilled, precaution being taken to insure the entire expulsion of the nitric acid, which was then estimated, as above stated, by PELOUZE'S method.

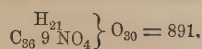
The quantity of cotton in a given sample of gun-cotton having been determined by reduction by KS , HS , and the nitrogen by the above method, it is easy to see whether the compound contains any equivalents of NO_5 , not displacing a like number of equivalents of HO . The following results of analysis leave no doubt that it is purely a substitution-compound:—

Compound A.—Produced by action of the strongest acids, and most probably by repeated immersion in any mixture not weaker than $\frac{\text{HO, NO}_5}{2(\text{HO, SO}_3)} + 3\text{HO}$. Quite insoluble in any mixture of ether and alcohol, but soluble in acetic ether. Highly explosive.

- I. 27.5 of pure cotton gave, by three hours' immersion in strongest acid, 49.88 first time; 49.6 second time.
- II. 6.85 of this gun-cotton gave, by reduction, 3.78 of cotton.
- III. 6.37 of gun-cotton, by reduction, gave 3.48 of cotton.
- IV. 20.50 of gun-cotton gave $\text{NO}_5 = 10.84$.

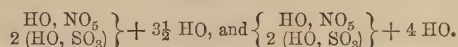
	By analysis.			By calculation. $\text{C}_{36}\text{H}_{21}\text{O}_{30.9}\text{NO}_4$
	I.	II.	III.	
Cotton found,...	55.13	54.6	55.19	54.54
$\text{NO}_4 - \text{H}$,.....	—	—	44.07	45.46
			99.26	100.00

The composition of cotton being fully determined by the analyses of MITSCHERLICH, PELOUZE, and PAYEN, to be in the proportion of $\text{C}_{12}\text{H}_{10}\text{O}_{10}$, the preceding analysis would give rise to the formula,



100 of cotton produced 181.34: by calculation, 183.3.

Compound B.—Produced most probably by any acids of composition intermediate between



That which was examined was obtained by several immersions in $\frac{\text{HO, NO}_5}{2(\text{HO, SO}_3)} + 3\frac{1}{2}\text{HO}$. It is explosive, yet perfectly soluble in ether + $\frac{1}{8}$ alcohol; quite insoluble in acetic acid.

- I. 27.6 grains of cotton gave, by first immersion in the above mixture, 46.2 grains; by the second immersion, 47.1; by the third, 47.31.
- II. By reduction, 6.08 grains of the compound gave 3.50 of cotton.

	From synthesis. I.	By analysis. II.	Calculated. $\text{C}_{36}\text{H}_{22}\text{O}_{30.8}\text{NO}_4$
Cotton found,.....	58.34	57.56	57.45
$\text{NO}_4 - \text{H}$,.....	—	not determined.	42.55
			100.00

Formula would be $\frac{\text{H}_{22}}{\text{C}_{36}\text{O}_8\text{NO}_4} \text{O}_{30} = 846$.

100 of cotton produced 171.4; by calculation, 174.

Compound C.—Produced by $\frac{\text{HO, NO}_5}{2(\text{HO, SO}_3)} + 4\text{HO}$.

Like the preceding, this compound is very soluble in ether, but differs from it in being likewise perfectly soluble in *glacial acetic acid*. In this, as in the former compounds, the cotton fibre is quite uninjured. It is highly combustible rather than explosive, and burns with a slow jet of flame when rammed into a tube and ignited.

- I. 24.1 grains of cotton weighed, after first immersion, 38.26; after second immersion, 39.26; after third immersion, 39.53.
- II. By reduction, 9.94 grains of the compound gave 6.00 of cotton.

	By synthesis. I.	By analysis. II.	By calculation. $\text{C}_{36}\text{H}_{23}\text{O}_{30.7}\text{NO}_4$
Cotton found,.....	60.96	60.36	60.67
$\text{NO}_4 - \text{H}$,.....	—	not determined.	39.33
			100.00

Formula, $\frac{\text{H}_{23}}{\text{C}_{36}\text{O}_7\text{NO}_4} \text{O}_3 = 801$.

100 of cotton produced 164.0: by calculation, 164.8.

Compound D.—The existence, composition, and identity of this compound with xyloidin, are inferred from the following reasons:—

1st. There is a compound lower than C, since $\frac{\text{HO, NO}_5}{2(\text{HO, SO}_3)} + 4\text{HO}$ produces, by one immersion, an increase of only fifty-nine per cent., yet this product is perfectly soluble; if, however, C were the last, all products not attaining sixty-four per cent. in their amount of increase would contain unchanged cotton, and would be only partially soluble.

2nd. The product of the action of $\frac{\text{HO, NO}_5}{2(\text{HO, SO}_3)} + 5\text{HO}$, in which the texture of the cotton is more or less destroyed, is only partially soluble in ether—cotton, apparently unchanged, remaining behind; it thus appears that the soluble portion is the lowest compound obtainable by the actions of mixed acids on cotton.

3rd. As the next number in the series, its composition would be $C_{36} \left\{ \begin{smallmatrix} H_{24} \\ 6 NO_4 \end{smallmatrix} \right\} O_{30}$, which exactly corresponds with that assigned to xyloidin; and one hundred of cotton should yield 155.5. The soluble portion of these products further corresponds with xyloidin in giving an *opaque* film on drying, and in its solubility in glacial acetic acid. Although the xyloidins of woody fibre and starch agree in composition, they may be distinguished by the action of KS, HS, which reduces each to its proximate constituents, when the usual reaction with iodine may be obtained in the one case, but not in the other.

The modifications produced by the action of hot acids have not yet been examined; there is in these cases greater difficulty of avoiding loss in washing, in consequence of their disintegrated state, if immersed sufficiently long to obtain definite compounds. It is evident, however, that there are at least two, produced respectively by $\left\{ \begin{smallmatrix} HO, NO_5 \\ 2 (HO, SO_3) \end{smallmatrix} \right\} + 3 HO$, and $+ 4 HO$, since the former becomes insoluble after drying, while the latter remains soluble. All the compounds soluble in ether give transparent films on drying, except D. The presence of this last-named compound is one of the causes of opacity on the drying of some collodions; the other causes are, water in the alcohol or ether, or the presence of acetic ether. All these compounds may be prepared with mixtures containing much larger proportions of sulphuric acid and water; but these have the disadvantage of rapidly dissolving the compounds if used warm.

While endeavoring to ascertain the state in which nitrogen exists in these compounds, HADOW was led to examine the action of caustic potassa on the highest compound, with which, as is well known, it produces a solution capable of reducing salts of silver to a mirror-like surface upon the vessel that contains them. The decomposition of gun-cotton by a solution of potassa takes place slowly at ordinary temperatures, but almost instantly on raising it to 160°. Each portion then immersed causes a considerable extrication of heat, by which the temperature is soon raised to the boiling point, and ammonia is evolved with effervescence. In making the solution for examination, the temperature was kept at 150°, to avoid the formation of secondary products. At this point the gun-cotton quietly disappears without effervescence, producing at last a dark viscid fluid. This was diluted, neutralized with acetic acid, and precipitated by neutral acetate of lead. The filtrate gave a further abundant precipitate with the basic acetate, from which it was at first concluded that there were two distinct acids present; this, however, was afterwards found to arise from the solubility of the plumbous deposit in the acetate of potassa that had been formed, from which solution the basic acetate again throws it down. The liquid filtered from both precipitates contained nitrite and nitrate of potassa. The lead precipitates, after thorough washing on a linen filter, were diffused through water, and decomposed by sulphide of hydrogen, during which process effervescence occurred, with escape of NO_2 , showing that, notwithstanding the washings the deposits had

undergone, they still retained a portion of nitrate. The brownish solution obtained was again precipitated by acetate of lead, washed, and decomposed as before, when a pale yellow, strongly-acid liquid was obtained, retaining the original reducing power upon the salts of silver unimpaired, and capable of rapidly decomposing carbonates with effervescence. Its power of forming crystalline salts was examined by slowly evaporating a solution of the compound on a slip of glass, and viewing it under a microscope. The ammonia-salt appearing to be the most promising, the liquid was neutralized with ammonia, and allowed to evaporate *in vacuo*. After some time, little tufts of prismatic crystals formed. On examination, however, these were found to be devoid of reducing power, and proved to be oxalate of ammonia. That the oxalic acid had not been formed by the subsequent processes was proved by detecting it in the original solution of gun-cotton in cold aqueous potassa. The liquid, freed from oxalic acid by nitrate of lime, was found to possess many of the characteristics of saccharic acid, such as its property of carrying down nitrites with its lead salts, and its reducing power on salts of silver, which is manifested in both cases on adding to the respective menstrua a portion of a solution of nitrate of silver, ammonia sufficient to cause a clear liquid, and subsequently caustic potassa, without which in either case no mirror-like deposit will take place even on boiling. In certain proportions the color of the reduced silver is identical. Like the neutral saccharates, the neutral salts of this acid, which might be termed pyroxylic acid until its identity with some other is proved, likewise give precipitates with salts of lime, baryta, and cadmium. The principal differences between the two acids are, that no crystalline acid pyroxalate of potassa could be obtained, the solution drying *in vacuo* to a gummy mass, whereas the acid saccharate is very easily crystallised; and that the saccharates of the above-mentioned bases are far more soluble in the heat than in the cold, and are visibly crystalline under the microscope; while the pyroxalates of lime and baryta are but slightly soluble on warming the liquid, and that of cadmium does not redissolve at all on the mere application of heat, though, like the saccharate, it is readily soluble in an excess of the salt of cadmium. The precipitates are likewise all amorphous, with the exception of the lime salt, which has the form of little nodules. HADOW could not further examine the properties of this acid, or obtain a compound with the certainty of its being sufficiently pure for analysis, in consequence of the want of crystalline form and the obstinacy with which a portion of coloring matter is retained.—*Hadow*.

COLLODION.—This substance, which is formed by dissolving gun-cotton in spirit, has of late years been extensively employed in the manner subsequently stated, under the uses of gun-cotton. The following are the best proportions for making it:—

	Parts by weight.
Prepared cotton,	8
Rectified ether,	125
Rectified alcohol,	8

Put the cotton with the ether into a well-stopped

bottle, and agitate the mixture for some minutes. Then add the alcohol by degrees, and continue to shake until the whole of the liquid acquires a sirupy consistence. It may be then passed through a cloth, the residue strongly pressed, and the liquid kept in a well-secured bottle.

Collodion thus prepared possesses remarkably adhesive properties. A piece of linen or cotton cloth covered with it, and made to adhere by evaporation to the palm of the hand, will support, after a few minutes, without yielding, a weight of from twenty to thirty pounds. Its adhesive power is so great, that the cloth will commonly be torn before it gives way. The collodion cannot be regarded as a perfect solution of the cotton. It contains, suspending and floating in it, a quantity of the vegetal fibre which has escaped the solvent action of the ether. The liquid portion may be separated from these fibres by a filter, but it is doubtful whether this is an advantage. In the evaporation of the liquid, these undissolved fibres, by felting with each other, appear to give a greater degree of tenacity and resistance to the exsiccated mass.

In the preparation of collodion it is indispensable to avoid the presence of *water*, as this renders it less adhesive; hence the ether, as well as the alcohol, should be pure and rectified. The parts to which the collodion is applied should be first thoroughly *dried*, and no water allowed to come in contact with them until all the ether is evaporated.

A method for the preparation of elastic collodion is given by LAURAS. He prefaces it as follows:—

The important improvement to be made in this compound, which hitherto has not been of very frequent application in therapeutics, consists in giving efficacy to it, and in preventing the sufferings produced by its application on any portion of the body, and principally on the articulations, which are much constricted after having been covered with it—an effect due to its want of suppleness and elasticity, and which the skin requires both for stretching and contracting.

By adopting the following formula, every inconvenience is obviated, collodion becomes easy of employment, and enables the patient to move without suffering pain:—

Sulphuric acid, of specific gravity 1.847, three hundred grammes; dry nitrate of potassa, two hundred grammes. These are both mixed together in a stone-ware or porcelain pot, and ten grammes of carded cotton added.

Leave in contact for twelve minutes; withdraw the cotton, wash it with cold water to remove the acid which it retains, and after two or three rinsings, immerse it in water containing thirty grammes of carbonate of potassa in solution in one hundred grammes of water; plunge it again into ordinary water, agitate well, and dry at a temperature of 77° to 86°.

The cotton thus prepared takes the name of Xyloidin, and may afterwards be mixed with the ether and the other substances which form it into elastic collodion.

Elastic Collodion.—Xyloidin eight grammes, ordinary ether one hundred and twenty-five grammes. Place in a wide-mouthed flask, and add alcohol of specific gravity .825 eight grammes. Agitate, and then make

a mixture composed of Venice turpentine two grammes; castor oil two grammes; white wax two grammes; ether six grammes. Heat together the first three substances, add the ether, and combine the two mixtures.

ADULTERATION.—Should it be desired to ascertain whether ordinary carded cotton has not been added to sophisticate the gun-cotton, it may be arrived at by the following micro-chemical process. A small portion of the cotton is impregnated with a solution of iodine, and a drop of sulphuric acid added, and then submitted to the lens; the gun-cotton is very feebly affected by this treatment, and retains the yellow coloration communicated by the iodine only slightly intensified after some time, whilst under the same treatment the fibres of ordinary cotton would quickly disintegrate, and partake of a lively violet hue. The intensity of the latter will be a comparative indication of the probable amount of the adulterants.

USES.—Many attempts have been made to apply gun-cotton to mining purposes on account of its enormous explosive force, and the small quantity of smoke which it produces; but the objections to its use are numerous, the most fatal one being its liability to spontaneous ignition.

Gun-cotton continues to be an object of great interest on account of its application to the beautiful art of photography. When the cotton is prepared in such a way as to burn slowly, it is not liable to spontaneous ignition, and it is in this state perfectly soluble in ether, which the more explosive cotton is not. If the ethereal solution be poured on the surface of cold water, a paper is produced, which is prepared for the use of the photographer. This paper is a very active electric, and is perfectly soluble in ether. Collodion has also been made use of in surgery, by applying the ethereal solution to a wound, when a thin delicate artificial skin is formed by it, which perfectly excludes the air.—*Encyclopædia Britannica*.

GUNPOWDER.—*Poudre à canon*, French; *Schiesspulver*, German.—The article which bears this title is a singular mixture of nitrate of potassa—saltpetre—sulphur, and charcoal, and is so well known for its remarkable properties by every one, that it is unnecessary to enter into a detailed exposition of it. Regarding its manufacture and the uses to which it is devoted, however, in a true light, its importance as an agent of power, which places it side by side with steam at the present day, cannot fail to render it an object of deep research and inquiry.

It might well be said that no other branch of industry has, during many years, decided the destinies of people so much as gunpowder. Sometimes favorable to the progress of civilization, powder offers to the miner and engineer a ready and sure means of breaking all obstacles which intercept their progress in their labors; sometimes, on occasions of festivity, it becomes in the hands of the artificer a symbol of joyful public rejoicings; and, finally, on occasions of civil strife and warfare, it turns out to be a sure instrument of death and massacre—spreading the devastating bullet or shell with an effect which lays nations of greatness and pomp level with the dust, and raises others to the dignity of empires.

The invention of gunpowder formed a grand epoch in the world's history. TOMLINSON ascribes it to BARTHOLO SCHWARTZ, a German monk and alchemist, and the date of the discovery is supposed to be about the year 1320. The prior claims of ROGER BACON, whatever they be, are, however, unquestionable, as this substance is described in his writings about the year 1270, or half a century before the supposed discovery by SCHWARTZ. But even BACON himself has as little title to the invention as his imagined rival; nor, indeed, when his own description of this then wonderful compound is examined, can it be perceived that he makes any claim to be the discoverer. On the contrary, he quotes it as a well-known substance in common use all over the world, for making squibs for the amusement of children—so pertinacious are vulgar errors. DUTENS attempts to show that the claim, which certainly does not belong to BACON, is removed to MAGNUS GRÆCUS, whose manuscript he quotes, and from which he presumes BACON derives his knowledge of the invention; although, by his own showing, BACON need not have consulted an obscure writing for an invention of general notoriety. In the same manuscript are contained directions for making a rocket, which are such as to prove that the nature of this firework was thoroughly understood. It is even remarkable that he recommends the charcoal of willow wood, which the moderns have found by experience to be amongst the best for such purposes.

Thus far the date of the origin of gunpowder has been traced, not only beyond BACON, but beyond this supposed predecessor, as he himself professes to be a compiler, not an author of the *Liber Ignium*, as he denominates his treatise. If, in attempting to ascend still higher, the evidence becomes more rare and illegible, there are still insuperable facts to prove that its antiquity is far greater, however impossible it may be to approximate to the date of the invention, much less to assign that which appears to be buried amongst the obscurities of oriental learning. The question of gunpowder as applied to artillery is a separate one; but there is abundant reason to believe that this compound was not only used in some form or other as an explosive and combustible substance, but that it was applied even to military purposes—it may be, in the shape of rockets or other fireworks, which, for objects of amusement at least, have been familiar to the Chinese beyond all record.

The earliest date to which the knowledge of gunpowder can be referred, in defect of a sufficiently remote acquaintance with oriental history, is 355 before Christ, although, from the very nature of this attestation, it follows that it was then not only known to the Eastern nations, but that it must have long been so, since, even at that early period, it was applied to warlike purposes. In the code of Hindoo laws, indeed, where it is mentioned, it is referred to an era which oriental antiquaries have considered as coincident with the time of MOSES. But the evidence to which more particular allusion is made, is found in a passage of the *Life of Apollonius Tyanæus* by PHILOSTRATUS, the purport of which is that ALEXANDER was unwilling to attack the Oxydracæ, who lived between the Hyphasis and the Ganges, be-

cause they were under the care of the gods, and overthrew their enemies with thunder and lightning which they shot from their walls. The same account is given of the repulses experienced in this country by HERCULES and BACCHUS.

The next of these early dates, in which also the evidence is imperfect, is 212 before Christ; but the establishment of the proof of the last would render this one more credible. In the defence of Syracuse by ARCHIMEDES, VITRUVIUS relates that one of his engines threw stones with a great noise—a description which does not apply to any of the mechanical artillery of the ancients. On a notice so superficial, however, much stress must not be laid, and here ends all the information respecting the earliest knowledge of gunpowder. It seems, however, so decidedly capable of being traced from the East, through the intervention of the Arabs, that there can be little doubt of its oriental origin, and of its being thence imported into Europe. Indeed, the military use of rockets in the armies of India ascends to a very remote period.

Of the earliest date at which it was known in China, their own evidence is defective; but UFFANO, an Italian author, affirms that not only gunpowder, but ordnance, was in use in that nation in the year 85, and that in his day cannon were remaining from the most ancient times in some of the maritime provinces, made both of iron and of brass. Hence some writers presume that the Chinese communicated the invention to the Indians; whilst it has also been said, but on no sufficient authority, that they themselves received it from Tartary—a nation respecting which little or nothing is known and in which one would not be inclined to look for an early acquaintance with the arts. This, however, refers to a date so late as 917; so that, if there is any dependence to be placed on the Indian and Chinese hypothesis, the Tartars must themselves have borrowed the invention from those to whom they are said to have lent it.

There is after this a long blank; and the first author on the subject is an Arabic writer, in the Escorial collection, whose work, bearing date 1249—about twenty years before the date of BACON's narrative—is translated by CASIRI. His description is such that it may apply both to rockets and to shells. In the former case, it only involves the knowledge of the detonating compound; the latter, were it proved, would show that they were also acquainted with the use of ordnance, although it is not impossible but that such projectiles might have been thrown by mechanical artillery.

As the invention of gunpowder has been popularly ascribed to BACON and to SCHWARTZ, so the use of ordnance has been referred to the time of the battle of Cressy—1346. To pass over the Chinese hypothesis on this part of the subject, it will be found that cannon were known at least as early as the year 1312. This is derived from the source quoted by CASIRI; from Arabian writers who in 1312 and 1323 describe the use of ordnance; whilst, if BARBOUR is to be trusted, EDWARD III. was also provided with some pieces of artillery in 1327, and Père DANIEL asserts that cannon were known to the French in 1338. This discussion need not be carried lower; though, in favor

of the oriental origin of the invention, it may be remarked, that artillery was much in use in the Mediterranean when it was still but little used elsewhere; as by the Venetians in 1380 against Genoa, and by ALPHONSO XI. in his wars with the Moors.—*Encyclopædia Britannica*.

In the prolegomena it was stated that gunpowder is a composition of definite quantities of sulphur, saltpetre, and charcoal. From time to time various experiments have been conducted with considerable care for the sake of determining the most convenient proportions of the foregoing substances; and, singularly enough, people have, in almost every instance, fallen back upon the recipes given by the most ancient writers upon the production of this article. The knowledge that powder owes its extraordinary effects to the sudden transformation of its solid constituents into permanent gases, the volume of which is enlarged by the temperature resulting from the chemical action producing this change, will at once lead to the conclusion, that all matters incapable of undergoing such a modification injure or depreciate, in proportion to their quantity, the quality and efficacy of the product. Hence it should always be the desire of the manufacturer to use the purest materials; and, to assist him in his business, they will be considered here.

MATERIALS.—The greatest care is requisite in the preparation of pure ingredients for the manufacture of gunpowder.

The principal saline impurity in saltpetre is chloride of sodium—common salt—which has a very injurious action upon gunpowder, causing it to absorb moisture, whereby its power is soon considerably weakened. Saltpetre containing more than a three-thousandth part of chlorides, is rejected as unfit for use.

The solubility of saltpetre at 212° is about fourteen times greater than it is at ordinary temperatures, while that of chloride of potassium is only about twice as great, and that of chloride of sodium is but slightly increased. If, therefore, a solution containing these three salts be concentrated, the greater quantities of the chlorides will be deposited as the water decreases, even before the nitrate of potassa exhibits any symptom of crystallizing out. This separation is effected in practice, by placing a perforated iron ladle or dish on the bottom of the boiler in which the solution is being concentrated. The chlorides, as they separate by the evaporation of the water, deposit upon the dish, and may from time to time be removed. When small needles of nitrate of potassa begin to appear, the menstruum is run off into the crystallizing cooler, from which tolerably pure saltpetre will be obtained, to be refined by a similar operation.

At Waltham Abbey the refining of saltpetre is effected by first decolorizing its solution by ebullition with newly-burnt charcoal, and then by repeated crystallization. Great care must be exercised in this process, which will be fully dwelt upon under POTASSA.

Sulphur, as employed for the manufacture of gunpowder, is generally in the sublimed state, or that known in common parlance as *flowers of sulphur*. These are obtained by conducting the vapor of sulphur into large chambers, the sides of which must

be kept cool. The sulphur condenses in the form of a fine crystalline lemon-yellow powder. When the sides of the chamber become heated, the sulphur fuses, becomes limpid, and trickles down to the base of the chamber. To prevent this, which, of course, would spoil the whole deposit of flowers, as soon as the walls of the chamber get too warm, the communication between the latter and the retort is closed, and another one opened, leading into a metal receiver; the sulphur is allowed to distil over into this until the first chamber has become sufficiently cool, and the flowers have been collected from its sides, when the vapors are again passed into it.

The sublimed sulphur sometimes requires washing, in order to free it from the sulphuric acid which is generally formed with it, and which is caused by the oxidation of the sulphurous vapors by means of the common air which pervades the condensing chamber previous to the commencement of the distillation of each charge.

It has been suggested that the sulphuric acid should be removed by allowing the sulphur to remain between damp cloths for some time previous to use.

Charcoal.—The third principal constituent of gunpowder is charcoal reduced to an impalpable state. This constituent demands no less attention in the selection than the other components; for much of the efficiency of the powder depends upon its possessing such qualities as experience has shown to be required. Even in the time of MAGNUS GRÆCUS, as already mentioned in the preceding historical notice, the charcoal of willow-wood was preferred, and experience has fully proved that the charcoal of the soft woods always produces the best results. Some time since, dogwood was adopted, as giving the most friable charcoal; but it has since been shown that the woods of the willow, poplar, black alder, and chestnut trees afford equally suitable products. The hard woods are invariably rejected, and with justice; though the presence in them of deleterious salts is not the only objection to their use.

Two considerations must not be overlooked in choosing a proper charcoal—namely, the nature of the wood, and the manner in which the carbonization of the same is conducted; and each demands the utmost circumspection in the manufacturer who is desirous of producing an article which will yield the greatest possible amount of force, and combine at the same time the quality of inflaming readily, as well as that of leaving the least quantity of residuary matter after its ignition.

There is no doubt, says the writer of the article GUNPOWDER in the *Encyclopædia Britannica*, that wood which contains carbonate of potassa or other deliquescent salts, is unfit for the purpose, and for obvious causes. This is the case in the oak, elm, fir, and other trees. But there is another reason for the badness of these kinds of charcoal, which is not so obvious, although it is evidently connected with their hardness. It appears to depend on the small proportion of hydrogen combined with the carbon in these charcoals, compared to that which exists in the produce of the softer woods. Even these can be reduced to the same state by subjecting them to higher temperatures. Thus the hydrogen is dissipated, the charcoal becoming

so hard as to scratch steel; in which case, however obtained, it is unfit for gunpowder.

Thus experience has found, from time to time, how ill-adapted for this manufacture are many of the charcoals usually prepared; but such acquisitions were frequently gained at the expense of a loss sustained by the failure of some experiment. In later times, however, scientific research clears the path for the manufacturer to some extent, so that he who desires to progress has not to confide in the results of haphazard experiments, the principles of which may be but ill understood, but rather decide according to the conclusions drawn from the well-contrived investigation on the subject. PROUST is one of those who has made the materials and preparation of gunpowder his study, and from them considerable information may be gained. With the view of finding the best quality of charcoal, he practised the following ready and simple means. He makes a mixture of twelve grains of the charcoal and sixty-two of nitrate of potassa by careful grinding in a mortar, and then introduces it on a small tray into a copper tube two and a half inches in length by three lines in diameter; he primes on the top of this with a little fowling powder, and when this is done, the lower part of the tube is fitted in a dish of cork, or other light material, which is floated on the surface of water. It is evident from these arrangements, analogous as they are to those under which the powder is inflamed, that the mixture which burns the more readily is that which is most suited to the manufacture. By experiments conducted in this way, and with all the precautions available under the circumstances, PROUST obtained the following results:—

Mixture of sixty-two grains of saltpetre and twelve of charcoal.	Time of the combustion in seconds.	Weight of residue in grains.
From hemp or hemp husk, . . .	10	12
“ stalks of asphodel,	10	12
“ vine branches,	12	20
“ pea stalks,	13	21
“ pine,	17	30
“ bourdaine,	20	24
“ spindle-tree,	21	27
“ hazle,	23	30
“ maize canes,	25	38
“ chestnut-tree,	26	36
“ walnut-tree,	29	33
“ maize,	55	43
“ coal-coke,	50	45
“ sugar,	70	48

When submitted to the same operation, he found that the charcoal produced from starch, wheat, rice, gall-nuts, indigo, gluten, gelatin, albumen, blood, and skin, and, in fact, those derived from all animal matters, would not undergo combustion.

From the foregoing table it is evident that those which precede the charcoal from hazlewood rise in the scale of superior fitness, whilst those beneath the latter evidently descend, and are not well adapted for the manufacture.

Other experiments upon the same subject, founding the comparison of the different charcoals upon the volume of gas which they yielded when ignited with saltpetre, have been conducted by French and British chemists, and the results are tabulated below. In each case the proportions used by the former were sixty grains of nitrate of potassa to twelve of charcoal; but

in the latter the calculations are made to correspond with the same standard:—

Charcoal.	Proportion of gas in cubic inches.	Residue in grains.
From French hemp stalks, . . .	62	12
“ asphodel,	62	20
“ vine,	64	20
“ pea stalks,	62	21
“ spindle-tree,	66	28
“ fir,	66	30
“ chestnut,	66	36
“ hazle,	66	33
“ lamp-black,	54	44
“ coke,	54	45
“ filbert,	72	30

Much of the interest which might otherwise be taken in the foregoing results of the French chemists is lost, on account of the subjects being not likely ever to enter practically, at least to any extent, into the manufacture under consideration. Below are given results arrived at in England, by operating upon the more frequently-occurring woods:—

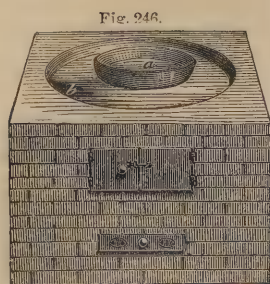
	Proportion of gas
Filbert,	72
Oak,	61-63
Mahogany,	58
Elm,	62
Willow— <i>Salix Alba</i> ,	76-78
Alder,	74-73
Dogwood— <i>Rhamnus frangula</i> , . . .	80-82-84
Oak bark,	58
Animal charcoal,	50-46-42-40
Coke,	52-48
Lamp-black,	54-52
Oak charcoal overheated,	54-56
Willow “ “	59 64-66

TOMLINSON attributes much of the difference in the latter table to the method in which the charcoal is prepared, rather than to the substance itself, since he considers that to overheat the matter in its carbonization is injurious to its power of combustion. This is evidenced by the results which the modified charcoal from oak and willow afforded; and, in fact, several researches have led to the acknowledgment of the same fact. VIOLETTE has shown that the most combustible charcoal loses this quality in proportion as the heat applied in the carbonization is raised, till ultimately, when the charring is made at the fusing point of platinum, the product obtained is so incombustible as to be ignited with difficulty even when the heat is 2282°. During his researches upon the carbonization of wood and the application of charcoal, he examined with considerable skill and acuteness the various products which most of the ordinary woods afford by charring, in reference to their combustibility in air, and the temperature of their ignition according to the caloric applied in their manufacture, and also with regard to the same kind of charcoal when subjected to an increasing heat in close vessels; the temperature at which charcoals decompose nitrate of potassa, as well when they are the result of a standard degree of heat, as when this degree has been varied in their manufacture. To these researches he has coupled the estimation of the necessary caloric required for sulphur to decompose the saltpetre, and that at which it burns in air, and many others; such as the thermometric degree at which powder is ignited, the several mixtures used for the manufacture of powder with regard to the amount of their constituents, *et*

cetera, to which reference will be made in their respective places. As the susceptibility of charcoal taking fire is a subject which, to those who are under the necessity

of storing it for some time in magazines, is highly interesting, it may be well to lay before the reader the procedure of VIOLETTE, for the estimation of the degree of heat at which charcoals enter spontaneously into combustion.

He adopted an apparatus similar to Fig. 246, in which A is a small flat plate-iron basin, floating upon a bath of tin or pewter, B, which is heated by a fire



at C. The pieces of charcoal, prepared in pellets 0.01 inches in length and 0.001 in thickness, were placed symmetrically in the basin, A, and the fire urged, thus increasing the heat of the tin bath, and, consequently, that of the small iron basin containing the cylinders of charcoal. The order of their inflammability was noted as each, in succession, gave indications of combustion by a luminous point appearing upon the circumference of the superior section, and which quickly enveloped the whole surface, and resulted in leaving only the ash. In the following table, the series in the column A show the order of the spontaneous ignition of the materials which had been thoroughly charred, whilst those in B represent the order with reference to brown charcoals, or such as retained a portion of their constituents, and, therefore, had only been but imperfectly made:—

SERIES A.

The order of the ignition of charcoal.	Temperature of the carbonization of charcoal.	
1	500°	500°
2	270°	518
3	280	536
4	290	554
7	300	572
9	310	590
10	320	608
11	330	626
12	340	644
13	350	662
21	432	819
22	1023	1873.6
23	1300	2372
24	1500	2732

SERIES B.

The order of the ignition of charcoal.	Temperature of the carbonization of charcoal.	
"	"	"
5	250°	482°
6	230	446
8	240	464
14	220	428
15	210	410
16	190	374
17	170	338
18	200	392
19	180	356
20	160	320

From the above, it may be inferred that charcoal, prepared at 500°, is the most liable to undergo spontaneous combustion. It is remarkable that the phenomena observed with regard to the brown or torrefied woods in the second column, before their entering into ignition of complete carbonization, was effected first, as indicated by the quantities of fumes which were disengaged from them; *id est*, they were converted into a charcoal such as that prepared at 500°. As soon as this condition was attained, they underwent spontaneous ignition. In the second place, it is easy to see that the inflammability of the charcoals decreases in proportion as the temperature of their preparation is more elevated. To make the examination more definite than the comparative but necessarily indeterminate one above mentioned, the following process was followed:—A porcelain crucible was selected, and about sixty grammes of saltpetre fused in it. The bulb of a mercurial thermometer immersed in it, showed that the melting occurred at 644°. Gradually pieces of the most inflammable charcoal, such as those prepared at 500°, were projected into the molten mass, and the crucible quickly inclosed to prevent cooling by radiation; on taking the cover off, the particles of charcoal were observed to be undergoing several commotions, but without taking fire, notwithstanding that, by increasing the heat only 1.8°, the matter burned. Hence it may be stated, that charcoal obtained at 500° ignites spontaneously at 645.8° or 646°. On increasing the temperature of the crucible and nitrate of potassa by

regular increments of heat, it was found that charcoals prepared at temperatures from—

500° to 536°	ignited at 680°
536 to 662	" 698

On raising the heat a little above 698°, the charcoal resulting at 819° ignited, but the other kinds, produced at a higher heat, refused to burn. As the thermometer ceased to indicate truly any higher heat, the bath had to be changed for one of pewter or tin. Having introduced the more incombustible charcoals, then gently raised the temperature with a charcoal fire till near the point of redness, they began to show the first signs of combustion.

In the annexed table the results are tabulated:—

The temperature at which charcoal has been carbonized.		The temperature at which the charcoals have taken fire.
260° = 500°	340° — 680°
270 = 518	}	340 to 360 — 680 to 698
280 = 536		
290 = 554		
300 — 572		
310 — 590	}	360 to 370 — 698 to 716
320 — 608		
330 — 626		
340 — 644		
350 — 662	}	600 to 800 — 112 to 1472
432 — 819		
1023 — 1873.6		
1250 — 2282		
1300 — 2372	}	1250 — 2280
1500 — 2732		
Charcoals made at temperatures which fuse platinum.....		

The foregoing determinations possess a peculiar interest for the powder manufacturer, especially when it is understood that frequently charcoal, produced at temperatures between 500° and 662°, are employed for the purposes of sporting powder; the black kinds obtained at a higher heat, such as 819° or so, being reserved for the article in demand for the military and mining requirements. Now, since the first kind ignites spontaneously at 680°, the origin of the various explosions happening in powder mills may be easily traced. The increase of temperature by friction during the grinding, more especially when this is done by metallic bodies, often reaches the preceding degree, and, consequently, supplies the necessary conditions for inducing combustion in the mass; again, when placed in the state of fine powder in the recipients, it condenses so much air in its pores that the heat, which is a well-known result of such a condensation, is sometimes elevated to the above standard. Probably the compression referred to is not made without a chemical combination of a part of the oxygen with the hydrocarbon in the charcoal, and such slow combustion, gathering greater force as it progresses, may be in the end sufficiently active to ignite the whole mass.

VIOLETTE further examined several varieties of charcoal, all of which were prepared at 572° by both the foregoing methods; they inflamed between 680° and 716°, but in no case did they take fire at a lower heat than 680°. He observed that the charcoals from light woods generally ignited a little before the product from the harder kinds, with the exception of one, which is remarkable, namely, the charred product of the fungoid excrescence of the willow tree (*agaric de saule*). The latter was observed to take fire in one instance at a temperature so low as 572°, and in every experiment at 608°. Hence it is the most inflammable of all species of charcoal; and, as the above-named investigator remarks, had it been prepared at 500° instead of at 572°, doubtless its spontaneous combustion would take place at a lower temperature than even that given. It may well be inquired to what may this peculiarity be attributed? and, doubtless, as VIOLETTE suggests, the organic molecular state of the substance might exercise some influence whereby its rapid ignition is induced.

To sum up these results, it will be seen—

1. That the most inflammable of all wood charcoals (*agaric de saule*) takes place at 572°.
2. That the charcoals from different kinds of wood, when prepared at a constant heat of 572°, spontaneously ignite between 698° and 734°, according to the nature of the wood producing them; but that the product from the lighter burns quicker than that of the denser woods.
3. That charcoals from the same wood, only prepared at increasing temperatures, spontaneously undergo combustion at very unequal degrees of heat, as shown in the table, page 50, *ante*.

After attentively considering these results, very little doubt will remain as to the best means of carbonizing the wood. To a certainty the temperature of the charcoal, as prepared by most of the methods indicated under the charring of wood, vol. ii., *et seq.*, and also under ACETIC ACID, exceeds the limits laid down by

VIOLETTE; and, therefore, it follows that the combustion of a powder made by such materials will require a greater amount of caloric to induce its decomposition than if the charring heat was less. Where the process by superheated steam or gases is not adopted, evidently the choice should be decided in favor of that method which furnishes the charcoal at the lowest degree of heat. There are three methods in ordinary use by which the charcoal for the powder manufacturer is prepared, namely, the pit, the furnace, and the closed retort. When pits are selected, they are made smaller than those described in the foregoing articles, and the walls and sides, together with the apertures for the introduction of air, are constructed with more care; the wood is also arranged in them with greater caution, and the combustion watched so that, during the operation, the whole may be completely acted upon, and no half-burned material left. In the general particulars, however, no difference exists between the methods already alluded to and this, so that it will be needless to repeat the description. The product amounts to sixteen or seventeen per cent. of the wood. If the carbonization is effected in furnaces, the quantity of the product will not be so large; besides the consumption of fuel will be greater than in the preceding case. In England, however, the charcoal obtained by the distillatory process in closed retorts is always preferred, although a considerable expenditure of fuel is occasioned in heating the vessels. The apparatus described at vol. i., page 17, is the same as used in this operation. When the process of carbonization is coming to a close, the pipe connecting the cylinder with the pyroligneous-acid receiver must be closed, and very free egress must be allowed for the volatile matter; otherwise the charcoal is liable to injury by the deposition of a fuliginous varnish, and even by its reception of, and saturation with, condensable matter.

TOMLINSON, who writes the excellent article GUNPOWDER in the *Encyclopædia Britannica*, is inclined to consider this preference for distilled charcoal a mistake of the *causa pro non causa*. Pit charcoal, being made in coppice woods, is always the produce of oak; and it is probable that this wood, if charred in close vessels, would be even worse than it is now. There is more danger of overheating in the retort than in the pit, while the wood is not better burned; and hence, by a careless management of the process, even the charcoal of willow and alder may be rendered as bad as that of oak. Considering these various circumstances, charcoal requires to be submitted to three tests. It ought to act as little as possible mechanically, even on copper; no salts should be extracted from it by treating it with boiling distilled water; and it ought to give out no smoke when heated. The latter test is indicative of its being thoroughly burned.

The selected wood, whatever its variety, should always be cut when in sap, and never when dead. Wood of five or six years' growth is better suited for the manufacture of the charcoal than older kinds; for, generally, the latter contains more mineral matters, and, consequently, less carbon than the former; and the most convenient size is branches from three-quarters to an inch in diameter.

The charcoal, says Dr. URE, is considered by the scientific manufacturers to be the ingredient most influential, by its fluctuating qualities, upon the composition of gunpowder; and, therefore, it ought always to be prepared under vigilant and skilful superintendence. If it has been kept for some time, or quenched at first with water, it is unsuitable for the purpose. Charcoal extinguished in a close vessel by exclusion of air, and afterwards by exposure to the atmosphere, absorbs only from three to four per cent. of moisture, while red-hot charcoal quenched with water may lose, by drying, twenty-nine per cent. When the latter sort is used for gunpowder, a deduction of weight must be made for the water present. Charcoal, however, which has remained long impregnated with moisture, constitutes a most detrimental ingredient of gunpowder.

Before entering upon the description of the process for compounding the substances which constitute gunpowder, it may be well to give a few additional facts relative to the circumstances which affect the mutual decomposition of those bodies as they exist in this article, and render the phenomena of its explosion more easy of comprehension. Already some experiments of PROUST have been adduced, which elicit comparative data of the explosiveness of certain varieties of charcoal when mixed intimately with saltpetre; but they do not afford any real knowledge as to the degree of heat required to bring about such a metamorphosis, although they indicate that some kinds of charcoal form more inflammable mixtures with nitrate of potassa than others. The investigation of VIOLETTE upon the temperature at which charcoal decomposes this agent, is much more definite, and consequently interesting. He found that the degree of caloric which occasions the combustion of charcoal in the air, is much lower than what is necessary to cause the carbonaceous matter to decompose the oxidising agent which is incorporated with it in the powder. To determine this, he proceeded thus:—In a small porcelain crucible, heated by a carcel-lamp, which allowed the temperature to be easily regulated, nitrate of potassa was melted and maintained at 680° , being the degree at which the charcoals burned in the air. Into this bath a small cylinder of charcoal appended to a platinum wire, or glass rod, is plunged, so that it is all submerged; although numerous bubbles of gas were disengaged, yet the carbonaceous mass did not take fire at this temperature. By raising the heat gradually to 716° , and, trying the experiment at this stage, the effect was still negative, but ultimately it deflagrated after the bath had been raised to a higher degree of heat. The fusion of lead and zinc showed the thermometric effect to be above 680° ; but it being incapable of melting antimony, it was evident that the heat had not reached 819° , the fusing point of the latter metal. It may be concluded, therefore, that all charcoals prepared between 500° and under to 819° decompose nitrate of potassa at 752° , but that such as are obtained between 1832° and 2732° are not affected at the preceding, nor at much higher heat, since they do not even burn upon the surface of the bath.

The same chemist determined the degree of heat at which sulphur decomposes nitrate of potassa in an

equally ingenious way. He found that when sulphur was thrown upon the surface of the bath of fused salt, raised to the temperature of 680° , it floated about, melted, and inflamed; the combination, however, was with the oxygen of the air, and none of the saltpetre had been acted upon. A similar result was arrived at when the bath was at 752° , or even a few degrees higher; but when it had attained 819° , the fusing point of antimony, deflagration occurred by the decomposition of the potassa salt, and the evolution of a brilliant white light and a considerable quantity of gases. In the latter experiments it was necessary that the sulphur, like the charcoal in the last-mentioned examination, should be immersed in the fluid bath. To do this, VIOLETTE had a platinum crucible about the size of a pea constructed, and to this he appended a platinum wire, which might serve as a holder to it when immersed, mouth-under, in the bath. When 0.1 grain of sulphur was melted in this tiny vessel, and plunged into the bath in the manner shown in the annexed diagram, the effect was observed with considerable accuracy. Until the heat had reached the decomposing degree, the sulphur was observed to ascend in bubbles of colorless vapor through the transparent bath, and burst into a beautiful blue flame. As soon as the inflammation of the sulphur commenced within the fused saltpetre, the white light traversed the whole mass with the effect already detailed.

Fig. 247.



An observation of VIOLETTE's is worthy of notice here. During his examinations of the combustion of sulphur in nitrate of potassa, he tried at what temperature this element burns in the air, but found that the limits which are stated with reference to it in chemical treatises differed, both from one another as well as from his results. DUMAS gives the combustion of sulphur in air as taking place at 302° ; DALTON states that the heat is 500° , and THOMSON, 561° ; but VIOLETTE affirms the melting point to be exactly 480° . His experiments were performed on the surface of a bath of tin; contact of the sulphur and metal being avoided by placing it upon a thin pellicle of glass, and floating the latter upon the hot metal.

It was also observed that by sprinkling a little sulphur upon charcoal thrown upon the surface of the heated bath, ignition took place under the degree at which the most combustible charcoal kindles, *per se*. This occurs on account of the heat developed by the combustion of the sulphur at 480° , and which brings the charcoal to the state of redness, and consequently at which, when air is supplied, it rapidly inflames.

PROPORTIONS OF THE INGREDIENTS.—The progress of improvement in determining the proportions of the constituents of gunpowder, has been very gradual. In this country, a long period elapsed before the present state of perfection was attained; but this cannot well be wondered at, when one takes into consideration the ignorance which existed even up to the commencement of the present century, not only with regard to the theoretical laws of science, but also in respect of the properties of bodies purely chemical.

Such compounds as saltpetre, sulphur, and charcoal

in equal proportions were scarcely fit for squibs, much less for the purpose of projecting shot. Again, one finds such mixtures as saltpetre twelve parts, with three each of charcoal and sulphur; twenty-seven of nitrate of potassa to three of each of the other ingredients; saltpetre forty-eight, sulphur seven, and charcoal three parts; with many others which now-a-days appear equally ridiculous. At no very distant period, the French compositions were, saltpetre fifty, sulphur sixteen, charcoal thirty-four parts; saltpetre sixty-seven, sulphur thirteen, charcoal twenty; and again, saltpetre eighty-four, sulphur eight, and charcoal eight parts.

BAPTISTA PORTA was one of the first who endeavored to ascertain the best relative quantities of the constituents, and his proportions, obtained in the year 1515, approached very nearly those now employed in France. The deductions of GUYTON MORVEAU, BEAUMÉ, CHAPTAL, PROUST, and RIFFAULT, are represented below:—

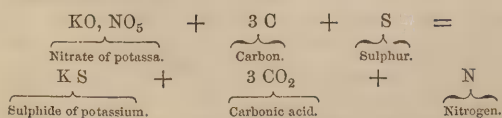
DUMAS gives the proportions, saltpetre 75, sulphur 12·5, and charcoal 12·5, as the most ancient known, and states, that however these proportions have been deviated from, either from pressing circumstances of time or place, the powder manufacturer had in the end to fall back upon the above mixture as offering the best composition. This seems to be the case, since the researches of the several original chemists who have taken up the question give mixtures closely approximating to those numbers, as may be seen from the annexed table of the mixtures recommended by them.

	Saltpetre.	Sulphur.	Charcoal.
Guyton Morveau,	76	9	15
" "	77	7	17
" "	80	5	15
Beaumé,	80	5	15
Chaptal,	77	9	14
Proust,	78	9	13

To these may be added the following:—

	Saltpetre.	Sulphur.	Charcoal.
Powder of Bâle,	75·0	10	14
" Grenelle,	76·0	12	12
" Riffault,	77·5	7·5	15
" Bouchet,	77·0	9·5	13·5

Of the latter class, that of Bâle is accounted the best for military and general warlike purposes; but, notwithstanding the superiority it possesses when recently prepared, if the compound has to be retained for a long time in magazines or to endure long transport, it does not answer so well as the old proportions above referred to. Theoretically considered, this is, granting that all the materials possessed absolute purity, the best composition; for if the nature of decomposition of powder be attended to, and the products of the combustion examined, it will appear that only carbonic acid, nitrogen, and an alkaline sulphide are produced. Hence it may be reasonably inferred that the chemical symbol corresponding with this decomposition, admitting of no loss, would be,—



—that is, one equivalent of saltpetre, three of charcoal,

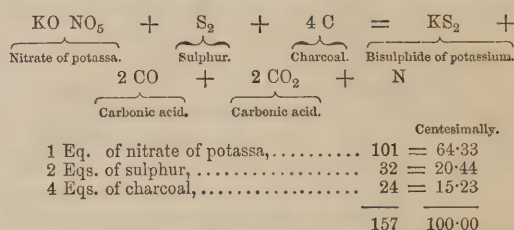
and one of sulphur, by being made into a powder, affords one equivalent of sulphide of potassium, three of carbonic acid, and one of nitrogen. Calculating from these data the percentage quantity of each to be taken, the annexed results are obtained:—

	Theoretically.	Practically
1 Eq. of nitrate of potassa,	101	74·81 = 75·0
1 Eq. of sulphur,	16	11·85 = 12·5
3 Eqs. of carbon,	18	13·34 = 12·5
	135	100·00 100·00

The difference between these numbers is so minute as to be worth noticing, even were nothing else to be taken into account; but as shown by the analysis of several charcoals, as given under FUEL, there is always more or less hydrogen present, which concurs to make the combination more complete, and in accordance with theoretical results. Another instance of the accuracy of the quantities taken for the preparation of another quality of powder, is the variety generally used for mining and blasting purposes. The proportions taken for this are:—

Saltpetre, 65; sulphur, 20; charcoal, 15;

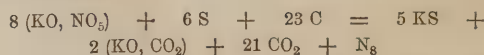
Numbers which closely correspond with the formula,—



Sporting powder is another of these compositions which may be reduced to the simplicity and certainty of a chemical formula. The usual quantities of the materials taken in this case are:—

Saltpetre, 78; sulphur, 10; charcoal, 12;

Numbers which may be expressed by equation, although this is not so simple as the preceding, owing to there being a slight excess of oxygen over and above what the charcoal combines with, and the amount of sulphur used being incapable of retaining all the potassium in the state of sulphide. This will be seen from the formula,—



That is, eight equivalents of saltpetre, six of sulphur, and twenty-three of carbon, afford five equivalents of sulphide of potassium, two of carbonate of potassa, and twenty-one of carbonic acid and eight of nitrogen. The truth of the formula is proved in a very striking manner by the following calculation:—

	Centesimally calculated formula.	Given mixture.
8 Eqs. of nitrate of potassa, ..	808	77·54 .. 78
6 Eqs. of sulphur,	96	9·21 .. 10
23 Eqs. of charcoal—carbon, ..	138	13·25 .. 12
	1042	100·00 100

The analogy in both the foregoing instances is suffi-

cient to show that the powder-maker has in compounding his mixtures an unfailing guide, by following which he cannot get far wrong. A little difference is occasioned in the foregoing, in the quantity of the calculated charcoal especially; but the explanation of the presence of hydrogen, which takes up such a large quantity of oxygen from the nitrate of potassa during the explosion of the powder, accounts for this. Indeed, were it not for this excess of hydrogen which makes up for the assumed amount of carbon in the charcoal, it would be difficult to reduce the quantities of real matter in the substances within the expression of a simple formula. Analyses show that the quantity of carbon in the charcoals which are usually incorporated, varies from sixty-eight to ninety per cent., and it is evident that when numerical quantities of the ingredients, such as ex-

pressed above for the manufacture of the powder, are strictly adhered to, serious differences occur in the quality of the article, according as the charcoal is more or less rich in carbon. To adhere, therefore, to the strict proportions indicated by the numbers laid down, and which assume that the materials are pure, it becomes absolutely necessary to determine the amount of carbon in the charcoal, and regulate the quantity according to such an estimation; otherwise it is not at all surprising that two powders prepared exactly according to any given recipe, but with different materials of unknown qualities, should have very unequal effect when exploded.

The following table shows the proportion of the ingredients used by the powder-makers of different nations:—

Countries.	Artillery Powder.			Musket Powder.			Sporting Powder.		
	Saltpetre.	Sulphur.	Charcoal.	Saltpetre.	Sulphur.	Charcoal.	Saltpetre.	Sulphur.	Charcoal.
England—Government Mills, Waltham Abbey,.....	75·0	10·0	15·0	76·5	9·00	14·5	79·7	7·8	12·5
	75·0	8·0	17·0	78·0	9·25	12·75	78·0	8·5	13·5
	76·0	9·5	14·5	78·0	8·5	13·5	78·0	8·0	14·0
	70·0	16·0	17·0	72·0	15·0	17·0	....	....	....
Austria,.....	76·0	11·0	13·0	75·5	11·3	13·2	80·0	12·0	14·0
France,.....	75·0	12·5	12·5	75·0	12·5	12·5	78·0	10·0	12·0
United States,.....	75·0	12·5	12·5	....	....	....	....	....	....
Russia,.....	71·0	11·5	17·5	80·0	8·7	11·3	80·0	8·0	12·0
	75·0	10·0	15·0						
Prussia,.....	75·0	11·5	13·5	....	....	....	....	....	....
Spain,.....	76·5	10·8	12·7	....	....	....	....	....	....
Haarbourg,.....	72·0	14·0	14·0	....	....	....	....	....	....
Hanover,.....	71·2	10·8	18·0	....	....	....	....	....	....
Hesse—Grand Duchy,.....	74·4	10·6	15·0	73·7	10·7	15·6	....	....	....
“ Electorate,.....	73·4	13·3	13·3	....	....	....	....	....	....
Holland,.....	70·0	14·0	16·0	....	....	....	....	....	....
Italy—Milan,.....	76·0	12·0	12·0	....	....	....	....	....	....
Portugal,.....	75·7	10·7	13·6	....	....	....	....	....	....
Saxony,.....	75·5	8·2	16·3	76·5	10·5	13·0	....	....	....
Sweden,.....	75·0	9·0	16·0	....	....	....	....	....	....
Wurtemberg,.....	75·0	12·0	13·0	74·5	10·7	14·8	....	....	....
Baden,.....	76·0	10·0	14·0	76·0	10·0	14·0	76·0	10·0	14·0
China,.....	61·5	15·5	23·0	....	....	....	....	....	....
	75·7	9·9	14·4	....	....	....	....	....	....

Several other proportions are in use in the countries specified above, which, to some extent, vary from those given. It is reasonable to suppose that in choosing the foregoing numbers, the manufacturers of the several countries mentioned have conscientiously selected the numbers given as affording the best results; still, as there seems to be no tabulation of the composition of the materials, more especially of the charcoal, the Editor believes that a considerable amount of empiricism must be connected with it; at all events, the variation in the proportions must be attributed to the inequalities in composition of the varieties used: for, had each sought the most appropriate mixture, and employed charcoal of a known per-centage of carbon, doubtless, instead of the many variations, one invariable proportion would be adhered to by all, and a close analogy in the explosive force of the powder could be calculated upon. The species of powder which is used for mining and similar purposes vary in composition from the kinds used for the military and for sporting; it has a much larger proportion of charcoal than the latter, and consequently it is less expensive. From the example given in the preceding of the parts of such powder centesi-

mally, and the exposition of its decomposition by a rational formula, this is shown to be the case: besides, the products of the explosion contain, with carbonic acid, a large volume of carbonic oxide. As will be shown further on, the volume of gases which such a powder affords is larger than what results from the shooting powder; but still the propulsive effect is less than with the latter.

With reference to the study required to insure the production of the best possible compound, and to find a general recipe, VIOLETTE submits a suggestion to which the Editor subscribes, as it would contribute more than anything else to register the quality of the various powders and excite inquiry; namely, that a register of the propelling powder should be kept annually, and such submitted to a competent party for consideration. As to the indications in the targets, however, they are liable to be affected by the nature of the piece; and, in fact, the powder itself, when made from precisely the same ingredients by two neighbouring establishments, varies in some measure, in consequence of the dissimilar manipulations.

To ascertain how far the powders prepared from

variable quantities of materials of the same centesimal composition differ in their ballistic effect, VIOLETTE prepared a number of samples of fowling powder, each weighing about twenty kilogrammes, forty-four pounds, and submitted them to the test. The following are the results :—

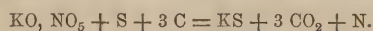
No.	Per-centage composition of materials.			Amount of carbon in one hundred parts of charcoal.	Speed of the ball by the ballistic pendulum.
	Saltpetre.	Sulphur.	Charcoal.		
1.	78	10	12	68	357
2.	72	9	19	68	350
3.	72	10	18	68	355
4.	71	10	19	68	361
5.	71	11	18	68	363
6.	71	9	20	68	370
7.	71	11	18	85	337

In this table No. 1 is the regular proportion, and the speed of the ball with such, supposing all the powder to be consumed, would be, according to the usual rule, three hundred and fifty metres. It is surprising to observe that No. 6 in the above collection, in which the saltpetre is diminished by eight parts, and the sulphur by one, and the charcoal increased by eight, is a superior powder to No. 1. No. 5 also constitutes a very good powder, but its quality would be considerably deteriorated by using, instead of the charcoal containing only sixty-eight per cent. of carbon, one yielding eighty-five per cent., as shown in the last. This forms a striking example of the way in which an inequality in the per-centage of carbon in the powder affects it.

The chief qualities which a good gunpowder ought to possess, are ready inflammability, complete decomposition of its constituents, the production of the largest possible volume of elastic gases, and finally, that of affording only the smallest possible amount of residue, and even that should be of such a nature as not to injure the gun.

Inflammability of Powder.—From what has been stated in the preceding pages relative to the degrees of heat required to decompose the constituents of powder, a good inference may be drawn as to the degree of heat at which powder will take fire.

However, if a small quantity of powder be slowly heated, and the temperature be gradually raised, it will be observed that the sulphur, which is the most inflammable constituent, will begin to burn with a blueish flame at 482°, or thereabouts; and the heat developed in this partial combustion brings the other constituents into that state at which the nitrate of potassa is decomposed by the charcoal, whilst the remainder of the sulphur adds to the effect by combining with the metal of the oxidising agent, thus—



To ascertain whether the powders, as usually manufactured, actually do ignite at the burning point of sulphur, VIOLETTE made some examinations by placing portions of the powder to be tested on the surface of a bath of tin, in which the bulb of a thermometer was immersed, the whole being heated by a small carcel-lamp: the following results were obtained—

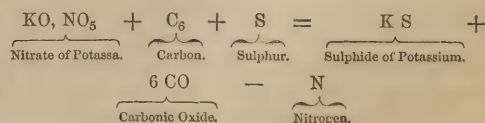
No.	Species of Powder.	Temperature which produced deflagration.	
		Powder in angular grains.	Pulverized powder.
1.	Blasting powder,.....	518°	509°
2.	War ".....	528.5	510.5
3.	Sporting " fine,.....	536	514.8
4.	do. " extra-fine,....	608	518.0

Of these No. 1 was made with black charcoal, and No. 4 with brown or torrefied charcoal, the inflammability of which takes place at a much lower degree of heat than the first; still it is a matter of some surprise to find that the former, in the shape of powder, burns at a lower heat, excepting the variation in the quantity of sulphur present in them may influence the deflagration. This element is present in the four samples in the following ratio, namely, 20, 12.5, 10, and 9 per cent.; the most combustible of the powders having the largest amount of sulphur, which, of all the elements, is the most ready to enter into ignition. It may likewise be remarked that the size of the grain influences, in some measure, the temperature at which the powder burns.

Balistic or Propulsive Effect of Gunpowder.—The force with which a ball is projected, or a rock fractured, is, as may be easily understood, in proportion to the volume of gases which is produced when gunpowder or any other modification of this article is deflagrated. In case of gunpowder, these gases are principally carbonic acid and nitrogen; and where mining powder is operated upon, carbonic acid is likewise a product. But besides these it is found that small quantities of many other products are invariably formed, among which may be mentioned carbonic oxide, sulphurous acid, sulphide of hydrogen, bisulphide of carbon, carbonate of potassa, cyanide, and sulphocyanide of potassium and aqueous vapor. The most important products of a careful and complete combustion, on a small scale, of powder of the above composition, have, however, been found to correspond pretty closely to the above theoretical expression.

The gases disengaged in the combustion of this powder, would comprise, at 32°, a volume three hundred and twenty-nine times as great as that occupied by the powder. The force exerted by the evolution of these gases is, however, mainly dependent upon their enormous expansion at the instant of the explosion, by the heat evolved in the action; for it is calculated that one volume of powder of the above composition yields, at the moment of ignition, at least two thousand times its volume of gas.

If gunpowder contain more carbon in proportion to the nitrate of potassa than the quantity above stated, a proportionate amount of carbonic oxide is produced in its explosion; thus if six instead of three equivalents of carbon be employed to one equivalent of saltpetre, the whole of the oxygen contained in the latter would theoretically be eliminated as carbonic oxide on the decomposition of the powder, as the following equation shows :—



Now, since the space occupied by equal equivalents of carbonic oxide and carbonic acid is the same, it is evident that a much larger volume of gas would be evolved—calculated for a temperature of 32° , and ordinary barometric pressure—from the gunpowder which contained the larger amount of charcoal. But it must be borne in mind that the amount of heat disengaged in the production of carbonic oxide is far less than that generated when carbonic acid is produced, and that consequently the powder which contains the minimum quantity of charcoal will yield, *at the instant of explosion*, by far the greatest bulk of gas. That this expansion of the gas by heat is of the utmost importance, is very evident from what has been already stated. The fact that the temperature evolved by the combustion of gunpowder, estimated at 2192° , has been found to be sufficiently intense to fuse gold, silver, and other metals, and that the expansion of gases increases greatly with an augmentation of temperature—two hundred volumes of gas raised to 2428° occupying the same bulk as three hundred volumes, which are only heated to 1466.6° —render the value of a slight elevation of temperature at the moment of explosion still more apparent.

As it is difficult, nay impossible, under ordinary circumstances, to gain a knowledge of the quality of powder by any method involving the necessity of measuring the gases and caloric evolved, a more direct course of experiments is resorted to. This method was founded by PROUST partly upon the duration of the combustion, coupled with the volume of gases which were eliminated. The methods of operations employed were the same as those already described with regard to the estimation of the time required to deflagrate charcoal and nitre, *et cetera*. The following were his results:—

No.	Saltpetre.	Sulphur.	Charcoal.	Time of combustion in seconds.	Products in gas in cubic inches.
1.	60	10	15	6	91
2.	60	10	12	6	91
3.	60	10	10	6	91
4.	60	10	$8\frac{1}{2}$	7	88

It is presumed that these determinations, however, leave much to be required, not only in the accuracy of the determinations, but with respect to practical application.

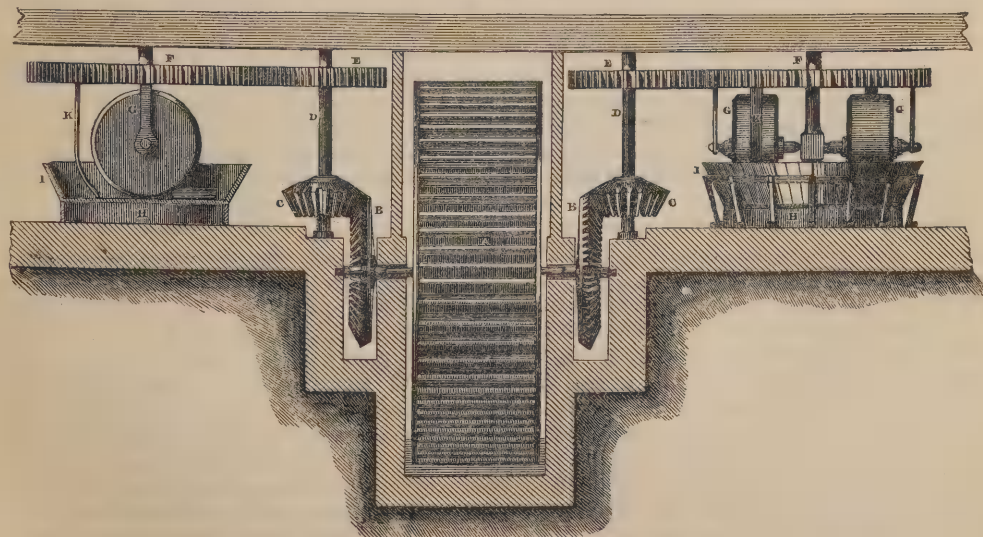
TOMLINSON adopted another method, which, on the whole, is more applicable to practice—namely, the determination of the altitude of rockets, and which he describes as being less liable to disturbances from collateral causes than any practice with pieces of ordnance. The rockets were of compound dimensions, and were all made with the same proportions and driven with the same hand, so as to insure all possible uniformity; the only variation being in the nature of the charcoal. The vertical elevations were taken by two quadrants at the same time, and all the flights that deviated from the perpendicular were rejected. The mean vertical ascent made with a great number of these, in which the charcoal was from the willow, alder, and dogwood, was four hundred and eighty yards; but between these three charcoals the difference was so great as to give various results, which may be represented by the following numbers:—

Dogwood charcoal,.....	515, 550, 525
Willow “	470, 480, 490
Alder “	455, 460, 470

To the methods in use, and recognized by the military and powder manufacturers generally, reference will be made further on.

Upon comparing the composition of the powders prepared in different countries for fire-arms, they will be found to agree more or less closely with the cen-

Fig. 248



tesimal composition as above expressed. It must be remembered, however, that the proportions have been arrived at by experience, in most cases long before any

theory concerning the chemical composition or action of powder was advanced. In some cases the deviations from the theoretical numbers may be readily ex-

plained. Thus in the manufacture of the Waltham Abbey powder, a slight excess of charcoal is always employed in order to allow for the small quantity of inorganic matter always associated with carbon in that form; while the proportion of sulphur is reduced as much as is compatible with the production of a strong powder, in consequence of the injurious action of that substance, and even of sulphides in the presence of moisture, upon metal.—*Abel and Bloxam.*

MANUFACTURE.—The merely mechanical part of the manufacture of gunpowder is essentially the same in principle, and differs only to an immaterial extent in detail, whether in the various gunpowder mills in Great Britain, or in those of her continental neighbors. The Editor will trace the method of manufacturing gunpowder as it is employed at the Government Mills, Waltham Abbey:—

In the first place, it may be stated that water is the motive power in most gunpowder mills; the necessity of the presence of fire when steam is made use of is attended with so much danger, that this agent has not yet been introduced for the purpose.

The gunpowder mill is represented in Fig. 248, where A is the water-wheel; BB, two vertical bevel wheels fixed upon the axis of the great wheel, and working into CC, which turn the shafts, DD; EE are two horizontal spur-wheels, fixed to the upper part of DD, and driving the large wheels, FF. To the shafts of these latter are fixed the runners, GG, which traverse the bed-stone, HH; II are the curbs surrounding the bed-stone to prevent the powder from falling off; K is the scraper.—*Ure.*

The materials, having been pulverized in the mill, are apportioned out, the following being the proportions at Waltham Abbey:—

	Pounds.	Ounces.	Drachms.	
Saltpetre,	31	8	0	0
Charcoal,	6	4	13	
Sulphur,	4	3	3	
	42	0	0	

This quantity of the ingredients, termed a *charge*, is placed in the mixing apparatus, which consists of a wooden cylinder traversed in its centre by an octagonal shaft provided with several fan-like arms. Both the shaft and cylinder are kept in motion, but in different directions. This latter arrangement so facilitates the commingling, that the homogeneous powder is ready for removal and further manipulation in from five to ten minutes, when it is transferred to bags which are pressed, and the mouths of which are firmly secured, in order to prevent the disunion or separation of the ingredients in the order of their density, during the transport to the incorporating mill. It is evident that if the charges were too lightly packed, the ingredients would be liable to be separated in a greater or less degree, the saltpetre finding its way to the bottom, while the sulphur and charcoal would form layers above; the latter, from its light, pulverulent state escaping, in the form of dust, between the fibres of the cloth of which the bag is formed.

The next process is the *incorporation*. The mixture is spread out upon the bed of the mill, distilled water is added to insure the intimate cohesion of the par-

ticles—the amount of water required varying much according to the temperature and other atmospheric conditions, as also in proportion to the degree of comminution of the constituents—and the whole is again submitted to the action of the mill, to insure the uniform pressure and bruising of the rollers; but in this case the motion is less rapid than during the grinding of the ingredients. A great degree of caution must be exercised to prevent the intervention of any hard or silicious matters. The requisite amount of moisture must be maintained during the operation, and for this purpose water is slowly added at suitable intervals, till the incorporation is complete, which is generally the case at the expiration of from three to four hours.

The homogeneous compound has now the properties of gunpowder; it indurates in a very short period, forming hard cakes, which should possess a dark greyish-black hue, and free from specks of any kind; it is now termed *mill-cake*. When this has lost much of its moisture, but before it becomes completely dry, it is passed between corrugated or channeled cylinders, termed the *breaking-down mill*, and is then submitted, between copper plates, placed in strong boxes, to hydraulic pressure of about one hundred and twenty tons per square foot, after which it is known as *press-cake*; it is now greatly altered in appearance, and apparently resembles slate, being in dense blackish cakes, about half an inch in thickness. This powerful pressure is productive of several advantages:—

1. The powder has a greatly augmented density, and a given quantity of it will evolve, on combustion, a far larger volume of gas, than an equal bulk of powder which has only received the pressure of the incorporating mill.

2. From the increased hardness of the powder, it better resists atmospheric action; and besides this, it is not so liable to loss from *dusting*, caused by friction, during its transport.

The powder has now to be granulated. The machine employed for this purpose at Waltham Abbey consists of a pair of metal cylinders, provided with large teeth, upon which, while in revolution, the press-cake is allowed to fall in fragments; by this means it is reduced to grains of various sizes. As these pass from the cylinders or rollers, they are submitted successively to the action of three sieves of graduated fineness, placed one over the other, and jolting or working continually backward and forward. The powder retained by the first sieve is subjected to the action of a second pair of rollers with finer teeth, whence it again passes to, and is sifted by, the upper screen. The portions still too coarse to pass through, are reduced by a third still finer set of rollers. The powder manufactured at Waltham Abbey is distinguished as L. G., or *large-grain*, F. G., or *fine-grain*, and *meal-powder*, or dust. The first variety is retained by the second sieve; the lowest sieve reserves the fine grain; the dust, or meal-powder, collects beneath. Each kind is collected, as it falls from the screen, in boxes running on wheels and rails.

Various other contrivances belong to this effective machine to obviate the necessity for the attendance of

workmen, and, consequently, to prevent their injury should any accident occur.

The granulated powder is next freed from dust by running it through *reels*, similar to the bolter employed in dressing flour—encased in boxes, and covered with canvas or with silk, of about fifty-six meshes to the inch, according as large or fine-grain powder is introduced.

The finest powder is now *glazed* by subjecting it, in a slightly moist state, to rotary motion in barrels or drums, similar to the mixing machine already noticed. The velocity of rotation must be just sufficient to cause the grains only to roll over each other slowly, and thus become polished by attrition. Blasting-powder is occasionally glazed with graphite.

The gunpowder is finally dried, which is now generally done by means of steam-heat; sometimes it is effected by transmitting a current of air, previously heated in another chamber to from 130° to 150°, over the powder placed on canvas shelves.

On the Continent, the powder is chiefly granulated in drum-sieves, generally made of perforated parchment skins or of copper, fitting into each other, and fixed in a frame to which rotary motion is communicated by proper machinery. On the uppermost of these is placed a circular piece of heavy wood, as *lignumvitæ*, sometimes loaded with lead, which traversing the surface of the sieve, gradually reduces the fragments of the powder, until they are sufficiently fine to pass through the perforations or meshes.

PROPERTIES.—Good powder, according to ABEL and BLOXAM, should be perfectly uniform in texture; light specks or glittering points indicate an incomplete mixture. The grains should be sufficiently hard not to be easily crushed between the fingers, and not to soil these or a piece of paper by mere contact. Gunpowder should burn rapidly, leaving only a *very slight* residue. If inflamed upon white paper, it should blacken it but slightly, and should on no account set fire to it. Powder is inflamed by any burning substance, by an electric spark, by red-hot metal, or by violent concussion. It does not ignite, however, by exposure to a temperature below redness. If subjected in an atmosphere of hydrogen or carbonic acid to a gradual increase of temperature, the sulphur may be completely separated, subliming upon the cool portion of the vessel.

It has been proved that powder may be inflamed, not only by the concussion of hard bodies, but by that of comparatively soft ones, provided it be sufficiently powerful. Experiment has shown that powder placed upon lead, or even upon wood, may be ignited by the shock of a leaden bullet fired at it.

No doubt the inflammability of a powder is greatly influenced by its physical state. A fine-grain powder will burn much more rapidly than powder of a larger grain. The greater the density, the more gradual is its combustion. Angular powder will burn more speedily than the round-grained, and the inflammability of powder is not only retarded by the presence of moisture, but also by the glazing.

Powder in which the theoretical proportions are exact, and in the manufacture of which a very inflammable charcoal has been used, the ingredients having

been mixed without the application of very great pressure, will undergo, when ignited, an almost instantaneous decomposition. Such a composition, in many respects, resembles the fulminates; the strain which it exerts upon the fire-arm is far too powerful; hence it is not so generally applicable as a more gradually disintegrating mixture.

Gunpowder always attracts more or less moisture, since charcoal, however dense, absorbs humidity from the air; though, of course, the hygroscopic property of powder is considerably increased by the use of porous charcoal in its manufacture, or by the presence of any considerable quantity of powder-dust. Powder, manufactured with perfectly pure nitrate of potassa, is found, if preserved in dry stores, to absorb about 0.5 per cent. of moisture; the amount naturally increases considerably if it is kept in a damp situation. Fine-grain powder is generally found to absorb moisture more rapidly than the large-grained.

The amount of ash left upon the ignition of gunpowder varies according to the purity of its ingredients, the proportions employed, and, more particularly, the nature of the charcoal used. Its gradual accumulation in a fire-arm is a source of great inconvenience, since it soon renders it foul and difficult to charge, thus limiting the number of rounds that can be fired in rapid succession, without cleaning out the instrument. This *fouling*, as it is termed, is avoided to some extent by the use of a small quantity of some fatty substance, which lubricates the barrel, and, by preventing the adhesion of the ash, promotes its expulsion by the gases as they make their escape.—*Abel and Bloxam*.

BISHOP affirms that gunpowder explodes exactly at the temperature of 600°. When exposed to a heat of 500°, its nature becomes totally changed; not only is the whole of the moisture expelled, but the saltpetre and sulphur are reduced to the fluid state. The powder on cooling is found to have changed from blackish-grey to an intense black; the grain has become extremely indurated, and by exposure even to very moist air, it then suffers no alteration by imbibing moisture.

The specific gravity of gunpowder, according to Dr. URE, as taken by him with five different kinds in oil of turpentine, varied from 1.793 to 1.80.

ANALYSIS.—The following is the ordinary method of analysing gunpowder:—

The water is first estimated by submitting a small portion, say three or four grammes of the sample to be examined, to a temperature of 212°, in a water-bath, until it ceases to lose weight. Some chemists prefer placing a known quantity over sulphuric acid *in vacuo*, but this method takes much more time, and the former is sufficiently accurate for all ordinary purposes. The loss after drying shows the amount of moisture in the sample, from which the per-centage may be readily calculated.

It may be well for the Editor to remark here, that the quantity of water should be a *mere trace*, if any. If it is found to contain several per cent. of water, it may be rendered again perfectly good by careful exsiccation.

The next step is the determination of the nitrate of potassa, which is effected by boiling the powder in

which the humidity has been determined, in about six times its weight of water; the residuum is then carefully collected on a tared filter, washed with tepid water until a few drops of the filtrate when evaporated upon platinum foil give no residue; the insoluble matter upon the filter being then desiccated at 212°, and weighed, the loss will indicate the amount of nitrate of potassa. The saltpetre may also be determined by evaporating to dryness the filtrate obtained as above, fusing the residuum at a low temperature, and then ascertaining its weight. Both these methods may be employed, the one thus furnishing a check upon the other.

Should the saltpetre contain chloride of sodium, as it ordinarily does, the amount of it may be determined as follows:—The dry and weighed residuum, procured as just described, is redissolved in water, and a little nitric acid and a weak solution of nitrate of silver added, when, if chlorides are present, a curdy precipitate of chloride of silver occurs; this is collected on a filter,edulcorated, dried, fused with great care in a porcelain crucible, and weighed. One gramme of the chloride of silver represents .407 chloride of sodium, or .247 of chlorine.

The amount of sulphur and carbon, respectively, may be ascertained by various methods.

One of these, devised by GAY-LUSSAC, consists in igniting in a platinum crucible a known quantity—say one gramme—of the gunpowder, with the same weight of carbonate of potassa and of nitrate of potassa, and four times the quantity of common salt; by this means the sulphur is oxidised into sulphuric acid, and may be determined as under:—The fused mass, which should be perfectly white, is dissolved in water, and acidified by means of hydrochloric acid. The solution is next filtered, and chloride of barium added so long as a deposit is occasioned. After some time, when the precipitate has subsided, the whole is filtered, and the sulphate of baryta aspersed with hot water, until sulphuric acid causes no turbidness in a portion of the washings. The precipitate is next dried, and then, as much of it as is possible being detached from the filter paper, the latter is burned in a platinum crucible until the whole of its carbonaceous matter is destroyed; the former introduced, heated to redness, and weighed. Each 116.5 parts of sulphate of baryta represent forty-nine parts of monohydrated sulphuric acid, and consequently sixteen of sulphur.

The per centage of moisture, nitrate of potassa, and sulphur being calculated, the difference indicates the amount of carbon.

WHITE GUNPOWDER.—AUGENDRE has described a new kind of gunpowder, consisting of one part of ferrocyanide of potassium, one part of white sugar, and two parts of chlorate of potassa. These are reduced to powder separately, and are then mixed with the hand. In experiments with small quantities, they may be pounded together in an agate mortar. Not the least fear need be entertained of the effects of the most powerful friction. In preparing it on a larger scale, the mixture is moistened with two or three per cent. of water, and triturated in a bronze mortar with a wooden pestle; fifteen minutes' pounding suffices for

small quantities, as the ingredients do not require such intimate admixture as in the preparation of ordinary gunpowder. The powder is granulated in the usual way, and dried in the air.

Gunpowder thus prepared is white; fires with the greatest ease, both in the granular state, and in that of an impalpable powder, by contact with an incandescent body; the flame with which it burns is greater than that of ordinary powder, and it leaves less residue. As taken from the mortar it is perfectly inflammable, so that there never need be any apprehension of its missing fire. It must be exceedingly dry for a violent blow of iron to explode it; friction between two polished bodies never produces this effect, nor does striking wood upon wood, or wood upon metal. It is formed of substances, the composition of which is well determined and fixed, and it can, therefore, always be obtained of the same strength. The materials are unalterable by the action of dry or humid air, so that they can be kept for any length of time, which cannot be done with the charcoal used for the ordinary article. The manufacture requiring less time, a fortress might, in case of necessity, be provided with the several constituents in powder, and the mixture made when required, by which means the danger attendant upon large deposits of gunpowder would be avoided. The force is much greater, so that there is space for a larger number of charges in the artillery caissons. The dust having the same effect as the grain, each constituent might separately be reduced to a very fine powder, and the whole commingled in a leather barrel.

But though possessed of all these superiorities over common gunpowder, it is not free from serious disadvantages, one of which is, that it oxidises iron barrels very much, and its use is consequently limited to bronze ones, and to the filling of hollow projectiles. It is more easily inflamed than common gunpowder, but not so readily as the other compounds of chlorate of potassa which have been prepared for the same purposes.

AUGENDRE directs attention to the circumstance, readily conceivable from the behavior of chlorate of potassa towards several other substances, that the greatest care should be taken to avoid introducing into the mixture any charcoal or sulphur, or mixing with it any ordinary gunpowder.

The proving of gunpowder, and many other subjects connected with the present article, are not of a sufficiently chemical nature to be treated of here.

STATISTICS.—Gunpowder is always packed in strong oak barrels, containing from eight to one hundred pounds each, the latter being the maximum weight allowed by Government to be contained in a single package. When for sporting purposes, it is in canisters and strong papers.

Owing to gunpowder being entirely free from duty, the returns of the Board of Trade can scarcely be expected to give even an approximation to the amount of imports and exports. Indeed, the import returns during the years 1850 to 1853 inclusive are entirely blank, while, for 1854, they are registered as one hundredweight, and in 1855, 11,851 hundredweights. During the years 1850-55 inclusive, there were no returns of exports.

GUTTA-PERCHA.—This valuable substance, the name of which is the same in all languages, and which was unknown in Europe previous to the year 1843, is the inspissated juice of a tree which grows in the Malayan forests and the islands of the Eastern Archipelago. In its origin, character, and composition, it is analogous to caoutchouc, but wants the peculiar elasticity of that substance; on the other hand, it possesses special and distinct properties, which render it applicable to an extraordinary variety of important uses, and which, within the short time that has elapsed since its introduction into Europe, have given a remarkable development to its manufacture.

It may not be out of place, even in a scientific work, to correct an erroneous mode of pronouncing the name of this substance, which has become very general. The name is a pure Malayan one, and not Latin, as might be supposed from a mere coincidence in the spelling—*gutta* meaning in the Malay language the gum or concrete juice of a plant, and *percha* the particular tree from which the juice is procured. Dr. MONTGOMERIE, its discoverer, states that the *ch* is not pronounced hard like a *k*, but like the *ch* in the English name of the fish *perch*; and that if a European were to inquire of a Malay for gutta *perka*, he would be told the thing was unknown, when perhaps plenty of the gutta-percha might be procurable by pronouncing the name properly. He adds, that had he thought there was a probability of the name being mispronounced, he might have used the uncouth orthography *pertscha*, but then it would have run the risk of being taken for a Russian or Polish appellation.

HISTORICAL NOTICE.—It appears that this substance, though only of recent introduction into commerce, was brought into England in the days of TRADESCANT, as a curious product, under the name of *mazer wood*; and subsequently it was frequently brought from China and other parts of the East, under the designation of india-rubber, in the form of elastic sticks, whips, and other trifling articles. The products of the East Indies, shown by the Honourable East India Company at the Great Exhibition, proved that the natives of the country in which the gutta-percha tree grows, knew also how to appropriate it to the manufacture of different kinds of vases, and that European industry and the wants of an advanced civilization have only developed its application to a greater variety of uses than were known or required in the countries to which it belongs.

The merit of first appreciating its value and making it known in Europe, is claimed by two individuals, who seem to have endeavored about the same time, and quite independently of each other, to bring it into public notice, namely, Dr. WILLIAM MONTGOMERIE, a Scotchman, for some years assistant-surgeon to the Residency at Singapore, on the Malay peninsula; and Sir JOZE D'ALMEIDA, who had been for many years resident in the same settlement. This last-named gentleman came over to England in the beginning of the year 1843, bringing several samples of the gutta-percha with him; and, among other channels of communication with the scientific world, had the honor of presenting specimens to the Royal Asiatic Society,

for which he received their letter of acknowledgment and thanks. On the whole, however, the merit of priority of discovery seems, by general assent, to be assigned to Dr. MONTGOMERIE, who, in point of fact, was not only the first European who discovered the value of the product, but the first who exerted himself actively and successfully to bring it into general use. Before the attention of this gentleman was directed to it, it was not only quite unknown to Europeans in general, but was known as an article of value only to a few of the inhabitants even of those localities in which it is produced, and was applied by the natives to very trifling uses; being chiefly employed to make handles for *parangs* or wood-choppers, as a substitute for wood or buffalo-horn.

The valuable qualities of the substance were no sooner publicly announced than it came into general demand. The immediate effect of its discovery may be compared to that of the gold-fields in California and Australia; and perhaps no substance except the precious metals has been more eagerly sought after or more highly appreciated. Its singular adaptation for an infinite variety of purposes was quickly recognized, and an extensive trade in it sprang up almost immediately. In the year 1844, previous to which its very name was unknown to European commerce, two hundredweight of it were shipped experimentally from Singapore. In 1845 the exportation of it from that port rose to one hundred and sixty-nine piculs—a picul being equivalent to 133·3 pounds; in 1846, to five thousand three hundred and sixty-four piculs; in 1847, to nine thousand two hundred and ninety-six; in 1848, to twelve thousand. In the first four and a half years of the trade, twenty-one thousand five hundred and ninety eight piculs of gutta-percha, valued at two hundred and seventy-four thousand one hundred and ninety dollars, were shipped at Singapore; the whole of which was sent to England, with the exception of fifteen piculs to Mauritius, four hundred and seventy to the Continent of Europe, and nine hundred and twenty-two to the United States.

The knowledge of the article, stirring the avidity of gatherers, gradually spread from Singapore, Northward, as far as Penang; Southward, along the East coast of Sumatra to Java; Eastward, to Borneo, where it was found not only at Sarawak, but also at Bruné and Pontianak on the West coast, and at Reti and Passir on the East.

This eager demand for the precious gum, animated by the thirst for immediate gain, was productive of a reckless destruction of the valuable trees that produced it. Instead of simply tapping the trees to obtain the juice, as is practised in the case of caoutchouc, the monarchs of the forest were felled to the ground; a magnificent tree of fifty or one hundred years' growth was cut down, the bark stripped off, and the milky juice collected and poured into a trough formed by the hollow stem of the plantain leaf; and some idea may be formed of the havoc thus made to procure the large supplies which were imported into Singapore, when it is stated, that on an average not more than twenty or thirty pounds were procured from one tree. The result was, that in the course of three and a half years,

two hundred and seventy thousand trees were felled, in order to get at the gum. It was, therefore, apprehended that the tree, although at first sufficiently plentiful, would soon become difficult to be procured; and this would undoubtedly have been the case, had not the Gutta Percha Company, subsequently formed in England, acted with a wise precaution, and embarked a considerable capital in seeking to promote the tapping, instead of the felling of the trees.

THE GUTTA-PERCHA TREE.—For some years after the introduction of gutta-percha, the character of the tree which produces it remained a mystery. At length from specimens which were sent home by Dr. OXLEY, in 1847, Sir W. J. HOOKER was enabled to refer the plant to Dr. WRIGHT's new genus of *sapotaceæ*, called by him *isonandra*; and accordingly he proposed to designate the gutta-percha plant *isonandra gutta*—the name by which it is now known. The tree is from forty to seventy feet high, and from two to four or even six feet in diameter. It is found all up the Malayan peninsula, as far as Penang, and its favorite localities are the alluvial tracts on the foot of hills, where it forms the principal portion of the jungle. In its general aspect, says Dr. OXLEY, it resembles the Durian—*Durio Zibethinus*, Linnaeus—so much so as to strike the most superficial observer. The trunk is straight; the leaves alternate; their upper surface of a pale green, and their under covered with a close, short, reddish-brown hair. The flowers are axillary, from one to three in the axils, supported on short curved pedicels,

Fig. 249.



and numerous along the extremities of the branches. The wood is described by HOOKER as peculiarly soft, fibrous, and spongy, pale-colored, and traversed by longitudinal receptacles of reservoirs filled with the gum, forming ebony-black lines. Fig. 249 is a portion of a branch of the gutta-percha tree, exhibiting also the leaves, flowers, and fruit.

There is no doubt that these are the characteristics of the tree from which the substance known as gutta-percha is obtained; but SEEMAN states that the gum termed by the Malays gutta-percha, is not the produce of the *isonandra gutta*, but that of a botanically-unknown tree, a species of *ficus*, and that the substance which has been improperly termed gutta-percha by Dr. MONTGOMERIE, and must now continue to be so called, is really the *gutta-taban*. It must ever be an object of regret, he remarks, that on the first introduction of the *taban gum*, its real name was not promulgated. The name, however, is now fixed beyond recall; and, to prevent misunderstanding, the reader has only to bear in mind that the substance known in Europe as *gutta-percha*, though stated by SEEMAN to be the *gutta-taban* of the Malays, is really the produce of *isonandra gutta* above-described.

EXTRACTION AND INSPISSATION OF THE GUM.—The sap or gutta circulates between the bark and body, in vessels, of which the course is well marked by black longitudinal lines upon the wood. To obtain the juice, it was formerly the practice, as already stated, to cut down the full-grown tree close to the root; rings were then made in the bark at distances of about twelve to eighteen inches apart, and a cocoa-nut shell, spathe of a palm, or such like receptacle, was placed under the fallen trunk, to receive the milky sap that immediately exuded upon every fresh incision. The quantity of gutta obtained from each tree so destroyed varied from five to twenty cattie; so that taking the average of ten cattie, it would require the destruction of ten trees to produce one picul, or one hundred and thirty-five pounds of gutta.

Fortunately, experience has now taught the natives that the milky juice may be collected by cutting notches here and there in the trunk of the living tree, and that in this way it may be preserved for future tapplings. This more economical method is rapidly gaining ground; and, considering the vast extent of territory occupied by the tree in its several varieties, and that European industry is now so deeply interested in its culture and preservation, there is little danger of the supply becoming exhausted.

The sap coagulates in a few minutes after it is collected; but before the crude gum becomes quite hard, it is kneaded by hand into compact oblong masses, from seven to twelve inches in length, by four or five in thickness. This part of the work is mostly performed by women, as represented in the annexed engraving—Fig. 250—which exhibits not only the ordinary appearance of the native Malays, but the character of the internal forest scenery of the tropical regions which they inhabit.

Dr. OXLEY's account differs somewhat from the preceding. He states that the sap, instead of coagulating and being made up into blocks on the spot, is collected in bamboos, taken by the natives to their houses, and boiled, in order to drive off the watery particles and inspissate it to the consistence it finally assumes. He adds, however, that although the process of boiling appears necessary when the gutta is collected in large quantities; yet, if a tree be freshly wounded, a small quantity allowed to exude, and it be collected and

moulded in the hand, it will consolidate perfectly in a few minutes, and have all the appearance of the prepared article. The apparent discrepancy between the

Fig. 250.



two statements may perhaps be explained by the fact, that Dr. OXLEY's account was written when the trees were uniformly felled to procure the juice, and when the latter was, therefore, collected in considerable quantities at a time, which rendered boiling necessary; whereas, when slowly collected in smaller portions from a number of living trees, the watery ingredient will evaporate as the juice exudes, and, with the assistance of kneading or moulding by the hand, that consolidation will take place to which Dr. OXLEY alludes as occurring in the case of small quantities.

PROPERTIES.—Gutta-percha, when quite pure, is of a greyish-white, but, as brought to market, it is more ordinarily found of a reddish-brown hue, arising from chips of bark that fall into the sap in the act of making the incisions, and which tinge it. It may be readily obtained in a pure state by dissolving the crude gutta in sulphide of carbon, filtering the turbid and brown solution under a bell-glass, and evaporating the filtrate by simple exposure to the air in a flat porcelain dish. After desiccation, the thin plate or cake of purified gutta is easily detached from the vessel by covering it for a few minutes with cold water, which destroys the adhesion. Nearly the whole of the extraneous tinctorial matter remains on the filter, with a portion of the undissolved substance.

Thus februated, the gutta is almost white, is semi-translucent in thin leaves, but opaque in thicker plates; it is greasy to the touch, and has a peculiar leathery

smell, somewhat similar to that of india-rubber. Its specific gravity, as determined by Dr. A. ADRIANI, was 0.999 at 68°, when subjected to the action of an air-pump to remove the adhering water-bubbles; without this precaution, it was only 0.728. A specimen of gutta-percha mechanically purified, and shaped in cakes, was found to have a specific gravity of 0.966°. The average density of the commercial article is 0.975°. The great variations in its density under different treatment imply a peculiar porosity in its structure, which was experimentally verified by PAYEN. Having placed a drop of its solution in bisulphide of carbon on a slip of glass, and allowed it to evaporate in the manner above-described, so as to obtain a thin film of the substance in a state of purity, he observed with the microscope numerous small holes or cavities, which were rendered still more visible by a drop of water; the liquid gradually insinuating itself, and rendering the film more opaque, while the cavities were observed, by means of the lens, to be enlarged. Similar results were obtained by keeping immersed in water for a considerable time, thin transparent laminae, obtained by the evaporation by heat of a solution of gutta-percha.

It was these observations which led this eminent chemist to conclude that the common commercial gutta-percha, retaining, in consequence of its porosity, a great many minute particles of air, owed to this circumstance its appearance of possessing a less density than that of water. In fact, on stretching gutta-percha under strong pressure, and immediately cutting the strips thus produced into very small pieces under water, the greater part of the fragments fell to the bottom of the vessel—some immediately, others absorbing a certain quantity of moisture. The same result was also obtained by keeping very thin leaves of gutta-percha, prepared by different methods, immersed in water deprived of air; their pores being gradually filled with the liquid, they became heavier than it, and then ceased to float. Gutta-percha is also heavier in proportion to the length of time it has been exposed to the air, particularly in thin leaves.

The porosity of gutta-percha, which allows a slow transudation of liquids through its mass, is the principal drawback to its use when formed into bottles or other vessels for holding chemical fluids. This porous structure becomes changed into a fibrous texture when it is drawn out so as to double its length; then, retaining little extensibility, it supports, without breaking, the action of a force equal to double that required for its elongation in the first instance.

Gutta-percha is a bad conductor of both electricity and heat. When rubbed it becomes negatively electric, and if dry, is an insulator equal in efficiency to shell-lac. Hence, among many other important applications, which will be noticed afterwards, its extensive employment in the covering of wires for the submarine telegraph.

But the great peculiarity of this substance, and that which makes it so eminently useful for many purposes, is the effect of heat upon it, applied either directly, or through the medium of boiling water. At ordinary temperatures it is a tough inelastic substance, and cold water has no effect upon it; from 32° to 77° it possesses about as much tenacity as thick leather, with rather

less flexibility; towards 120° it softens, and becomes sensibly doughy, although still very tough; and when raised above 150°, either by exposing it to the fire or by immersing it in hot water, it becomes soft and plastic, so as to be capable of being moulded to any required shape or form, which it retains upon cooling. Its ductility is such that, at a temperature of from 150° to 240°, it is readily extended into thin sheets, or drawn into threads or tubes; its flexibility and ductility diminish as the temperature becomes lower. It does not possess, at any temperature, the peculiar elastic extensibility which characterizes caoutchouc. When cold, it again becomes hard, and possessed of extraordinary tenacity.

It melts at 248°, and may be made to boil without acquiring a sensible color; the transparent fluid gives abundant vapors, which are condensable into a nearly colorless oily liquid. The portions last distilled have a brownish-orange hue, and a thin layer of carbonaceous deposit remains adherent to the sides of the vessel. Heated beyond this point, it is decomposed, yielding inflammable products; a strip of it cut off burns with a bright flame, emitting sparks, and dropping a black residuum in the manner of sealing-wax, which in its combustion it very much resembles.

Common gutta-percha is perfectly insoluble in water at any temperature; it effectually resists damp, and hence its valuable applications as a waterproofing material, and as a substitute for leather in soling boots and shoes. It likewise withstands the various influences which excite fermentation, but experiences a sort of doughy fusion when exposed to the direct action of the solar rays in summer. Soda and potassa, even when caustic and concentrated, ammonia, saline solutions of all kinds, water containing carbonic acid, the various vegetal and mineral acids, do not act upon it. It is not affected by fermented liquors, such as wines, beer, *et cetera*; even alcohol scarcely dissolves a trace of it. Olive-oil has no action upon it when cold, but when hot, it dissolves a small portion of it, which is again precipitated on cooling.

Concentrated nitric acid attacks gutta-percha rapidly with effervescence, and an abundant evolution of fumes of nitrous acid; the gutta is disintegrated, and colored of a brownish-orange red; it becomes doughy, and afterwards solidifies by degrees, but remains friable. Concentrated sulphuric acid produces the same effect more gradually, rendering it brown, and causing its disintegration, with a sensible evolution of sulphurous acid. MILLER affirms that hydrochloric and dilute hydrofluoric acids have no action upon it; hence it is employed in the preparation of bottles and vessels used for containing these liquids; but PAYEN states that hydrochloric acid, in its saturated solution in water at a temperature of 68°, attacks gutta-percha slowly, and gives it a more or less deep-brown color, at length rendering it brittle.

The same chemist remarks that, in the cold, and even by heat, not more than 0.15 to 0.22 of the gutta-percha is dissolved by anhydrous alcohol or ether; but ARPPE states that thirteen per cent. of gutta-percha is dissolved by alcohol, and that, separated from mechanical admixtures, it is *soluble in ether which is free from alcohol*,

whereas, *if it has been previously treated with alcohol, it does not dissolve in ether*. This observation, which seems to have been overlooked by M. PAYEN and other chemists, has an important bearing on the analysis of gutta-percha.

Benzol and oil of turpentine dissolve gutta-percha partially when cold, but almost completely by heat. One part of the gutta requires for its solution from four to six parts of oil of turpentine. Bisulphide of carbon and chloroform dissolve it cold, and by either of these solvents it may be obtained pure in the manner already described.

ELEMENTARY COMPOSITION.—Gutta-percha is, like caoutchouc, a carbide of hydrogen, and nearly isomeric with that substance, as the following analyses will show:—

	Gutta-percha.	Caoutchouc.
Carbon,.....	86.36	87.2
Hydrogen,.....	12.15	12.8
Oxygen,.....	1.49	—
	100.00	100.0

It is a question indeed whether the elementary composition of the two substances is not precisely the same, the small quantity of oxygen detected by Dr. MACLAGAN in gutta-percha being probably derived from the air during the process of purification. Its acknowledged porosity, and the difference in its specific gravity under different conditions, are facts which afford a strong presumption in favor of this view.

But like other isomeric substances, gutta-percha and caoutchouc, though strikingly similar in many of their properties, and more especially in their resistance to the action of most chemical agents, differ considerably in other respects, and this must be attributed to the different grouping of their elementary constituents, if not to the actual presence of oxygen as one of the essential ingredients of gutta-percha.

Professor PAGE states that gutta-percha, when rolled into thin sheets or drawn into ropes, comports itself like a fibrous substance, which is not the case with caoutchouc. A strip cut from a thin sheet of gutta-percha may be stretched considerably in one direction, that is, in a line with the fibre, but any attempt to stretch it across this is followed at once by a rupture. It is not so with a sheet of caoutchouc, which will stretch *equally well in all directions*. On examination of sheets of these two substances—so far believed to be *isomeric*—a marked difference of texture is at once perceived. The caoutchouc gives little or no change of color, while the gutta-percha exhibits a beautiful spectacle. It appears to be built up of prisms of every variety of hue, and, as it were, fused into each other. Professor PAGE states that it resembles more nearly some specimens of ice which he had examined, than anything else. The caoutchouc and gutta-percha must be kept under considerable tension during the examination.

PROXIMATE PRINCIPLES.—PAYEN states that purified gutta-percha is formed of three proximate principles, very different from each other as regards their properties, but isomeric as regards their elementary composition, and also isomeric with purified caoutchouc, being all of them carbides of hydrogen, and

each represented by the formula $C_8 H_7$. These three proximate principles, which he terms *gutta*, *albane*, and *fluavile*, he describes as being found in gutta-percha in the following variable proportions :—

	Centesimally.
Gutta,	78 to 82
Albane,	16 to 14
Fluavile,	6 to 4
	100 100

PAYEN commenced his experiments by submitting the gutta-percha to the action of alcohol. Reduced to thin leaves, it was treated, in a close vessel, with fifteen to twenty volumes of cold anhydrous alcohol; the heat was raised slowly, by means of the water-bath, to the point of ebullition, 172° , and kept at this temperature during several hours; the liquid was then filtered whilst boiling, and left in a closed flask, when it was found, at the end of from twelve to thirty-six hours, to begin to deposit on the sides of the vessel, and on the surface of the solution, white opaline granules, distant from one another, but some of them in groups; their size gradually increasing for some days. These granules, carefully examined under the microscope, were found to have the form of spherules truncated by the sides of the vessel. Their surface was either smooth or bristling with very small, transparent, elongated, lamellated crystals. Some superficial fissures appeared to indicate that these spherules were formed of a sort of transparent yellow nucleus, covered with a white pellicle; and PAYEN ascertained on examination that such was really their singular crystalline structure, of which perhaps no other example is known. He found also that cold anhydrous alcohol dissolved the whole of the yellow internal spheroidal substance, while the superficial pellicles, in the interior of which the alcohol had then substituted itself for the solid yellow globules, appeared consequently whiter and more transparent. The alcoholic solution, which had been for some days depositing this complex spheroidal crystallization, was again capable of taking by heat a further portion of the two proximate principles remaining in the substance, allowing a fresh quantity to crystallize on cooling, and thus to be developed respectively in the white pellicle and yellow nucleus. The extraction was completed by returning the boiling alcohol several times upon the gutta-percha till nothing more was dissolved.

The solid substance, which entirely resisted the action of the alcohol, possessed, with some modifications, the principal properties of crude gutta-percha; and this is what PAYEN termed *pure gutta*, or simply *gutta*. Of the two other organic principles developed by the method which he adopted, the *white crystalline resin* which covered the spherules was what he called *albane*; and the *yellow resin*, which was much more soluble in cold alcohol than the other, was the substance which he termed *fluavile*. The commercial varieties which he examined gave him the proportions above stated; their special properties were as follow :—

1. *Pure Gutta*.—It will be seen that the most abundant of the three principles distinguished by PAYEN is the so-called *pure gutta*, or that portion insoluble in

alcohol, and which is described by the same chemist as being insoluble in ether. M. PAYEN probably failed to effect its solution, from the circumstance that he employed the same gutta which had previously been treated with alcohol; in that case, according to M. ARPPE, it is not dissolved by ether.

PAYEN describes his *pure gutta* as presenting the principal properties of the commercial substance. It is white, transparent at a temperature of 212° , when all its parts are melted together; opaque or semi-transparent when cold, from its then acquiring a structure which causes the interposition of air, or of a liquid possessing a different refraction from its own. He states that this structure appears still more distinct than in the natural substance containing all these principles. In thin sheets, and at a temperature of 50° to 86° , it is supple, tough, extensible, but not very elastic. At 112° it softens and turns back upon itself, and becomes more and more adhesive and translucent in proportion to the elevation of temperature, undergoing a sort of doughy fusion, which becomes more distinct towards 212° to 230° . Heated beyond this point, it melts, boils, and distils, furnishing a pyrogenous oil, and eliminates carbides of hydrogen. Its behavior with acids, alcohol, and oils, chloroform and bisulphide of carbon, is the same as the commercial article.

After the extraction, by means of ether, of the two resins contained in the thin leaves of white or purified gutta-percha, leaving the last portion of ether with which they were impregnated to evaporate in the open air, these leaves, inclosed in a flask, experienced, after remaining there for two months at a temperature of from 68° to 82° , an alteration which appeared to depend on their porosity, the action of the air, and perhaps the ether retained in their pores. However it be, these leaves had then acquired new properties; they were brittle; exhaled a very distinct sharp odor; brought into contact with an excess of anhydrous ether, they were partially dissolved; the soluble portion obtained by the evaporation of the ether, and exsiccation at 194° , was glutinous and translucent; it became opaque and hard by cooling down to 14° .

The same chemist states as a fact which he had personally ascertained, that thin leaves, exposed for eight consecutive days to the action of the sun in moist air, were discolored, and that their substance had become in great part soluble in ether.

2. *Albane*.—The albane, or crystalline white resin, presents itself as a light pulverulent mass, apparently opaque, which, under the microscope, exhibits thin transparent lamellar crystals. From 32° to 212° it does not experience any sensible change; its fusion commences at 320° ; at 347° to 356° it acquires an oleiform fluidity and complete transparency, without any noticeable color; it solidifies on cooling, shrinks, which causes it to split, and remains transparent and a little heavier than water.

The crystalline resin is not attacked or readily moistened by either cold or boiling water; or by hot or cold caustic alkaline solutions, ammonia, and the various dilute acids. Monohydrated sulphuric and nitric acids attack it rapidly, producing similar phenomena to those observed in their action upon pure gutta.

Hydrochloric acid, on the contrary, does not act upon the white resin.

3. *Fluavile or yellow resin.*—This amorphous transparent resin, of a lemon or orange color, according to its thickness, is a little heavier than water, solid, and even hard and brittle at 32°; it gradually becomes more flexible in proportion as the temperature is raised; at 122° it becomes pasty; it does not become completely fluid below 212° to 230°. Heated beyond this point it boils, but then gradually undergoes considerable alteration, becomes brown, and evolves acid fumes and carbides of hydrogen. It strongly retains the alcohol in which it has been dissolved; but is separated from it by heating *in vacuo* to 212°, until bubbling entirely ceases.

This resin is soluble in the cold in alcohol, ether, benzol, turpentine, bisulphide of carbon, and chloroform: all these liquids, when evaporated, leave as residue the amorphous resin. Dilute acids, concentrated alkaline solutions, and ammonia, do not attack the yellow resin. Monohydrated sulphuric and nitric acids act upon it rapidly, producing phenomena analogous to those exhibited with the other two principles. Hydrochloric acid, even in its saturated solution at 68°, is without action upon it. But the most remarkable character of this resin is the power of forming, under the circumstances already indicated, those globose crystals covered with a white pellicle of another resin, and presenting in their complex form the appearance of opaline spherules.

MANUFACTURING PROCESSES.—It has been stated that the gutta-percha, after its extraction from the tree in the form of a milky juice, is first allowed to coagulate, and then made up into lumps or blocks of some pounds' weight. These, as they arrive in Europe, are far from being pure, for besides containing chips of bark, leaves, and other adventitious substances which fall accidentally among the juice, the natives make no scruple of introducing stones, earth, and other rubbish, to increase the weight of the blocks. The first and most essential process in the manufacture of gutta-percha is, therefore, its purification; and in fact, ever since its introduction into Europe, gutta-percha has found everything provided for the purpose of cleansing it, being worked by processes and instruments very similar to those which had been previously employed in the purification of india-rubber. It is also vulcanized, and cut or moulded into different shapes, in much the same manner. The general nature of the operations may be briefly described as follows:—The blocks of gutta-percha being first cut into slices by revolving knives, are softened by means of hot water, and then divided and torn into shreds by the same machine that is used for india-rubber, which serves also to knead the gutta-percha in such a manner that the crushed stones and earth may be separated from it on being diluted in the water; it is then dried, and submitted, by means of a powerful machine, to a mastication similar to that which caoutchouc is made to undergo; and when, after some hours of kneading, the mass has become homogeneous and sufficiently softened, it is extended by the drawing-mill into cylindrical cords, moulded into tubes of various diameters, or spread out by means of the flattening machine into sheets of dif-

ferent thicknesses, which are finally divided into bands or slivers, and from these are cut out with a nipping tool the pieces which are required to be employed in different uses.

These various operations, together with the vulcanization of gutta-percha, will now be described successively and in detail—premising that in this country the manufacture is confined to two or three companies, which work the various patents secured from time to time by Mr. HANCOCK and others. A simple description of the manufacture, as conducted by the London Gutta-Percha Company, will, therefore, embrace all that is really important in the different operations.

PURIFICATION.—*The Cutting Machine.*—When a visitor enters the works of the Gutta-Percha Company, he observes in the yard or court the imported blocks of the raw material piled in great heaps. These blocks, when they are required for use, are first taken from the heaps to the cutting or slicing machine, which is a large solid vertical disc of iron, armed on one side with sharp knife-edges, and revolving at the rate of two hundred turns per minute against the extremity of a sloping iron table. The block of gutta-percha being brought to the edge of the table, is rapidly caught by the knives, and literally reduced to shavings, which fall into a receptacle beneath.

Fig. 251.

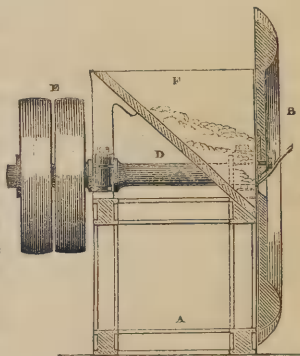
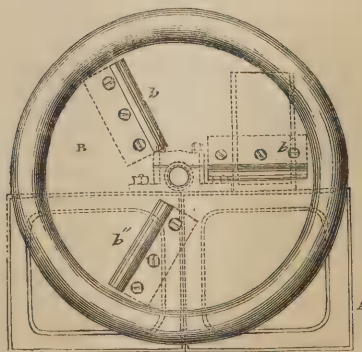


Fig. 251 is a side elevation of this machine, and Fig. 252 a front elevation of the disc, with part of the frame. The revolving disc, B, is a circular iron plate, of about five feet diameter, into three slots in

Fig. 252.



which are inserted three radial knives, *b*, *b*¹, *b*², in a similar manner to the iron of an ordinary plane or spoke-shave. Supported by the frame *AF* is the shaft *D*, to one end of which the plate *B* is attached, and to the other the strap-pulleys *EE'*, by one of which motion

is communicated to the shaft from a steam-engine, or any other convenient first mover. *c* is an inclined shoot, down which the lumps of crude gutta are dropped against the knives of the revolving disc, and are cut into slices of a thickness corresponding to the degree of projection given to the knives.

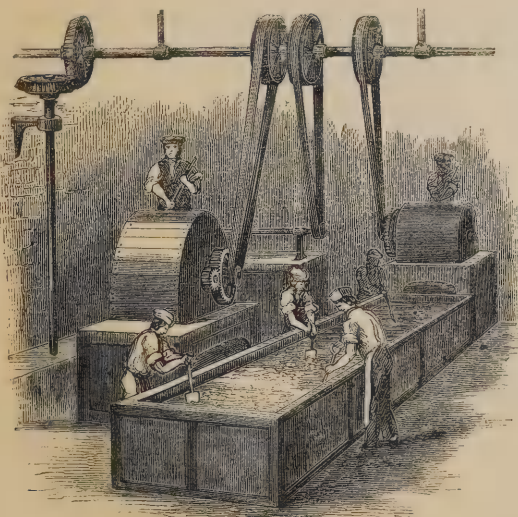
The knives are represented in Fig. 252 as being straight, but Mr. HANCOCK, the patentee, states in his

Fig. 253.



specification, that where the gutta-percha to be cut happens to be of a more than usually hard or intractable character, he finds it advantageous to substitute knives of a curved or reaping-hook form, on account of their more gradual mode of action. The machine, which is

Fig. 254.



put in motion at the Gutta-Percha Company's works through the agency of two fifty horse-power engines, is represented as in operation in Fig. 253; and it may be remarked, in passing, that the stones and other

adulterative materials which the cupidity of the Malay gatherers has added to the mass, are often discovered by this process, very much to the injury of the cutters.

First Boiling and Teasing.—Having been reduced to shavings, the gutta-percha must next be perfectly cleansed of the dirt, leaves, and other extraneous matter. This is effected by throwing the shavings into a large tank containing water, as shown in Fig. 254, to which the waste steam of the engine is conveyed, for the purpose of boiling. This process softens the whole into a fluid mass, and separates the more considerable impurities, which, by the agitation of the boiling, sink to the bottom. The greater part of the rubbish having thus subsided, the partially-purified gum is collected into one mass, and carried to what is called the *teaser*—a sort of large circular box, containing a cylinder or drum covered with rows of bent jagged teeth. Two of these machines are represented in the same figure. Revolving at the rate of about eight hundred turns in a minute, the teaser quickly tears the mass into shreds, which fall into a vat of water beneath. Here the gutta-percha, being in its naturally porous state lighter than water, floats upon the surface, while the impurities disengaged from it by the action of the teaser fall to the bottom. The gutta-percha is now cleansed from all impurities; it has a crisp and fresh-looking appearance, and is ready for the next operation, which consists in working and kneading it into a homogeneous mass.

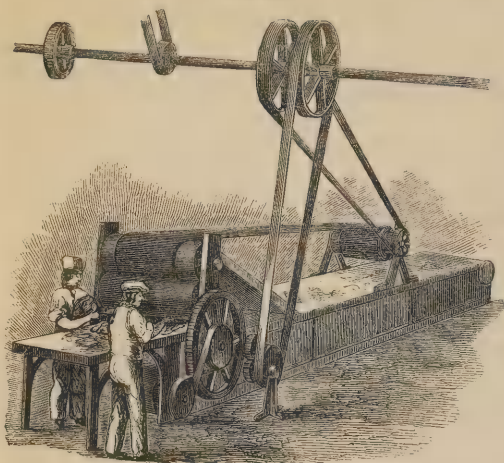
Second Boiling and Kneading.—The operation of teasing is followed by a second boiling, which has the effect of blending the fragments of the now purified substance into a warm soft mass, and in this state it is introduced into the *kneaders* or *masticators*, which are thick, strong, circular iron boxes, about three feet long and a foot and a half deep, containing revolving cylinders armed with cogs or pins on their surface. The cylinders and their containing boxes are of cast-iron, and are heated by steam. The gutta-percha, when introduced, is thus kept in a soft state, and being carried round by the action of the revolving cylinders, it is forcibly squeezed against the sides of the box; while, by the action of the cogs or pins, every air-bubble is expelled, and the whole is brought to a perfectly homogeneous mass of uniform consistency, without a particle of water in its composition.

In April, 1853, a patent was taken by Mr. NICKELS for using two rollers with screws on their surfaces, in place of teeth or projections, for masticating or kneading. The rollers work parallel, and nearly up to each other; and in each of the threads of the screw-rollers there are notches, which the patentee prefers to be made in a diagonal direction. This form of machine is considered the most effective, and is now most commonly used.

ROLLING INTO SHEETS.—In the state in which the gutta-percha comes from the kneading or masticating machine, it is ready for being manufactured into different shapes, and, with this view, it is now rolled into sheets, or pressed out into tubes. The first operation is required to prepare it for its subsequent conversion to most of the useful and ornamental purposes to which it is applied; and, with this view, the kneaded mass is

carried to the *rolling machine* represented in Fig. 255. This apparatus is similar to that employed in paper-mills, the gutta-percha, like the soft paper, passing on

Fig. 255.



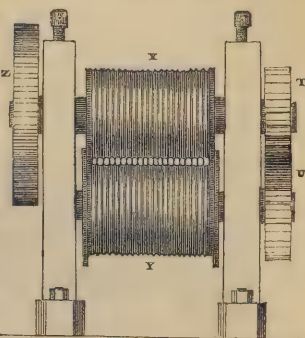
an endless band between steel cylinders placed at the requisite distances apart, according to the thickness of the sheet required. By means of screws the cylinders can readily be adjusted to produce with equal ease the stoutest driving band, or the thinnest *gutta-percha tissue*, so successfully employed as a substitute for oiled silk, hydropathic bandages, *et cetera*. After passing between the rollers in a soft and impenetrable state, the sheet performs a long journey on the endless band, in the course of which it gradually cools and hardens, and finally appears at the other end a smooth, firm, flat sheet, which admits of being received and wound on a drum till the requisite length has been worked off. If, however, the sheet be too thick to cool sufficiently by merely travelling the prescribed distance, it is ventilated, as it passes along, by a series of fans like those of a winnowing machine.

DRAWING RIBANDS AND CORD.—When the material is required to be in bands or strips, it is generally cut into that form, while being rolled into sheets, by a series of knives so placed as to divide the sheet while yet plastic into any number of bands of the required width, just before quitting the rolling machine. The knives are set upright in a frame, edge foremost, at the requisite distances from each other, and, without interrupting the progress of the sheet, they slice it into bands, which, as before, are made to travel till they cool, and are then wound upon a drum.

In 1847, an ingenious machine was patented by Mr. CHARLES HANCOCK for cutting gutta-percha into narrow ribands, and manufacturing it into thread or cord of any required shape. A front elevation of as much of this machine as is necessary to understand its construction, is given in Fig. 256, in which *x y* are two grooved rollers, made of steel or iron, and mounted in suitable framework. The grooves of each roller are semicircular, so that when the grooves of one roller are brought opposite to those of the other, they form together a series of circular holes, as shown in the

figure, at the line of contact between the two rollers. The under roller is flanged at both ends, and the two ends of the upper roller are made to fit inside of these flanges, in order to keep the cutting edges from shifting or being damaged. From the prime mover, motion is communicated to the toothed wheel, *z*, on the shaft of the roller *x*, and thence through the wheels *t* and *u*, to the roller *y*. To cut thin sheets of gutta-percha with this machine into narrow strips or ribands, the material is passed through it cold, and only the cutting edges are brought into operation. To make round thread or cord by means of it, a sheet of gutta-percha, of a

Fig. 256.



thickness equal to the diameter of the holes formed by the grooves of the rollers, is passed through it at a temperature of about 200°, by supplying the material from a feeding chamber, heated to that degree by steam or otherwise; and the threads or cords, after passing between the rollers, are received in a tank of cold water, from which they are wound on reels or drums, conveniently placed for the purpose. Or, by another method, the gutta-percha is employed in a plastic state, and passed towards the machine under a gauge, after the manner employed in the caoutchouc manufacture.

Should it be desired to produce cord of a semicircular section, the lower grooved roller is replaced by a plain roller; or should cord of a form neither circular nor semicircular, but square, triangular, hexagonal, or of any other angular form be required, two cylinders are employed, grooved in such a manner as to produce the desired shape.

Cord and thread are likewise manufactured by means of a stamp, bearing a number of close parallel sharp edges, which are brought down upon a sheet of gutta-percha so as to cut it nearly through in a series of corresponding parallel lines. The narrow slips are then severally torn off, and polished up by hand for use.

CUTTING, SHAPING, AND MOULDING.—Besides the operations above-mentioned, the gutta-percha, when formed into sheets, admits of an infinite variety of applications. Softened by boiling water or steam, it may be shaped into any required form by the hand, the knife, the mould, and the press. The numerous workshops in the establishment of the Gutta-Percha Company are crowded with men and boys engaged in various operations. One apartment is occupied as the cutting and stamping room, and here the paper-cutting machine, invented by Mr. WILSON, is brought into extensive use, while moulds of every description are being employed to produce the different articles. If shoe-soles are required, the cutting machine is brought down upon a pile of stout broad bands, dividing a dozen of them at one operation into rectangular pieces, which are afterwards cut *en masse* into the required

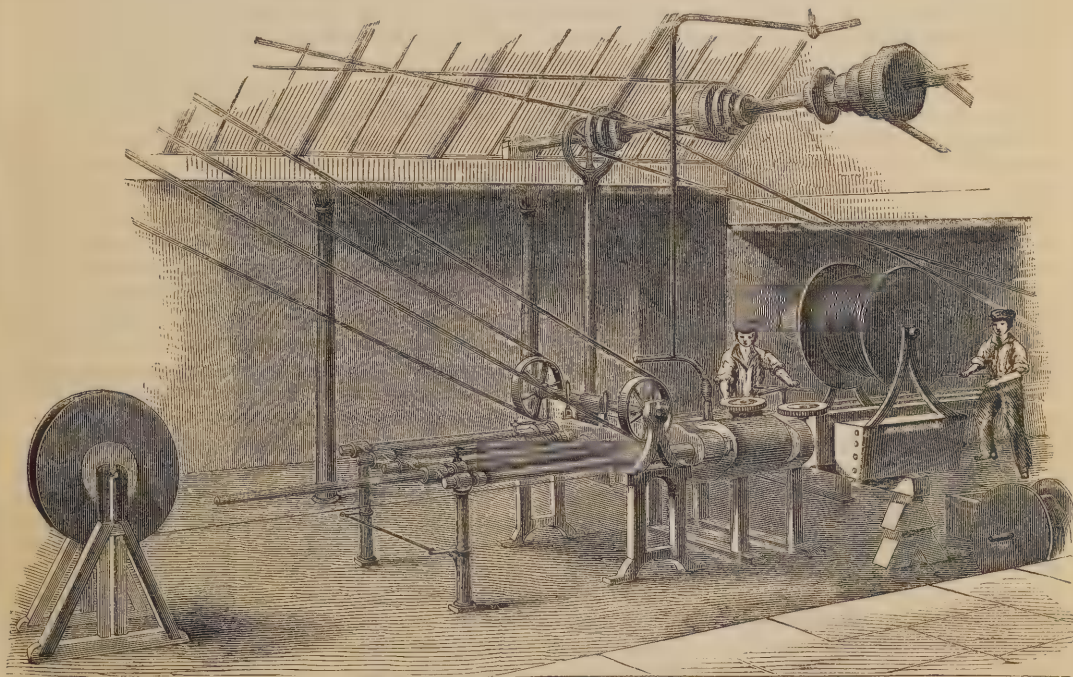
shape by means of a sharp-edged frame. In one place are seen revolving tables, bearing inverted iron moulds, from which workmen are turning out buckets, bowls, bottles, and mariners' hats, while others are moulding bosses for flax-mills, rings, whips, *et cetera*. In one apartment cisterns and trunks for emigrants are being lined; in another, ornamental mouldings, medallions, pen-trays, ink-stands, picture-frames, and other fancy articles, are stamped from electrotype copper dies or wooden moulds. For the stamping or moulding, the sheets are cut into pieces, and each piece is warmed sufficiently to take the impress of the die.

GUTTA-PERCHA TUBING.—Perhaps the most important use to which gutta-percha has been applied is that of tubing, in which form it is extensively used for pump-barrels, ship-pumps, feed-pipes for locomotive engines, siphons for mines, suction or ejection pipes for fire, garden, and washing engines; and, being unaffected by acids, it is also available in this form for bleaching with chlorine and other chemical purposes. Accordingly, while the process of sheet-rolling, already described, forms the basis of a large department of the manufacture, the making of tubes constitutes another important and distinct department—the tubes being formed directly from a softened mass of the purified material, which has passed through the kneading or masticating machine. The process, while highly inge-

nious, is exceedingly simple. The softened material is forced by a piston through a steel cylinder, terminating in a mould that consists of a solid circular piece of metal set within an iron tube, the space between the two being the thickness required. The gutta-percha thus leaves the mould in a tubular shape, but would immediately collapse unless subjected, until it cools, to an even pressure both within and without. To accomplish this, it is received from the mould into a canal of water about fifty feet in length, along which it travels, being wound off upon a drum at the other end. The water, filling the interior, and pressing equally upon the outside of the tube, preserves it in perfect shape while it speedily cools it into hardness. The feeding cylinder is so contrived as to admit of being constantly replenished with new material, so that a tube of one thousand feet has been manufactured without a single break, being the longest ever made in one piece of any substance whatever.

COATING TELEGRAPH WIRES.—Another application of gutta-percha, which may vie in importance with that of tubing, though not of such varied usefulness, is that of covering wires for telegraphic purposes. In this respect its high insulating power, combined with its flexibility and imperviousness to water, render it of essential service; and, indeed, it may be doubted whether the submarine lines of telegraph, uniting dif-

Fig. 257.



ferent nations, islands, and continents, could have existed at this day without the valuable assistance rendered by gutta-percha. Its introduction into Europe, contemporaneously with the inauguration of these magnificent projects, by which the earth is being girdled with wires of living intelligence, can scarcely be re-

garded otherwise than as an express dispensation of an overruling Providence to advance the progress of civilization and human happiness. A good piece of gutta-percha, says Dr. FARADAY, will insulate as well as an equal piece of shell-lac, whether it be in the form of a sheet, a rod, or filament; but being tough and

flexible when cold, as well as soft when hot, it will serve better than shell-lac in many cases where the brittleness of the latter is an inconvenience.

A thin coating of gutta-percha may be communicated to a wire by drawing it through a glass or metal tube, filled with gutta-percha in solution, or rendered fluid by heat; but for the conducting wires of the electric telegraph, whether intended to be buried in the earth, or to form the core of a submarine telegraph cable, the coating, to insure perfect insulation, must possess considerable thickness, varying from one-sixteenth to upwards of one-eighth of an inch.

Accordingly, telegraph wires are now coated in much the same manner, and by mechanism much the same in principle, as that employed for moulding tubes. This will be seen from the preceding woodcut, Fig. 257, which exhibits in actual operation the machinery employed by the Gutta-Percha Company for coating the wires of the great Atlantic cable. The central conducting wire of this cable is *a strand* made up of seven wires of the purest copper of the gauge known in the trade as No. 22; it is about the sixteenth of an inch in diameter, and is formed of one straightly-drawn wire, with six others twisted round it. This strand received a coating of three separate layers of refined gutta-percha, which together bring its diameter up to about three-eighths of an inch. The gutta-percha employed for this great work was prepared with the utmost possible care. Lumps of the crude substance were first rasped down by a revolving toothed cylinder, placed within a strong hollow case. The raspings were then passed between rollers, macerated in hot water, and well agitated. They were next washed in cold water, and then, by means of a hydraulic apparatus, driven at a boiling water temperature through wire-gauze sieves, attached to the bottom of hollow vertical cylinders. Emerging from the sieves in plastic masses of exceeding purity, the gutta-percha was then submitted to the powerful action of the masticators already described, to expel from the purified substance the last traces of water, and to render it sound, compact, and homogeneous throughout. When thoroughly masticated and kneaded, it was then introduced into the horizontal cylinders, shown in the drawing; and through these, which were heated by steam to keep the gutta-percha in a uniformly soft and plastic state, it was squeezed by means of screw pistons, worked down slowly but resistlessly by the machinery. Under this pressure the gutta-percha emerged, as in tube-moulding, through a die, which received the termination of two cylinders, and which at the same time had the strand of copper wire moving along through its centre, instead of being stationary like the mandril in tube-moulding. The strands were drawn forward between the cylinders and through the die by a revolving drum. They entered the die in the form of bright copper wire, and issued from it like brown tubes or cords of gutta-percha. Six of these strands are represented in the drawing as being coated together, ranging along side by side; and this operation was repeated a second and third time, to produce what is termed *the core* of the Atlantic cable.

PATENT MOULDING.—In March, 1855, a patent was

taken by Mr. CHARLES GOODYEAR for ingeniously extending the principle of the apparatus above-described to moulding of every description; in other words, the machine which he employs is constructed in a similar manner to those now employed for coating telegraph wires, and for moulding tubes. Like these, it consists of a cylinder or barrel, into which the gutta-percha is introduced, and into the cylinder or barrel a piston works, being operated on by a screw or rack-and-pinion, or otherwise. In this case, also, the cylinder is enveloped in a steam-jacket to keep the contained material at a suitable temperature, and in the end of the cylinder is formed a nozzle or orifice, through which the contents are *forced into the mould* by the motion of the piston. The moulds are constructed of two or more pieces of metal, which are held together with bolts and nuts; they are formed with a suitable interior configuration for producing the article desired; and there are two or more passages which lead into the cavity, the largest of which is for the purpose of allowing the plastic substance to pass into the mould, and the others for allowing the air contained in the mould to escape. When the piston advances, it forces the gutta-percha from the barrel or cylinder into the mould, until it begins to escape from the air orifices. The piston is then arrested, and the mould, when removed and emptied, is ready to be again filled.

VULCANIZED GUTTA-PERCHA.—Among other properties in which gutta-percha strikingly resembles caoutchouc, is the change which it undergoes when intimately mixed with sulphur or its compounds, and afterwards submitted to a somewhat elevated temperature in close vessels. By this *vulcanizing* treatment, as the process is termed, it is rendered, like caoutchouc, less readily affected by changes of temperature, and more permanently soft and elastic, so as to be better fitted for bands and other purposes. To effect this remarkable modification, it is subjected to precisely the same methods of treatment as caoutchouc, and, indeed, it is frequently combined with that substance to give it the pliancy and elasticity required for some of its applications. Accordingly, most of the patents which have been taken in connection with this subject, are not confined to gutta-percha, but embrace also caoutchouc and various combinations of these with each other, as well as with other substances.

In Vol. I., pages 448 and 449, of this work, there are two methods described of vulcanizing caoutchouc—one of which consists in kneading it with sulphur or its compounds; the other, in immersing it in liquid compounds which hold sulphur in combination, and afterwards, in both cases, exposing it to the requisite heat. Gutta-percha may likewise be vulcanized by either of these methods, or by exposing it to the action of a mixture of steam and sulphurous vapors in HANCOCK'S apparatus, which was patented in 1847, and is figured and described at the pages above referred to.

In March, 1846, Mr. ALEXANDER PARKES of Birmingham obtained a patent for vulcanizing caoutchouc and gutta-percha, by dissolving it in bisulphide of carbon, coal-naphtha, turpentine, or any other suitable solvent; preferring, however, the bisulphide of carbon for the purpose, along with chloride of sulphur. The caout-

chouc or gutta-percha, when taken out of the solution, is suspended in a drying-room or stove, heated to about 80°; and, when the solvent has evaporated, the gutta-percha is well washed in water, or boiled for one hour in a solution of caustic potassa or soda, containing one pound of the alkali to a gallon of water. The gutta-percha being then dried, is ready for use.

Mr. HANCOCK, in the specification of his first patent, of November, 1846, recommended the sulphurizing of gutta-percha by means of sulphides, such as orpiment or liver of sulphur, in preference to sulphur itself; and in that specification he stated, that though a portion of sulphur might be used in place of an equal portion of sulphide, yet he considered the use of sulphur to be altogether objectionable, because of its offensive smell and tendency to efflorescence. Subsequently, however, he ascertained, as stated in the specification of his second patent, of date February, 1847, that if a very minute portion of sulphur be used along with a sulphide, a better result is obtained from a combination of the two than from either substance alone. The proportions which he found best in practice were six parts of sulphide of antimony, sulphide of calcium, or some other analogous sulphide, and one part of sulphur, to every forty-eight parts of gutta-percha. When the mixture of these materials has been effected, he places the compound in a boiler, and raises it, under pressure, to a temperature of 260° to 300°, in which state he leaves it for a period varying from half an hour to two hours, according to the thickness of the materials; by which time it becomes completely vulcanized, or, in other words, *metallo-thionized*.

In August, 1851, a patent was taken by Mr. STEPHEN MOULTON, for applying to gutta-percha his process for vulcanizing caoutchouc with hyposulphite of lead, to which allusion has been made in the article CAOUTCHOUC, Vol. I., p. 450. The same process is applied to a combination of equal parts of gutta-percha and caoutchouc, as to either of these alone; and when it is desired to produce a hard-cured gutta-percha, or a hard composition of gutta-percha and caoutchouc, described by the patentee as similar to horn or ivory, he adds from two to twelve ounces of calcined magnesia to each pound of gutta-percha composition, alone or combined with caoutchouc. The whole is then exposed in a close vessel to steam or dry heat of from 250° to 300°, for a period of time which will vary from two to ten hours, according to the thickness of the material and the quantity of goods introduced in one mass. The patentee adds, that after the gutta-percha goods, whether in the form of coated cloth, sheet gum, moulded, or any other article, have undergone this process, which he terms *curing*, they will be found not only impermeable to wet, but extremely tenacious, possessing the elastic property of the cured caoutchouc, and also unaffected by changes of temperature.

In December, 1856, a patent was taken by Mr. EMORY RIDER of London, for improvements in the method of vulcanizing gutta-percha; the principal novelty of which consists in the addition of one part of sulphur, or an equivalent thereof in some of its compounds, and *one part of litharge*, to sixty-six parts of the gutta-percha, prior to the exposure of the latter to

a temperature of 235° to 245°, for the purpose of expelling the volatilizable ingredients. The sulphur or hyposulphite of lead or zinc, or the artificial sulphide of lead, or other compound of sulphur employed for this purpose, is first mixed with the gutta-percha, and then thoroughly incorporated by passing the mixture repeatedly between metallic rollers heated to a temperature sufficient to make the gutta-percha very soft, and easily kneaded or worked. The mode of effecting this, which Mr. RIDER states that he has found to be most beneficial in practice, is by the employment of a machine in which the rollers work at different degrees of speed, and produce a teasing or grinding action, which he regards as of considerable importance in working the material. After being thoroughly incorporated and ground, the material is placed in a strong metal vessel, which is filled to about one-third of its capacity, so as to leave ample room for the swelling or expansion of the compound under the action of heat. It is then exposed to a temperature of about 235° to 245° for about three hours, and for this purpose the patentee prefers steam-heat, by which he is enabled to subject the gum under treatment to a greater pressure, and to obtain a more regular degree of heat than by other means. He adds, that the gutta-percha, having undergone this preliminary heating, may be vulcanized by the application of a much lower degree of heat than has been ordinarily used in that process, and that he has found a temperature of 255° to 265° to be sufficient to effect the change.

RENOVATION OF VULCANIZED GUTTA-PERCHA.—The fact that caoutchouc or gutta-percha, or compounds of these substances which have undergone the change produced by the vulcanizing process, can in that state be only very partially acted on by solvents, and with difficulty wrought by any of the usual means employed when operating upon the natural substance, renders it necessary to mould and finish the articles before they are submitted to this process, or to vulcanize them in the moulds, having previously mixed the gutta-percha with the sulphur in the kneading or masticating machine. By the process of vulcanizing, properly so called, is meant the subsequent heating, which can be applied in the act of moulding, when the articles require to be submitted to that operation.

But that very circumstance which renders it impossible to shape or manufacture gutta-percha into new forms after it has passed through the vulcanizing process—namely, the difficulty of acting on the vulcanized material either by means of heat or the usual solvents—must entail a considerable loss in the shape of waste, unless it be possible by some expedient to renovate the vulcanized gum, and restore it to its original state. It was stated in the article CAOUTCHOUC, Vol. I., p. 448, that the separation of the sulphur from that substance presented so many difficulties that it had not yet been accomplished. It may here be remarked, however, that several attempts have been made to effect this desirable object, and that, so early as in 1846, Mr. PARKES proposed and patented a method which is attended with partial success. According to this method, eight or ten pounds of the waste-cuttings, or old and worn articles, either of caoutchouc or gutta-percha, are

boiled in twenty pounds of the chloride of calcium, for a longer or shorter period according to the thickness or bulk of the substance, until, by testing a few of the pieces, it is found to be in a state to be readily united by pressure. It is then removed from the bleaching liquor, and washed, first in a hot alkaline water, and afterwards in pure water, also hot, when he states that the substance may be re-manufactured, and again submitted to either of the vulcanizing processes already described.

In January, 1856, a patent was granted to Mr. NATHANIEL SHATTSWELL DODGE, for a method which is stated to be more effective, and by which, in the words of the patentee, scraps or waste pieces of vulcanized india-rubber, or vulcanized gutta-percha—such, for example, as old shoes, railway-buffers, carriage-springs, *et cetera*—may be rendered fit to be re-used or worked up into useful articles or fabrics, *without requiring to be re-vulcanized*. For this purpose, the material to be treated, if existing in large pieces, is reduced into smaller ones, and is then placed in a vessel capable of being hermetically closed or made air-tight. To this material is now added pure alcohol—*alcohol absolutus*—and bisulphide of carbon, in the proportion of a quarter of a pound of the former and ten pounds of the latter to one hundred pounds of the material, the alcohol and the bisulphide being previously mixed together, and then poured over the material to be treated. The vessel containing the ingredients is then closed air-tight, and allowed to remain so for about two hours, more or less, at the expiration of which time the cover may be removed, when the whole, says the patentee, is found to be in a soft, plastic, or gummy state, and ready to be ground in the ordinary way of grinding such gums, for the purpose of manufacturing it into various useful or ornamental articles without repeating the process of vulcanizing. By adding a larger proportion of the alcohol and bisulphide of carbon, the gums may be reduced to a liquid state. The relative proportions of the two may, however, be varied according to circumstances, and the effect which it is desired to produce.

VARIOUS COMPOUNDS OF GUTTA-PERCHA.—In addition to that combination of gutta-percha with sulphur or its compounds, which, with the subsequent exposure of the material to a high temperature, constitutes the process of vulcanizing, a great variety of patents have been taken for combining this substance with other materials to render it softer or harder, more or less elastic, or more durable, and so to fit it for one or other of the almost innumerable purposes to which it has been proposed to apply it. To enumerate the whole of these patents in detail, so as to describe with precision the various processes and applications proposed, would both exhaust the patience of the reader and exceed the limits of this work. It is necessary, however, to give an abstract of the most important of these patented compounds and processes, to prepare the reader for a subsequent enumeration of the wonderful variety of uses to which this valuable substance has already been rendered subservient; and, in doing so, the Editor conceives that the best arrangement he can adopt is to follow the order of dates:—

Mr. HANCOCK's patent for January, 1846—the first patent taken on the subject—embraced a claim for making a compound elastic water-repelling substance, for manufacturing purposes, by mixing gutta-percha with jintawan, a somewhat similar material then recently imported from the East Indies, and also with caoutchouc, or with both, in proportions varying according to the softness, stiffness, pliancy, or extensibility which it was proposed to give to the compound. He states in his specification, that a good composition for bands or tape is formed by combining fifty parts of gutta-percha, twenty-four parts of jintawan, twenty of caoutchouc, and six of orpiment. These are incorporated together in the masticating machine, and the combination is facilitated by moistening the mass with rectified oil of turpentine, or some other solvent. The orpimented or sulphurised compound is then exposed to a heat of from 300° to 340°, for a period varying according as the temperature is higher or lower. With a heat of 300° about sixty minutes are required; while fifteen minutes are sufficient for a temperature of 340°. The required heat may be obtained either by means of high-pressure steam, or of water heated under pressure, or of hot air.

Another claim embraced in Mr. HANCOCK's first patent consisted in a method of improving gutta-percha in softness and pliancy, as also its combinations with caoutchouc and jintawan, supposing the substance, whether single or compound, to have been previously sulphurised. For this purpose, he subjects the article, whether in the state of blocks, sheets, threads, or any other form, to the action of sulphurous acid, either by exposing it to the acid in the state of vapor, or by steeping it in water impregnated with the acid, or by spreading over the article a paste made of sulphuric acid and ivory, or bone-dust, or animal charcoal, and then placing it in a steam-heated vessel or chamber.

Another method of producing the same effect—claimed also in the same patent—consists in adding to the gutta-percha and its compounds when passing through the masticating machine, and whether they are mixed or not with orpiment or any other sulphide, about ten per cent. of vegetal wax or tallow.

In October, 1847, a patent was taken by Mr. THOMAS FORSTER, for combining gutta-percha with animal charcoal, hydrate or milk of sulphur, ground whalebone, fragrant essential oils, musk, tonquin beans, orris root, or gum-benzoin, and for applying all or either of these ingredients, alone or in combination with caoutchouc or other matters, to fabrics or leather for clothing, lining for railway carriages, cart and rick covers, wrappers for goods, *et cetera*. For this purpose the gutta-percha is first cleansed or purified, and then put into a hot masticating pan with one or more of the substances above-mentioned, in the proportion of four parts of the gutta-percha to one of animal charcoal; or four of gutta-percha, two of india-rubber, and two of animal charcoal. The latter should be of the finest description, and carefully sifted through a very fine sieve. When these matters are thoroughly incorporated, a portion of any solvent is to be added—by preference, oil of coal—in such proportions as are needful for the particular fabric to be coated. The patentee found

equal weights of each to be good proportions. When the gutta-percha and solvents are well combined by heating them in a vessel enveloped in a steam-jacket, and are in a fit state to be spread upon the fabrics, Mr. FORSTER adds orris root or other perfumes in such proportions as are necessary to give the goods the desired scent; but if caoutchouc is a component part of the compound, he says it is best to use orris root, tonquin beans, musk, or gum-benzoin only, as the fragrant essential oils are apt to act injuriously upon the rubber in the course of time. For coarse goods, such as carriage covers and the like, he takes gutta-percha four parts, ground whalebone and hydrate of sulphur, each one part, and one-sixteenth part of any mineral preservative of vegetal matter—by preference, arsenic—works the whole in a mastrating pan, and afterwards spreads it upon the fabrics, with or without a solvent. If the fabrics are required to be of any particular tint, he adds to any of the above compositions the color necessary to produce it.

In forming such articles as are required to resist moisture, as buttons, tea-trays, military ornaments, *et cetera*, he first saturates the fabrics with any water-repellent matter, preferring for this purpose boiled linseed oil, dries them thoroughly in a stove, and then coats them with the first-mentioned composition of gutta-percha. In making panels for carriages, doors, boxes, *et cetera*, he uses staves of wood, deal as the cheapest, and coats them with any of his gutta-percha compositions, using one part of the composition to two of the solvent. When the solvent has thoroughly dried, he takes pieces of the required size and heats them, lays one upon the other, taking care to reverse the grain of the wood, and then presses the whole while hot, keeping the pressure upon them till cold.

The compositions he prefers for moulding without fabrics are—gutta-percha four parts, bone-charcoal two parts, and one-sixteenth part of arsenious acid; or, gutta-percha four parts, ground whalebone or the rasping of horns and hoofs two parts. If a hard composition of a light color is required, he uses gutta-percha three parts, ivory or bone-dust one part, and Cornish clay a half part. He states that a large quantity of animal charcoal or bone-dust will make these compositions much harder at the expense of their toughness. The articles he makes directly from these solid compositions are carriage and other wheels, ornamental leaves and scrolls for furniture, military and other ornaments for harness, trays, frames, cornices, leaves, and flowers. The quantity of perfumes to be used in any of these compositions must depend upon the purity of the material. He finds, however, that of orris root half a pound to every five pounds of the composition is necessary; of benzoin, two ounces to every five pounds; of the essential oils, about half an ounce to five pounds.

To finish the surfaces of fabrics or leather prepared with gutta-percha or its combinations, he coats them with transparent colors, made by combining the colors with oils or varnishes. His mode of operating is as follows:—Suppose the fabric is coated with gutta-percha, and animal charcoal or lamp-black, the color would be a dull black; to improve upon this, he takes

ten pounds of linseed oil and twenty ounces of Prussian blue, grinds and mixes, boils the whole gently until it is as thick as treacle, which is readily seen by trying a drop on a bit of glass, and when cold it will be found to be a brown transparent varnish. Apply a thin coat to the surface of the cloth, it will be dry in a few hours, and in drying will absorb oxygen and become blue, thus giving the cloth the fine color of black enamelled leather.

If other colors are required—as red, for example—the fabric should be coated with gutta-percha and vermilion. Take one pound of any oil-varnish, or pale linseed, nut, or poppy oil, previously made *drying* by any of the ordinary methods, and three ounces of crimson lake; grind them well together, and coat the fabric with a thin layer. If the fabric has been embossed or corked to imitate morocco leather, the result will not be a bad imitation of that article. Of course, any tinge may be produced by a similar process.

In July, 1848, Mr. ANTHONY LORIMER obtained a patent for improvements in the means of purifying gutta-percha, and for new combinations of that substance with other materials. The first part of the method claimed consists in a somewhat intricate system of knives and other machinery for slicing and kneading the gutta-percha; the second consists in combining it with burned clay, burned flint, broken articles of porcelain and earthenware, marble, Portland, Cornish, and other stones, all crushed and sifted; also, the oxides of zinc and copper, the hydrate and oxalate of lime; also a compound of lime slacked with oxalic acid dissolved in water. He uses about three pounds of acid to a bushel of lime, the acid being first dissolved in a quantity of water suitable for slacking that proportion of lime. For making soles for boots and shoes, the great object is to incorporate as much of either of the above matters, or mixtures thereof, as the gutta-percha will take up, and retain a flexible and adhesive character; but in cases where the compounds are to be subjected to strain, such as straps and bands, then smaller quantities of these substances must be combined with the gutta-percha. The gutta-percha compounds so produced may be moulded into any desired form, or pressed into sheets between rollers.

In November, 1854, a patent was taken by HENRI JULES DUVIVIER and HENRI CHAUDET of Paris, for a method of treating gutta-percha with the chloride, bromide, iodide, or fluoride of sulphur, or with the corresponding compounds of phosphorus, boron, silicon, and arsenic, or the bichlorides of tin and antimony; but of these substances the patentees prefer to employ the chloride of sulphur, although they allege that results similar to those obtained by the use of that compound may be obtained by the use of any of the other compounds above-mentioned. The process which they adopt for applying these substances is merely a modification of that vulcanizing process originally patented by Mr. PARKES. The gutta-percha is dissolved in bisulphide of carbon, the solution being made in a close vessel, and at a temperature of 86°. This menstruum, when purified by deposition, is evaporated to dryness, and another clear solution is made, to which from two to fifteen per cent. or more of chloride of sulphur,

diluted with bisulphide of carbon, is added and well mixed; or if any of the other substances before mentioned are employed in place of chloride of sulphur, then from fifteen to fifty per cent. should be employed. The patentees make the following interesting statements with reference to the properties of the resulting compounds, according to the proportions in which the ingredients are mixed:—

1. By mixing only two per cent. of chloride of sulphur, or only fifteen per cent. of the other substances, with the sirupy solution of gutta-percha, a compound is obtained which does not materially differ from gutta-percha in its properties.

2. When more than two per cent. of chloride of sulphur is employed, the compound can be extended when heated to 100° or 120°, and it remains extended when cooled, but retakes its original form when again heated; and at about 212° it agglutinates.

3. When five per cent. of chloride of sulphur is added, the compound only differs from that just described in being less softened by heat, and in being slightly elastic when cold.

4. When ten per cent. of chloride of sulphur is added, the properties of the gutta-percha are quite changed, and the compound is unaltered by a temperature of 212°.

5. When above fifteen per cent. of chloride of sulphur is added, the compound becomes horny and harder as the quantity of chloride of sulphur increases.

Articles may be formed from these compounds by pouring them as soon as mixed into metal or other suitable moulds, and there allowing them to set. In the same way the patentees cast blocks of elastic gutta-percha, which are afterwards cut up into pieces of a suitable size for rubbing out pencil marks. The compounds may also be used for glueing or attaching one substance to another, in which case they should be applied in a fluid state, and the two surfaces to be attached should be held together until the cement is quite hard. When attaching leather by this cement, the surface of the leather should be made rough. Or the process may be varied by first coating the surfaces to be attached with untransformed gutta-percha, and then wetting the surfaces with a solution of two to ten parts of chloride of sulphur in one hundred parts of bisulphide of carbon, and pressing the surfaces together till hard.

In a similar manner, articles may be coated with transformed gutta-percha, by dipping them first into a sirupy solution of gutta-percha in bisulphide of carbon, and afterwards plunging them into a bath consisting of two to ten parts of chloride of sulphur dissolved in one hundred parts of bichloride of carbon.

When it is desired that the gutta-percha should penetrate, in place of remaining as a coating on the surface of the article, as is sometimes desirable when treating sheets of fabric, wood, leather, and similar materials; then, in place of simply dipping the article in the solution of gutta-percha, it is allowed to soak therein for twenty-four to thirty-six hours, and is moderately heated, passed between rollers, and afterwards dipped into a solution of ten parts of chloride of sulphur in one hundred parts of bisulphide of carbon.

If the articles subjected to these processes are of such a nature that they would be damaged by the acid vapors formed during the operation, the patentees state that carbonate of soda should be mixed with the solution of gutta-percha, in quantity sufficient to neutralize the acid formed.

In June, 1855, a patent was taken by P. AUGUSTIN GODEFROY for mixing cocoa-nut shells in a finely-ground or comminuted state with gutta-percha in the process of its manufacture, by which it is alleged that the following advantages are obtained:—1. Considerable economy in the manufacture; 2. Greater durability in the product, especially when applied to the manufacture of boot-soles, clogs, goloshes, and other articles exposed to much wear; and 3. Greater elasticity, with the power of resisting a higher temperature than ordinary gutta-percha. By grinding machinery fitted for the purpose, the patentee reduces the cocoa-nut shells to powder of three degrees of fineness. The first, or finest quality, he employs for mixing with gutta-percha intended for tubing, for an insulating coating to telegraph wires, and such like purposes; the second or coarser, for driving-bands, boot-soles, ornamental mouldings, *et cetera*; the third, or coarsest quality, for lining ships, for hut linings, for covering floors and walls, and other similar purposes. The Editor can see no objection to a little adulteration of the gutta-percha for the latter two modes of its application; perhaps the admixture of cocoa-nut shell might even, in some respects, increase its adaptation for these and other purposes; but he doubts how far the same admixture would improve the quality of gutta-percha as an insulator of electricity, or as an admixture in the composition of tubes intended to resist acids, and to be impermeable to moisture.

A communicated patent, dated November 27, 1855, was taken for improvements in the manufacture of india-rubber and gutta-percha, by mixing with these materials calcined shells, or other cheap substances of a like nature, so that when afterwards vulcanized and rendered hard by being subjected to a high degree of heat, the material may be applicable to the manufacture of bobbins, cylinders, rollers, racks, ratchet-wheels, and other parts of spinning machines. Though gutta-percha is embraced in the patent, india-rubber seems to be the substance to which the admixture of calcined shells is considered most applicable.

In August, 1856, a patent was taken by Mr. CHARLES GOODYEAR for an improvement in combining gutta-percha with asphalte or pitch. The method previously in use was, to combine gutta-percha and asphalte by masticating the two together, in the same manner as gutta-percha and india-rubber are combined in the kneading machine. Mr. GOODYEAR's improvement consists in effecting the combination by the aid of hot water, by which the two matters are softened, and made comparatively fluid. For this purpose a close vessel is used, into which the substances are introduced, mixed with a quantity of water, and the temperature is raised to such a degree as to melt both; after which they are to be well stirred, to blend them together. He considers that this melting of them together effects the most perfect combination. And having been thus

thoroughly blended in a fluid state, they may, when desired, be further combined with sulphur, also with india-rubber and other matters; and the various compounds thus produced are, when required, subjected to high temperatures, in order to produce the change which is known as *vulcanizing*.

WATERPROOFING AND DEODORIZING.—Mr. HANCOCK's patent of January, 1846, embraced a method of producing varnishes which might be applied to the waterproofing of leather or cloths; and by applying them either alone or mixed with coloring matters to gutta-percha or its compounds, or to articles made from them, they might have a fine glossy exterior given to them, and the smell of any ingredients which might have been mixed up with them, such as that of the sulphur in vulcanizing, would be effectually removed. For this purpose he mixed gutta-percha and caoutchouc, or gutta-percha and jintawan—using the substances indifferently, so far as regards the proportion one bears to the other—with sulphur or orpiment, or other sulphide, in the proportions that are usually employed for vulcanizing, with about eight to ten parts of animal or vegetal wax, or animal or vegetal fatty matter, and then dissolved in rectified spirits of turpentine, and evaporated. He adds that these varnishes, mixed with colors, may be used for the purpose of painting or printing cloth, leather, or any other fabric, and will be found very useful as waterproof cements, particularly in combining gutta-percha and its compounds with silk, cotton, and other textile fabrics.

In November, 1853, a patent was taken by Mr. JOSEPH FRY for improvements in preparing solvents for india-rubber and gutta-percha, and in rendering waterproof fabrics free from smell. With reference to the first claim, it is stated in the specification, that previously the solvents employed for india-rubber and gutta-percha had been distilled and rectified before their application; but it had been found by the patentee that these solvents are improved if india-rubber or gutta-percha be combined with the solvents before distilling them, or be present in a certain proportion during that operation. The solvents usually employed for waterproofing purposes are turpentine and coal-naphtha, or coal-oil. In proceeding to distil one or other of these, he introduced into the still, along with the solvent, from four to six ounces of the india-rubber or gutta-percha to each gallon of the liquid; and he affirms that the product distilled over is materially improved for the purpose of its subsequent use in dissolving larger quantities of the same substances, while the residue in the still will be found useful for fabricating common or inferior articles, and for waterproofing coarser and lower-class cloths. Or, by another method, the crude solvent might be first distilled without india-rubber or gutta-percha being present, and afterwards be combined with india-rubber or gutta-percha, and again distilled or rectified. The latter mode of treatment is regarded by the patentee as producing the best result.

The second part of the claim, which has for its object the removal of the odor of articles fabricated of india-rubber or gutta-percha in which solvents have been used, consists in subjecting the waterproof cloths, whether before or after being made up into garments or

other articles, to the action of steam in a close chamber or steam-chest; and for this purpose the patentee does not find it necessary to employ steam of a much higher pressure than that of the atmosphere. A longer or shorter time is required to remove the odor of the solvent, according to the amount of it that has been present.

DECOLORING GUTTA-PERCHA.—In February, 1853, a patent was taken by Dr. NORMANDY for decoloring gutta-percha by means of animal charcoal, embracing also a novel method of forming it into sheets and balloons. The gutta-percha to be operated upon by this process is previously purified as much as possible by cutting, and pressing or kneading it in hot water. It is then exposed at a gentle heat to the action of some volatile solvent, such as essence of turpentine or benzol, but preferably of bisulphide of carbon, in which latter case no heat should be applied. One part by weight of gutta-percha dissolved in about twenty parts of solvent, yields a brown, turbid, sirupy mass, which is clarified and partly decolorized by first allowing it to stand till the heaviest particles subside. The supernatant liquid, still much colored, is thoroughly purified by filtration through animal charcoal; it is then put into a still provided with a refrigerator, and if it be desired to obtain the gutta-percha in a solid state, the distillation is continued to dryness. But to obtain sheets, or to make balloons, shades, and various other forms of gutta-percha, the patentee proceeds as follows:—He takes the purified solution of gutta-percha in bisulphide of carbon, and pours a certain quantity of it into a vessel—for example, a glass cylinder stopped at one end. He then inclines the vessel, and turns it in every direction, until its sides are completely and evenly coated over internally by the solution, and then allows the excess of liquid to drain off, by holding the glass cylinder with its mouth downwards. In a short time the bisulphide of carbon volatilizes completely, leaving the inside of the glass covered with a film or thin lining of gutta-percha, which loosens by its contraction in drying, and may then be readily extracted. Care must be taken, however, not to touch the cylinder with a warm hand, for the gutta-percha will adhere to the glass at the points which have been thus warmed. If the part which was in contact with the bottom, or closed part of the cylinder, be now cut off, a cylinder of gutta-percha, open at both ends, is obtained, and this being cut longitudinally, will form a sheet. Thin semi-transparent balloons, or almost any other form, may be produced in the same way, since the solution of gutta-percha will necessarily take the form of the vessel into which it is poured. When, however, the gutta-percha membrane has to be removed through a small aperture—which happens when the sirupy liquid has been poured into a bottle, or glass balloon, or mattress—some contrivance must be resorted to, as that of introducing into the vessel a tube, by means of which the air in the vessel can be sucked out, either by the mouth, or with a syringe; the gutta-percha membrane will thus be made to collapse and recede from the sides of the vessel, after which it may be easily removed. It is evident that the more viscid the solution, the thicker will be the membrane obtained.

DYEING OF GUTTA-PERCHA, AND ITS COMBINATIONS.—A method of coloring articles formed of gutta-percha, or coated with a varnish of that substance, has been just stated, in connection with Mr. HANCOCK's method of waterproofing and deodorizing. It is obvious that the same varnish which excludes moisture, and confines the odor of the solvent, may be mixed with colors, and will thus form a pigment of any required tint. This process may be termed painting, or color-varnishing; but in Mr. PARKES' patent for March, 1846, was embraced a claim for *dyeing* caoutchouc or gutta-percha, alone or in combination, and afterwards, when desired, treating those matters by vulcanizing agents, either in solution, or by the dry method. To dye caoutchouc, or gutta-percha, or their compounds, he boils them from a quarter to half an hour in the following preparations:—

Black.—One pound of sulphate of copper dissolved in one gallon of water, with one pound of caustic ammonia, or chloride of ammonium. Or—one pound of sulphate or bisulphate of potassa, and half a pound of sulphate of copper, with one gallon of water.

Green.—One pound of chloride of ammonium, half a pound of sulphate of copper, two pounds of caustic lime, and one gallon of water.

Purplish.—One pound of sulphate or bisulphate of potassa, one quarter of a pound of sulphate of copper, and one quarter of a pound of sulphate of indigo. Of course, the depth of color may be varied by varying the proportions of the ingredients.

Or the following colors may be applied directly:—

Blue.—Victoria blue and ultramarine.

Red.—Vermilion, carmine, or rose-lake.

Green.—Brunswick green, or acetate of copper.

Yellow.—Chrome yellow, or oxide of uranium.

White.—The color known as satin white. Mr. PARKES prefers generally to use this as a ground for the hues above-mentioned. *The coloring processes must precede the vulcanizing of the material.*

METALLIZING.—In Mr. HANCOCK's patent of February, 1847, was embraced a method of improving the quality of gutta-percha, both in its natural and vulcanized state, by exposing it for a minute or two to the action of binoxide of nitrogen, obtained by the usual method of dissolving a metal, such as zinc, copper, or mercury, in nitric acid, or by immersing it in a boiling and concentrated solution of chloride of zinc, for a period varying from one to five minutes, according to the strength of the solution. In either case, the materials are afterwards well washed in some alkaline solution, or in soft water. Gutta-percha which has been thus treated, and whether vulcanized or not, is stated by the patentee to become exceedingly smooth to the touch, and of a lustre approaching to metallic.

SUBSTITUTES FOR GUTTA-PERCHA.—In December, 1853, a patent was granted to STANISLAS T. M. SOREL, of Paris and London, for certain improved compositions to be employed as substitutes for caoutchouc and gutta-percha. These compositions, though termed substitutes, are simply combinations of gutta-percha with other bodies, resembling in most cases those already mentioned as patented by other individuals for the same purpose. This will be at once seen from the following

ingredients and proportions employed for his principal mixture:—

	Parts by weight.
Colophony,.....	2
Pitch or bitumen,	2
Resin oil,	8
Hydrated lime,	6
Water,.....	3
Pipe-clay, or other like argillaceous earths,	10
Gutta-percha,	12
	43

The patentee prepares the composition in a copper, heated by any suitable means. He first introduces into the vessel colophony, bitumen, or pitch, and resin oil, and agitates the mixture with a stick, or spatula, until the former two are dissolved. He then adds slacked and broken hydrate of lime of the consistence of molasses, continuing to agitate and heat the mixture, and when the latter is completely liquefied he introduces the gutta-percha, cut into small pieces. The agitation is continued till the gutta-percha is dissolved, when argil is introduced, either powdered or mixed with water, and well incorporated with the mixture. An excess of water is then added, and the whole is heated to ebullition. The matter is now separated and kneaded in water, then withdrawn from the copper and again heated, and passed several times between the rollers of a rolling machine to render it homogeneous, when it is ready to be employed.

The colophony may be replaced by other resins, as burgundy pitch, or gum-copal. The argillaceous earth may be entirely suppressed in the composition. To render the latter more tenacious, he increases the quantity of gutta-percha; and to augment still more its tenacity, and render it a little elastic, he adds a small quantity of natural or vulcanized caoutchouc, cut up, like the gutta-percha, into small pieces. To render the composition more completely waterproof, he adds about five per cent. of bees' wax or stearic acid. It may be colored with smoke-black, or other coloring matters.

Subjoined are three combinations, in the first of which the colophony is replaced by pitch; in the second, both the resin and resin oil are superseded; and in the third, pitch is replaced by coal-tar from the gas-works:—

	I.	II.	III.
Pitch,.....	8	12	—
Resin oil,	4	—	—
Coal tar,.....	—	—	12
Slacked hydrate of lime,	6	6	6
Gutta-percha,	16	16	16
	34	34	34

Argil may be added to the above three compositions. They are stated by the patentee to be applicable for replacing caoutchouc and gutta-percha in their principal applications, and especially for waterproofing stuffs, and the manufacture of tubing, of driving-straps, waterproof boots and shoes, bobbins and cylinders for spinning machinery, capsules for stopping bottles, and other like articles. They may likewise be moulded for making vases, and other ornamental articles. For giving the composition greater tenacity, fibrous materials, such as cotton, wool, hemp, cow hair, and leather

waste, may be added. When properly rolled into sheets, it may be lined or covered with thin sheets of natural or vulcanized caoutchouc by means of a rolling machine, or by sticking them together with a solution of caoutchouc or gutta-percha, or any other suitable adhesive agent. These double sheets may be employed for the upper leathers of waterproof boots and shoes. The soles may be either of waterproofed leather, of gutta-percha, or of wood.

ADULTERATIONS.—From the list of patents which have been given for mixing or combining gutta-percha with other substances, including caoutchouc, pitch, pipe-clay, vegetal wax, calcined bones, coal-tar, lime, sulphur, cocoa-nut shell, Portland stone, and an almost infinite variety of other materials, all of which are assumed by the respective patentees to peculiarly adapt the resulting compound for certain specified applications, it may seem unreasonable to brand as adulterations the admixture of ingredients which are added by legal sanction for certain avowed purposes. On this extreme principle even the process of vulcanizing, which imparts to caoutchouc and gutta-percha more than half their value, would be a sophistication; for it presupposes the admixture of the article with sulphur, or some of its compounds. Allowing, therefore, that gutta-percha may be too often adulterated, and deteriorated for all practical uses, under patent authority, while, on the other hand, the fact is undeniable that by certain admixtures and combinations the qualities of the compound are improved for certain purposes, the Editor will confine himself to those adulterations which are practised by the native Malays and Chinese traders, and in consequence of which an impure or inferior article is palmed on the European importer.

The fact that the native Malays often introduce stones, earth, and other impurities, into the blocks of gutta, to increase their weight, has been already noticed, and may also be left out of consideration, as these impurities are often too easily detected, to the injury of the machinery of the manufacturer. Such impurities are also readily eliminated in the process of purification. But the case is otherwise, when, as frequently happens, the gutta-percha is mixed with other gums of an inferior character. The chief trade in the article is carried on by the Chinese, who adulterate it with the valueless juice of a tree called *Getah Malabeöya*, which they import from Palembang. By this admixture various sorts of gutta-percha are obtained, which differ considerably in price. Among several samples examined by M. ADRIANI, one was in cakes of five to six inches thick, and was darker on the outside than in the interior; another was of a very loose structure, and was much contaminated with small stones, but agreed in color, which was in general a flesh-red, with the former; a third sample was white, slightly inclined to brown. This last piece had been removed as an impurity from a large block of gutta-percha, but was found to be in quality perfectly equal to the best gutta, and was afterwards rolled out in the manufactory of MUNNICH, BECKE, and Co., into sheets of the thickness of paper, for address cards for that firm. The same chemist obtained a sample of

the *Getah Malabeöya*, imported from Palembang, and also a sample of gutta-percha adulterated with that substance. The getah, which seemed to be also an inspissated milky juice, was imported in the form of plates, of about an inch in thickness, of a greyish color, somewhat clammy to the touch, and brittle when dried. When cut, it was found of a dirty white color, and contained many impurities. Like gutta-percha, it was dissolved by chloroform. The vessel in which it was contained emitted, on being opened, a disagreeable acid smell. Treated like gutta-percha, and purified by hot water, it was much darker than the raw substance, and often quite black; the smell was equally offensive, and its consistency similar to that of wax or glaziers' putty. The gutta-percha adulterated with the getah was of a loose texture, of a more greyish color, and of a smell different from that of genuine gutta. In warm water the getah became soft and sticky; treated with boiling water, it formed a neutral milky liquid, which was precipitated by alcohol. When boiled with alcohol it became glutinous, the alcohol extracting a white fat, resembling wax and resin; ether extracted also resin. Being dissolved in chloroform and filtered, a black coloring substance remained behind, which could not be dissolved by the usual solvents, and was burnt without leaving a residue. It appeared to be nothing else but soot. The getah melts at 170°, and becomes decomposed only at a much higher temperature, when dark-colored oils are distilled off.

USES AND APPLICATIONS.—From several processes described in connection with the manufacture of gutta-percha, and from the list of patents enumerated under the head of its combinations, *et cetera*, the reader will have seen that the substance admits of a vast variety of applications; and, indeed, the mere consideration of its singular and valuable properties is sufficient to show that the only bar to its almost indefinite extension into the arts and uses of life is the considerable price of the article, arising from its necessarily limited supply compared with the great demand for it. Its chemical and other properties have been already stated, but in now proceeding to give a more extended list of its applications, it may not be out of place to remark that these will be found chiefly to depend on the following peculiarities:—

1. Its capacity of being moulded by gentle heat and pressure into any required form, and of retaining this impressed form when cold, with extreme tenacity.
2. Its pliability at common temperatures.
3. Its impermeability to water and other fluids.
4. Its power of resisting not only the solvent action of common liquids, but even the corrosive action of most acids, of caustic alkalies, and alcoholic liquors.
5. Its valuable property as an insulator or non-conductor of electricity, in which respect it ranks second to no other known substance.
6. Its singular acoustic properties, as a conductor of sound.
7. Its capacity of combining with sulphur or its compounds, and being vulcanized like caoutchouc, so as to be unaffected by considerable changes of temperature.
8. Its aptitude for uniting with various other substances in any required proportion, so as to produce

compounds combining remarkable hardness with a certain amount of elasticity.

9. Its power of receiving and retaining the sharpest and finest impressions from the die or mould.

10. Its great durability at common temperatures, and under almost all agencies.

To these properties, separately or conjointly, may be traced its peculiar fitness for the following applications, namely: For a protection to underground and submarine telegraph-wires—a purpose for which it is not less fitted by its pliancy and its resistance to moisture than by its high insulating power; for replacing the cylinder or disc of electrical machines; for insulating handles and other electrical apparatus; for tubes to convey not only cold water, but acids, alkalies, and other corrosive liquids; for bath-cisterns, buckets, bottles, or other vessels; for lining acid and alkali cisterns formed of wood; baths for photographic purposes, and different laboratory apparatus; sieves and pumps for acid and alkaline liquors; funnels, siphons, valves, and stop-cocks for corrosive solutions; conversation tubes for mines, ships, warehouses, or railways; stethoscopes and other surgical instruments; driving-bands for all kinds of machinery; rollers, bobbins, *et cetera*; boot and shoe-soles—one of its most extensive applications; waterproof clogs for dyers or maltmen; horse-trappings; waterproof cases for charts, maps, arms, and such like; noiseless rings for bed and window curtains; cords for window-sashes and blinds; clothes-lines; whips; waterproof portmanteaus; hats for miners, sailors, carriers, *et cetera*; moulded objects of every description, as fancy baskets, bread-trays, ink-stands, watch-stands, clock-cases, medals, picture-frames, buttons, flower-pots, and various similar applications.

The author of the Jury Report on the manufactures from gutta-percha in the Great Exhibition, says:—It is especially in the fabrication of articles for maritime use that gutta-percha—resisting, as it does, the action of water, and especially of brine—appears to be the best adapted. Buoys of every description for anchors, nets, *et cetera*, have been made of it; sailors' hats, speaking trumpets, and the like. It may be added that even fish-nets are formed of gutta-percha cord. It will be seen from the preceding enumeration of uses, that the decorative art has also taken large advantage of the plastic properties of gutta-percha. Various articles of furniture, the prices of which are so much enhanced by carving, are capable of being reproduced by means of pressure, and thus multiplied at a comparatively low price. Writing-tables, work-baskets, *et cetera*, can be produced in gutta-percha, and thus made to combine the threefold advantage of lowness of price, elegance of form, and absence of fragility. In the London Gutta-Percha Company's Works are made every day a great quantity of mouldings, friezes, panels, leaves, and articles of every description. These, combined by the decorator, and covered with gilding, which gutta-percha takes in perfection, are, in the manufacture of picture-frames, and in the decoration of furniture, capable of superseding the carving upon wood, which is so costly, or papier-maché and carton-pierre, which present the defect of great fragility.

Bronze articles have also been reproduced in a fel-

icitous manner. At the Great Exhibition, the West Ham Gutta-Percha Company, represented by Mr. HANCOCK, exhibited, among various other objects, a beautiful group representing a boar-hunt, covered with a metallic coating in imitation of bronze. The author of the Jury Report remarks, that the clearness of the edges and the purity of the forms which gutta-percha receives in the mould, make it easy to understand how this substance has been found capable of being used for making galvano-plastic moulds, and how some experiments have been tried for the purpose of substituting gutta-percha in the process of stereotyping, for the metal with which at the present day the pages of illustrated books are multiplied. Stereotype plates of gutta-percha, with specimen impressions, were actually exhibited by the London Gutta-Percha Company, in connection with a large unfinished machine, intended for printing therewith on endless paper, which was also to be cut and folded before leaving the machine, the gutta-percha types not requiring the paper to be damped. It does not appear, however, that this application of gutta-percha has been brought into general use. Moulded into the form of a jawbone, it has been found capable of holding together artificial teeth, and thus advantageously superseding those settings in gold which were so costly, and which, on account of their absolute rigidity, presented much inconvenience. The solution of gutta-percha in oil of tar and other solvents, which, by their evaporation, leave the gutta uninjured, can be made use of to obtain sheets of extreme thinness, which have begun to be extensively used in surgery. But, apart from its use as a covering for submarine telegraph wires, and its common application as a substitute for leather soles, it is more especially to the manufacture of tubes and chemical utensils for the conveyance and conservation of acids, *et cetera*, that gutta-percha seems calculated to render the greatest services.

STATISTICS.—The imports of gutta-percha into the United Kingdom in 1850, amounted to one thousand two hundred and fifty tons. The prices vary, according to the supply and demand, from fourpence to one shilling and fourpence per pound—average, eightpence—showing the aggregate value of the above imports to be equivalent to ninety-two thousand five hundred and fifty pounds sterling. The article is manufactured in London, Manchester, and Liverpool.

HYDROCYANIC ACID.—*Acide prussique*, French; *Berlinerblausäure*, *Hydrocyansäure*, German; *Acidum hydrocyanicum* vel *Borussicum*, Latin.—This important compound—which, from its animal origin, has also been named *zootic acid*, and the poisonous properties of which are, unfortunately, so well known—was first isolated by SCHEELE. DIESBACH and DIPPEL, in 1704, discovered Prussian blue. Forty-eight years afterwards, MACQUER found that lime-water resolved this substance into *calc of iron*—sesquioxide—and a *combustible coloring matter*, which he could not separate, but which combined with potassa, forming *phlogisticated potassa*—ferrocyanide of potassium. GUYTON MORVEAU concluded in 1772 that this principle had acid properties. In the year 1782, SCHEELE succeeded in preparing the aqueous solution of *prussic acid*, which

he said was composed of ammonia, acid of air, and phlogiston. BERTHOLLET, in 1787, described it, in similar terms, as consisting of carbon, hydrogen, and nitrogen. PROUST and ITTNER discovered several of its compounds, and the latter is said to have procured anhydrous hydrocyanic acid by the action of hydrochloric acid upon cyanide of mercury, but, being unable to condense the vapor, he pronounced it to be a permanent gas. GAY-LUSSAC, however, in 1811, effected its liquefaction, determined the relative proportions of its ultimate elements, and led the way to the intimate knowledge and useful application of many of its compounds.

SOURCES AND PREPARATION.—Hydrocyanic acid exists, ready-formed, in many vegetal substances; and is generated in many others, in which it was formerly believed to pre-exist, by the various methods which were devised for its extraction. The kernels of bitter almonds, plums, peaches, apricots, and cherries, the leaves and more tender branches of the peach, the leaves of the Portugal and cherry laurel, and many portions of other vegetables belonging to the sub-orders *Pomeæ* and *Amygdaleæ*, when steeped in water for a considerable time and then distilled, yield hydrocyanic acid. According to several authorities, amongst whom are LIEBIG and WÖHLER, the formation of the hydrocyanic acid during the immersion of the vegetal substances in water, is caused by the action of the *emulsin* upon the *amygdalin*—both of which they contain—as a ferment, decomposing the latter into grape-sugar, bitter almond oil, and hydrocyanic acid—the latter two passing over in the subsequent distillation.

It is now generally received that it is only in the more moist of such vegetal structures that the acid is ready-formed. There have been adverse opinions with regard to its presence in the leaves of the cherry laurel; GUIBOURT and LEPAGE maintaining that it is formed during their immersion, while WINCKLER holds that bitter almond oil containing hydrocyanic acid does really exist in the fresh leaves in minute quantity, which he believes varies with the amount of water present, disappearing entirely when the leaves are exsiccated.

Hydrocyanic acid is produced in many ways. According to FOWNES, when nitrogen gas is passed over a mixture of equal parts of pure sugar, charcoal, and carbonate of potassa in a porcelain tube at a red heat, carbonic oxide, and subsequently nitrogen, pass off; cyanide of potassium and a carbonaceous mass remaining. When ERDMANN and MARCHAND repeated this process with pure materials, and at a moderate red heat, no cyanide was formed; and even when the temperature was raised to such a degree that vapors of potassium were carried off with the carbonic oxide, they could discern doubtful traces only: on employing carbonate of potassa containing sulphate, the presence of sulphocyanide of the alkali was evident. WÖHLER states that the production of cyanide of potassium from sugar-charcoal, carbonate of potassa, and nitrogen, is indubitably ascertained, but it is required that the nitrogen should be at a red heat, and that the temperature of the tube and its contents should be such that potassium is volatilized.

DESFOSES has observed, that when nitrogen gas is

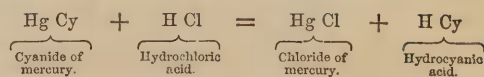
passed through a mixture of *wood-charcoal* and carbonate of potassa, heated to redness, a small quantity of cyanide is generated; but as wood contains albuminous matter, and its charcoal is not entirely free from it, the nitrogen might either wholly or in part emanate thence.

GMELIN, citing the experiments of RIEKEN,—in which carbonate of potassa mixed with charcoal obtained from the purest white sugar, and heated in a current of nitrogen gas, at a temperature sufficiently high to reduce potassium, was completely converted into cyanide of the alkali-metal; in one case so effectually that the cyanide did not even effervesce with acids—and taking into consideration the fact, that when a mixture of potassium or antimonide of potassium with charcoal is heated to full redness in a current of nitrogen, not a trace of cyanide of potassium can be detected,—concludes that this formation of cyanogen requires not only the presence of free potassium, but at the same time a temperature high enough to separate potassium from its oxide.

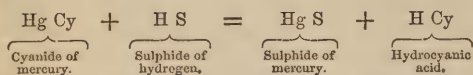
When blood, hoofs, horns, and many animal tissues are ignited with carbonate of potassa; when blood, fats, sugar, gum, starch, and many organic bodies, both nitrogenous and free from that element, are subjected to distillation with nitric acid; and in many other instances, and by other means, is hydrocyanic acid produced. PEREIRA mentions the statement that cheese, when exposed to the action of water and the sun, disengages ammonia, and when treated in this state with alcohol, yields traces of hydrocyanic acid.

Examples of the formation of hydrocyanic acid having been given, it now remains to pass on to its preparation. Many methods having this object in view have been devised; some intended to produce the acid anhydrous, others, in a dilute state. The former modes will first be noticed, commencing with that of GAY-LUSSAC, which is as under:—

Into a perfectly clean tubulated glass retort, introduce a quantity of finely-powdered cyanide of mercury, and then add rather less than the same weight of hydrochloric acid, having a specific gravity of about 1.2. Next adapt to the beak of the retort, in a horizontal position, a glass tube, about half an inch in diameter, and two feet in length. One third of this, at the end next the retort, is filled with pieces of marble, for the purpose of retaining any hydrochloric acid which may pass off with the hydrocyanic acid. To the remainder of the tube fragments of fused chloride of calcium are supplied, which absorb the aqueous vapor. To the outer extremity of this purification tube is adapted a small receiver, surrounded with a freezing mixture. The hydrocyanic acid is expelled by means of heat; but it is advisable not to raise this very high, as, in that case, too much hydrochloric acid might be evolved, and not only is this a source of inconvenience, but, by the disengagement of much carbonic acid from the marble, hydrocyanic acid may be carried off. The use of too large a quantity of hydrochloric acid is, for the same reason, to be avoided. The reaction in this case is thus represented:—

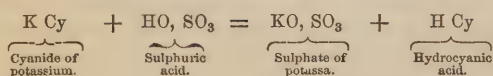


By VAUQUELIN's process the cyanide of mercury is carefully placed in a long glass tube, terminating, at one extremity, in a small receiver surrounded by a freezing mixture, and having attached to the other end a proper apparatus for the supply of pure dry sulphide of hydrogen; this gas, on passing over the metallic cyanide, liberates its acid, and unites with the mercury to form sulphide; thus:—



The whole of the cyanide of mercury may be decomposed by gently heating the tube, while the gas is still passing through it; but it is better to leave a little of the metallic cyanide undecomposed, the product of the operation being thus preserved from contamination with the sulphide of hydrogen.

The last mode of procedure which it will be requisite to describe here is that of TRAUTWEIN. Fifteen parts of finely-powdered ferrocyanide of potassium are distilled at a gentle heat with nine parts of sulphuric acid, previously diluted with an equal weight of water; the distillate is collected in a well-cooled receiver, containing five parts of pure chloride of calcium, broken into small pieces. When the hydrocyanic acid has accumulated in sufficient quantity to cover the chloride of calcium, it is poured off into a well-stoppered glass vessel. The cyanide of potassium of the ferrocyanide is decomposed as in the former two processes; thus:—



For medical purposes, hydrocyanic acid is always employed in a dilute state, and as the means for directly obtaining this are preferable and more certain than that of letting down the anhydrous acid with water, many have been devised. The London College directs that seven drachms of sulphuric acid be mixed with four fluid ounces of water, and when cooled put into a retort; next two ounces of ferrocyanide of potassium are dissolved in ten ounces of water, and added. Eight fluid ounces of water are then placed in a cooled receiver, and heat being applied to the retort, six fluid ounces of acid are distilled over. Lastly, to this dilute acid are added six more fluid ounces of water, or so much that one hundred grains of the acid are entirely thrown down by 12·59 grains of nitrate of silver. Hence, it contains two, or, more exactly, 1·92 per cent. of real hydrocyanic acid.

The dilute acid of the Edinburgh College contains, according to SQUIRE, 3·98, or, according to Dr. CHRISTISON, 3·3 per cent. of anhydrous acid. The Dublin College has not fixed the strength of the acid prescribed in its Pharmacopœia. SQUIRE represents it to contain rather more than two per cent. of dry acid.

EVERETT, in 1835, proposed an entirely different plan for at once preparing the dilute acid. Dr. PEREIRA characterises it as yielding an acid of uniform strength, and as being available when the acid is required for immediate use. It consists in decomposing forty grains of cyanide of silver, with forty minims of dilute hydro-

chloric acid—specific gravity 1·129—made up to a fluid ounce with water.

Dr. CLARKE has suggested another process:—

Eight and a quarter parts of cyanide of potassium are dissolved in one hundred of water, and to this solution is added another of eighteen and a half drachms of crystallized tartaric acid in twenty of water. Bitartrate of potassa is thus precipitated, while the supernatant fluid contains about 2·8 per cent. of hydrocyanic acid, together with traces of bitartrate of potassa held in solution.

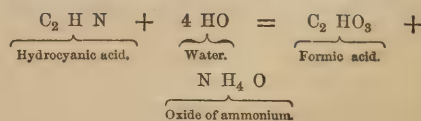
Again, a known quantity of cyanide of mercury is dissolved in water, and a stream of sulphide of hydrogen passed through the menstruum, which is then removed from the metallic sulphide by filtration. VAUQUELIN directs that the excess of sulphide of hydrogen should be thrown down from the solution by means of carbonate of lead. According to BRANDE, it is difficult to obtain a clear and colorless solution by this process without the addition of a drop or two of hydrochloric acid.

COMPOSITION.—It has already been stated in the introductory portion of the present article, that BERTHOLLET ascertained that the ultimate elements of hydrocyanic acid were carbon, hydrogen, and nitrogen. GAY-LUSSAC, in 1825, verified this, and, succeeding in obtaining the acid in an anhydrous state, determined the relative proportions of its constituents, with the following results:—

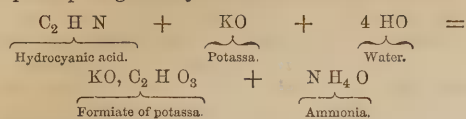
	At. weight.	Centesimally.
2 Eqs. Carbon,	12	44·45
1 Eq. Hydrogen,	1	3·70
1 Eq. Nitrogen,	14	51·85
1 Eq. Hydrocyanic acid, ...	27	100·00
Symbol:—C ₂ H N = H Cy.		

PROPERTIES.—At ordinary temperatures, anhydrous hydrocyanic acid is a clear, limpid fluid, possessing a strong penetrating odor—similar to that evolved when bitter almonds are bruised—and an acid, somewhat bitter taste. It faintly reddens blue litmus paper, but the tinge disappears as the acid evaporates in the air. It is so volatile, that when a drop is placed upon a glass plate, it freezes by the rapidity of its own evaporation. With water or alcohol it unites in any degree. Its specific gravity at 45° is 0·705, and at 64° 0·696. It boils at 79° or 80°. It congeals at 5° into a fibrous mass, having a great resemblance to crystallized nitrate of ammonia. SCHULTZ states that the perfectly anhydrous acid is still fluid under 0°, and that the solidification at 5° is owing to the presence of water.

Hydrocyanic acid is decomposed with facility under the influence of light, ammonia being generated, and a brown substance, not hitherto examined, deposited; this transformation is prevented by the presence of a small quantity of a mineral acid. Concentrated sulphuric, nitric, and hydrochloric acids decompose it, when water is present, into formic acid and oxide of ammonium, the elements of which it contains:—



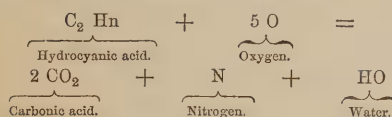
According to PELOUZE and GEIGER, the same decomposition of hydrocyanic acid into formic acid and ammonia is produced by the action of the fixed alkalies at elevated temperatures, probably in consequence of the predisposing affinity of the latter for formic acid:—



LIEBIG has found that when hydrocyanic acid is mixed with sulphide of ammonium, and the liquid heated till its color is destroyed, sulphocyanide of ammonium is formed, and this, giving immediately a blood-red hue with salts of sesquioxide of iron, forms the basis of a most delicate test for the acid, which is said to be distinctly recognizable, even when only the three thousand nine hundred and thirtieth part of a grain is present in the solution.

With nitrate of silver, hydrocyanic acid gives a precipitate, soluble, on boiling, in nitric acid; when with potassa, then a mixture of a proto- and sesqui-salt of iron, and, subsequently, an excess of hydrochloric acid are added to it, whether it is in the dilute or anhydrous state, Prussian blue is formed.

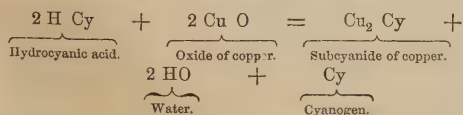
Both the anhydrous acid and its vapor are readily combustible, burning with a ruddy flame. The vapor, according to GAY-LUSSAC, has a density of 0.9476; when mixed with oxygen, it may be exploded by the electric spark, each volume of the former requiring for perfect combustion five of the latter. The products of this metamorphosis are—two volumes of carbonic acid, one of nitrogen, and one of water:—



The vapor mixed with hydrogen is, according to GAY-LUSSAC, but imperfectly decomposed by a succession of electric sparks, the gaseous compound depositing a small quantity of charcoal, and perceptibly increasing in volume. GMELIN remarks, that this expansion is not very easy to account for, unless it be due to the formation of carbonic oxide, or hydrogen arising from the presence of water.

Potassium heated in the vapor of the acid unites with the cyanogen and liberates hydrogen.

According to GAY-LUSSAC, hydrocyanic acid and hydrogen slowly produce, with oxide of copper, gaseous cyanogen and water, subcyanide of the metal probably being formed:—



The same authority asserts, that binoxide of manganese will absorb a mixture of hydrocyanic vapor with hydrogen gas, without separation of cyanogen.

PHYSIOLOGICAL EFFECTS, *et cetera*.—Although any notice, however brief, of the physiological effects of hydrocyanic acid may appear to be irrelevant here, as

belonging more properly to medicine, yet the Editor conceives that, without alluding to it, the article would not be complete, and it may have its uses. For most of the information on the subject he is indebted to Dr. PEREIRA.

Hydrocyanic acid is poisonous to the vegetal as well as to the animal kingdom. When the stems of plants, possessing irritability, are immersed in the acid, they lose this property. It prevents the milk of lactescent plants from leaving its cells, and deprives seeds of their germinating power.

Experiments have been made on animals generally, from the *mammalia* down to the *infusoria*, with hydrocyanic acid. The effects appear to have been similar in nearly every instance, the animals being convulsed, and losing sensation and voluntary motion.

According to GRAY, however, some larvæ of the *musca* remained uninjured after two or three days' immersion in the acid.

Rabbits, dogs, *et cetera*, are deprived of life by it in a few seconds, whether it is administered to them internally in the fluid form, or inhaled in the state of vapor. Even when a drop is placed on the throat or eye of a dog, death occurs in a very few moments.

It was first introduced into medicine about the year 1806 by the Italian practitioners, BORDA, BRUGNATELLI, and RASORI. Its use in England was much furthered by the investigations of Drs. A. T. THOMSON and ELLIOTSON in 1820 and the subsequent year. It has been tried as a remedial agent in many affections of the pulmonary organs, in derangements of the nervous system, in hydrophobia, as an anodyne, and as an anthelmintic, with questionable success; and it is now employed only for alleviating disorders of the stomach. The dose of course varies with the kind of acid employed. Of the acid prepared according to the London Pharmacopœia, two to seven minims may be administered. One to four minims of the acid of the Edinburgh College, or one to five minims of the Dublin preparation, are accounted a dose.

When given in medicinal doses, cautiously increased, the following effects may, according to Dr. PEREIRA, be observed:—A bitter, but peculiar taste; increased secretion of saliva; irritation in the throat; frequently nausea; disordered and laborious respiration, sometimes quick, at others slow and deep; pain in the head, giddiness, obscured vision, and sleepiness. In some instances faintness is experienced.

When administered in poisonous doses of moderate quantity, a remarkably bitter taste is experienced immediately after swallowing the acid; this is soon followed by a sensation of faintness and giddiness, with salivation, and is succeeded by tetanic convulsions and insensibility; the respiration is difficult and spasmodic; the odor of the acid may be recognized in the breath; the pupils are usually dilated, though sometimes contracted; the pulse is small and imperceptible. When recovery takes place it is usually very rapid, and the whole period of suffering seldom exceeds half an hour, though there have been exceptions, in which the symptoms have extended over several hours.

When hydrocyanic acid is taken into the human system in immoderate quantity, death supervenes so

speedily that the symptoms have scarcely been observed. They are probably similar to those noticed in animals, *videlicet*, imperceptible pulse, breathing not obvious; or there may be two or three deep, hurried inspirations, insensibility, and death. Convulsions may or may not be present.

The great variation in the strength of the acid renders uncertain three points of inquiry, each in itself interesting; namely, the quantity required to produce death, the time at which it begins to operate, and the period at which it proves fatal. Peculiarities not known or understood also affect the result. Very strong acid, in large doses, begins to operate very speedily, especially if its vapor be inhaled. The diluted acid, on the other hand, sometimes does not produce any obvious effect for several minutes, and death may not occur for nearly half an hour.—*Pereira*.

The mode in which hydrocyanic acid acts on the human frame is not without interest. Dr. CHRISTISON cites the case of ROBQUET, whose fingers were benumbed several days in consequence of their being exposed to the vapor of the acid. Hence it appears that the acid acts locally on the nerves. From the odor of the acid being exhaled from animals poisoned by it, and from the detection of it by KRIMER in the blood, it is clear that the poison is absorbed; but physiologists differ as to whether the remote effects produced by it are due to absorption. Dr. PEREIRA sums up the arguments which have been adduced in favor of this theory, as follow:—

Firstly: The acid produces no remote effects when applied either to the nerves or brain. Secondly: When applied to the tongue or stomach, it acts as an energetic poison, although the nerves of these parts were previously divided. Thirdly: That if the acid be applied to a part where circulation is arrested, the operation of the poison is prevented. Fourthly: The activity of the acid is in proportion to the absorbing powers of the part with which it is placed in contact. Fifthly: A sufficient time always elapses between its application to the body and the first symptom of its action, to admit of its operation by absorption.

The principal antidotes in cases of poisoning by hydrocyanic acid are chlorine, ammonia, cold affusion, and respiration by artificial means. Though the latter should on no account be omitted, yet the first two are universally admitted to be the most efficacious. Chlorine is given in various forms, as in very dilute aqueous solution, of which one or two teaspoonfuls may be administered at intervals. Or a weak solution of chloroxide of calcium—bleaching powder—or of chloroxide of sodium may be substituted for chlorine water. Chlorine gas largely diluted with common air may be carefully inspired by the patient. Ammonia is employed in the ordinary fluid state, largely emasculated; but much has been said in favor of the inhalation of the vapor of ammonia or its carbonate, as the preferable way of employing the volatile alkali.

ADULTERATION.—It cannot be positively affirmed that hydrocyanic acid is intentionally adulterated, though there is considerable reason to believe that it is often sold in too dilute a state. But, amongst all the methods for its preparation, there are none by

which it can be prepared absolutely pure without the use of the utmost precautions in every stage of the process. Hence, when due care is wanting, deteriorating substances often find their way from the retort to the receiver in considerable quantity. Again, however careful may have been its production, it is liable to decomposition if not properly preserved; this is especially the case when, from recklessness in its preparation, it contains foreign principles; for these, by their action on one another, on the acid itself, or from spontaneous decomposition, may give rise to a multiplicity of products, till ultimately the acid has completely disappeared, and there remains instead an *olla podrida* worthless to the owner, and which, if administered as a remedial agent, might be productive of the worst consequences.

Pure hydrocyanic acid is entirely volatilized by heat. Should a residue be left when it is carefully evaporated, it may consist of bitartrate of potassa, oxide of lead, cyanide of mercury, or of other substances according to the mode by which it is produced. Thus, the acid made by CLARKE's method often contains a portion of the first-named salt; while that prepared according to the directions of VAUQUELIN may be contaminated with the latter substances.

The stronger acids, as sulphuric or hydrochloric, are frequently present. In this case, litmus paper is strongly and permanently reddened; and when a mixture of cyanide of mercury with iodide of potassium—formed by commingling the concentrated solutions of these salts, when the double compound falls in white crystalline plates—is added to the suspected acid, the beautiful red iodide of mercury is deposited. This test occasions no change if the hydrocyanic acid be pure.

Sulphuric acid may be detected by the addition of chloride of barium, which occasions a white precipitate, insoluble in nitric or hydrochloric acid.

Nitrate of silver causes a precipitate of cyanide of silver; and should hydrochloric acid be present, of chloride of silver. The former—cyanide—is dissolved on the addition of boiling concentrated nitric acid, while the latter remains as a white curdy deposit.

Hydrocyanic acid containing ammonia soon acquires a brown color. When treated with a strong solution of potassa in the cold, ammonia is evolved, and may be recognized by the smell, and by the white vapors which are observable when a glass stirrer moistened with hydrochloric acid is placed in immediate contiguity with it.

The acid prepared by VAUQUELIN's process frequently contains lead. This may be detected by passing a stream of sulphide of hydrogen through the acid; if lead is present in large quantity, a brownish-black deposit is speedily formed; when the amount is small, a brownish coloration only is occasioned. Sulphuric acid will likewise throw down a white precipitate of sulphate of lead.

VAUQUELIN's acid may also hold cyanide of mercury in solution, if the current of sulphide of hydrogen were not long enough continued in its preparation. It is detected by saturating the acid with this gas, when the brown sulphide of mercury is formed.

When the hydrocyanic acid has been prepared, by

distilling a metallic cyanide with sulphuric or hydrochloric acid, formic acid may be retained in solution. This acid reddens litmus more strongly and permanently than does the pure hydrocyanic acid. On dissolving suboxide of mercury in the acid, and heating the menstruum, the mercury is reduced, producing a grey cloudiness, from which, when deposited, globules of metallic mercury may be elicited by friction. According to GEIGER, if the greater part of the fluid be gently evaporated, the residue reduces suboxide of mercury with effervescence.

Should hydrosulphocyanic acid be present in hydrocyanic acid, it may immediately be discovered, by adding a salt of sesquioxide of iron, when a fine blood-red color, more or less deep, appears.

DETECTION AND DETERMINATION.—The detection of hydrocyanic acid is oftentimes of the greatest importance, especially in cases of poisoning. Of late years, chemistry has, in this respect, given evidence most important and incontrovertible.

In many instances, hydrocyanic acid may be recognized by its odor, even when in a dilute state, when surrounded by decaying organic matter, or when itself partially decomposed. According to ORFILA, this test is the most delicate one, since, he says, it gives very marked indications when those afforded by the liquid reagents are only slight. This statement, however, must be received carefully, as much is necessarily dependent on the nature of the mixture containing or supposed to contain the acid.

The reaction of caustic potassa, proto- and sesquioxide of iron, and hydrochloric acid, upon a fluid containing hydrocyanic acid, is a valuable means of detecting the latter. The mixture under examination is saturated with caustic potassa, and a solution of a proto- and sesquisalt of iron is added. The precipitate thus formed may vary in color, according to the quantity of potassa or of the salts of iron present; sometimes being yellowish, at others blue, and again, partaking of both hues, being green. Whatever be the tint, it is immediately changed to that of Prussian blue, on the addition of a little hydrochloric acid. Care must be taken not to employ too much potassa, which would prevent the development of the Prussian blue.

Nitrate of silver also indicates with great delicacy the presence of hydrocyanic acid, causing a white flocculent precipitate, soluble in *boiling* concentrated nitric acid. The latter property distinguishes it from the chloride of silver, which it much resembles. Should further proof be required that the deposited compound is the cyanide, it may be carefully dried, introduced into a glass tube, and heated in the flame of a spirit lamp. Cyanogen gas is evolved, and this is readily combustible, burning with a purplish flame.

The discovery of LIEBIG, that when hydrocyanic acid was mixed with sulphide of ammonium, and subjected to a moderate degree of heat, a compound—sulphocyanide of ammonium—was formed, which possessed the property of giving an intense blood-red color with the sesquisalts of iron, afforded a test for hydrocyanic acid, which is equal, if not superior, to any at present known. Dr. PEREIRA remarks:—When the acid is in small quantity, and mixed with solids or

fluids, partially decomposed, then a modification of this test will enable one to detect a quantity of the poison which, from its minuteness, and from the absence of the usual odor, might otherwise escape notice. This slightly varied method is as follows:—Introduce the poisoned liquid or solid into a beaker or other similar vessel, which it should fill to within half an inch of the brim. Place upon a large watch-glass, which fits with tolerable accuracy to the beaker, two or three drops of sulphide of ammonium, containing an excess of sulphur, and invert it over the liquid. In three or four minutes, the watch-glass may be removed, and the moistened spot dried, with care and very gently, over a spirit-lamp or sand-bath. A white film remains, which may be either sulphur—resulting from the evaporation of the sulphide of ammonium—or sulphocyanide of ammonium, formed by the action of hydrocyanic acid, in the suspected liquid, upon the sulphide of the volatile alkali. In the latter case, the film will have a crystalline character, which, if not visible to the unassisted eye, may be detected by means of a microscope. Further, the film, if of sulphur merely, is not affected when moistened with water, and treated with a drop of sesquichloride of iron; whereas, when it consists of sulphocyanide of ammonium, the ferruginous sesquisalt immediately occasions a blood-red color, which is discharged upon the addition of a few drops of a solution of chloride of mercury. Should the film upon the watch-glass have a yellowish color, it is probably sulphide of ammonium, in which case the iron salt will give a black precipitate of sulphide of iron, thus showing that the evaporation has not been sufficient.

It should be observed, that both the Prussian blue and the nitrate of silver tests should be applied, when the suspected substance, as in cases of poisoning, contains foreign matters upon a distillate. Thus, if the contents of a stomach are under examination, they are introduced into a tubulated retort, and one-half distilled by means of a vapor or water-bath. Should the substance be alkaline—soon known by applying red litmus paper, which is at once colored blue—it may be owing to the generation of ammonia by putrefactive decomposition, and it is advisable to introduce a few drops of sulphuric acid into the retort along with the matters to be distilled.

It has been suggested that hydrocyanic acid may be formed during the distillation of organic matters. Dr. CHRISTISON rightly remarks that this objection appears only to rest on conjecture or presumption. The Editor would advise in all cases of importance, that the sulphur test, as modified by Dr. PEREIRA, and given above, should be first resorted to, and then the other tests may be proceeded with upon the original substance or a distillate from it, as its nature may render advisable, without risk of error.

The determination of hydrocyanic acid, which now presents itself to notice, is often of considerable importance, but never more so than when it is required to know the strength of an acid for medicinal purposes. Formerly, the density and the strength of the acid were supposed to be proportional, and Dr. URE constructed a table of specific gravities and corresponding strengths; but it has since appeared that these are

fallacious. He subsequently proposed the following method:—Weigh out a portion of the hydrocyanic acid, and add, by degrees, a known quantity of red oxide of mercury, agitating the menstruum after each addition, till it is no longer dissolved, and the odor of the acid has disappeared. By weighing the remaining oxide, the quantity employed is known, and since one hundred and eight parts of oxide require twenty-seven of anhydrous hydrocyanic acid for its liquefaction, the proportion of the latter is readily calculated. But DUFLOS has shown that the cyanide of mercury first formed is capable of taking up more oxide, even at ordinary temperatures, so that this method gives too much acid, especially if the liquid is not kept quite cool, and the addition of oxide stopped as soon as the odor of hydrocyanic acid has disappeared. Care, too, must be taken that the acid is perfectly free from hydrochloric acid, which also dissolves the protoxide of mercury. In this case, GEOGHEGAN neutralizes the hydrochloric acid with carbonate of lime before adding the oxide.

The last-mentioned chemist has directed, for the estimation of prussic acid, that nitrate of silver mixed with a small quantity of ammonia—so that the liquid after precipitation may be rather acid than alkaline—should be dropped into a known quantity of the acid, as long as a precipitate is produced. This is collected on a previously dried and tared filter, welledulcorated, dried at 212°, and weighed. One hundred and thirty-five parts of cyanide of mercury represent twenty-seven of the anhydrous acid.

Perhaps the most elegant mode of determining hydrocyanic acid is that last suggested by LIEBIG, and based upon the property of cyanide of potassium of dissolving chloride of silver, so as to produce a double cyanide containing an equivalent each of the cyanides of silver and potassium. The hydrocyanic acid is supersaturated with potassa, and mixed with a few drops of a solution of chloride of sodium; nitrate of silver is then added, until a permanent precipitate is produced. The proportion of the silver in the dissolved nitrate being known, the amount of hydrocyanic acid is readily calculated, since it is in the exact proportion of two equivalents to one of the silver consumed: thus supposing eighty-five grains of nitrate to have been used, which are equivalent to fifty-four of the metal, half the latter number—twenty-seven—will be the number of grains of anhydrous hydrocyanic acid present in the weighed portion operated upon. This nice method is also applicable for the estimation of the acid in cherry-laurel water, *et cetera*.

INK.—*Encre*, French; *Tinte*, German; *Atramentum*, Latin.—Ink, according to the purposes for which it is intended, is found in different forms. Writing ink, which is of various colors, is liquid, and may be either a clear fluid, as ordinary red ink, or may consist of a finely-divided precipitate equally diffused through the menstruum, as in common black ink. Printing ink is likewise of divers hues, but has a pasty consistence. The form of ink known as *Indian*, which is employed more especially as a water-color, is in solid cakes.

The present subject will be treated of in the following order:—

1. Writing inks, which are either *colored*, as black, red, blue, green, and violet; or *sympathetic*—that is, those which are colorless when committed to paper, as also when dried, but, by the application of heat, moisture, or of some compound which may be said to act as a mordant, they become visible, and are then either permanent or fugitive; in the latter case, the tint being generally caused to reappear by again applying the suitable means.

Besides these may be noticed the lithographic *transfer* inks, some kinds of which are used with the pen, and must consequently be included under this first class.

2. *Printing Inks.*—These, in all their numerous diversities of color and consistence, will be considered with reference to the purposes to which they are applied, as for letterpress, lithographic, and copperplate printing.

WRITING INKS.—There are few chemical preparations, perhaps none, of which the benefit in civilized life is so great, or of which the use is so widely extended, as that of common writing ink; consequently, there is no compound the quality of which it is so necessary to inquire into; and yet there is perhaps no subject which, up to a comparatively recent period, has been more neglected by chemists.

Before LEWIS, towards the close of the last century, directed his attention to the subject, no author appears to have particularly applied himself to inquire into the theory of the composition of ink, or to bring it to perfection. All that is to be found in the works of previous writers, consists merely of formulæ for various kinds of ink, which, being composed without any attention to chemical laws, were more or less defective; so that it may be truly said, that until the time of LEWIS, the preparation of writing fluids, the properties of which it is so essential to attend to, was left entirely to chance, or to empirical prescriptions.

It is indeed true, that some good kinds of ink have been discovered by accident; but those who devised them kept their composition secret, so that the public were either obliged to purchase those inks from the inventors, or to make use of such as were inferior in quality, and more or less perishable.

Ordinary black writing ink is now made from galls, sulphate of iron, green copperas, and gum. Other substances may be and often are employed, but those just named are the only requisite, and the best materials.

The ancient inks, according to the opinions of most writers, were similar to the Indian or Chinese ink of the present day. PLINY and VITRUVIUS allude to it as a combination of soot or lamp-black, with glue or gum; DIOSCORIDES even mentions the proportions of three of the former to one of the latter. To these, according to some authors, the liquor extracted from the cuttle-fish was added. When this could not be obtained, or from other causes, it is evident that some of the modern sulphurized ingredients were added by the ancients; many Greek and Roman manuscripts erased by the monks having been found to retain as much of the vitriolic principle as to become again legible on the application of chemical tests.—*Encyclopædia Britannica*.

Still, very little really definite knowledge of ancient writing inks can be obtained, and the Editor will therefore confine his attention to the modern ones.

Dr. LEWIS, already mentioned, found that equal weights of galls and sulphate of iron gave an ink, which, although of a good color when used, subsequently became yellowish-brown; that as the quantity of sulphate was increased, the inks were less durable in color, and that those in which the galls predominated, were most persistent. The proportions which he deemed best were:—

Powdered sulphate of iron,.....	1 ounce.
Ground logwood,.....	1 “
Bruised galls,.....	3 “
Gum-arabic,.....	1 “
White wine, or acetic acid,.....	1 quart.

He found that, although water answered for all ordinary purposes, white wine gave a deeper-colored product, and the ink made with acetic acid was still blacker. Alcohol was injurious to the hue, causing a deposition of the tinctorial precipitate. A decoction of logwood, substituted for water, improved the black both in richness and depth of tint. He directs the materials to be put into a glass, earthenware, or other non-metallic vessel, and the mixture agitated four or five times every day. In ten or twelve days it is ready for use—if placed in a warm situation, considerably earlier; but if the ink is allowed to remain on the matériel, it continues to improve for a lengthened period. When decanted, it may be kept in good order with greater certainty, if a few broken—not bruised—galls, and two or three fragments of iron, are placed in it.

LEWIS preferred distilled or rain water in making ink, but spring water containing calcareous salts is better adapted for the purpose. Some remarks on this subject, extracted from NAPIER, have been inserted in the article DYEING.—See Vol. I., page 584.

RIBAUCOURT, who devoted much attention to the manufacture of inks, and published an extended paper in the *Annales de Chimie*, in the year 1798, observes:—None of the ingredients of ink should be in excess. If there be a deficiency of galls, a portion of the sulphate of iron will not be decomposed; if, on the contrary, the galls are in excess, the ferrous sulphate will take as much as it can decompose, but the remainder will be nearly in the state of decoction of galls, subject to change by becoming mouldy, or undergoing a transmutation after the ink has been used, destroying the legibility of the writing much more completely than would be the case were the sulphate of iron present in too large quantity. He further considers it doubtful whether the principles of galls are extracted by mere maceration, and says that inks thus made always flow pale from the pen, and are never of so deep a black as those in the manufacture of which the galls have been subjected to a long-continued boiling. The following recipe was devised by RIBAUCOURT, as affording a good writing fluid:—

Boil eight ounces of coarsely-pulverized Aleppo galls and four ounces of thin logwood chips in twelve pounds of water for one hour, or until half the liquid is evaporated. Pass the decoction through a hair-sieve or

linen cloth, and then add four ounces of sulphate of iron, three ounces of gum-arabic, one ounce of sulphate of copper, and one ounce of sugar-candy. Agitate the mixture till the whole is dissolved, and leave it at rest for twenty-four hours; then decant the ink, and preserve it in well-stopped stoneware or glass bottles.

In making good writing ink, remarks Professor BRANDE, the great object is to regulate the proportion of sulphate of iron to the galls. If the former be in excess, although the ink may at first appear black, it becomes subsequently brown and yellow. Hence, some time should elapse before ink is used, after the ingredients are put together, in order to be tested from time to time, and the combinations perfectly regulated. The gum is added to retain the coloring matter in suspension, to prevent too great fluidity in the writing, and to protect the organic matter from decomposition.

If the paper has been made from inferior rags, bleached by an excess of chlorine, ink deposited upon it, however good, will be ultimately discolored. An excellent product is obtained as follows:—

Boil six ounces of finely-bruised Aleppo galls in six pints of water; then add four ounces of clean and well crystallized sulphate of iron, and four ounces of gum-arabic. Keep the whole in a wooden or glass vessel, occasionally shaken. In two months, strain, and pour off the ink into glass bottles.—*Brande*.

Dr. URE directs that twelve pounds of bruised galls be put into a cylindrical copper, of a depth equal to its diameter, and boiled, during three hours, with nine gallons of water, taking care to replace at intervals what may be dissipated by evaporation. The decoction is then to be emptied into a tub, allowed to settle, and the superstratum of liquid having been drawn off, the marc is to be drained. Some recommend the addition of a little bullock's blood or white of egg, to remove a portion of the tannin; but this abstraction, says URE, tends to lessen the product, and will seldom be practised by the manufacturer intent upon a large return for his capital. Five pounds of gum-senegal are next dissolved in a small quantity of hot water, and the mucilage thus formed, being filtered, is added to the clear decoction. Five pounds of sulphate of iron are now dissolved in as small a quantity of water as possible, and added. The color darkens by degrees, in consequence of the oxidation of the iron, on exposing the ink to the action of the air; when a moderately deep tint has been obtained, it should be drawn off clear into bottles, and well corked up. Dr. URE prefers digesting, rather than boiling, the galls.

The following prescription is given in the seventh volume of the *Pharmaceutical Journal*:—

Galls, bruised,.....	2 pounds.
Sulphate of iron,.....	5 “
Gum-arabic,.....	4 “
Water,.....	12 gallons.
Creosote,.....	2 drachms.

Boil the galls in three-fourths of the water for an hour, then strain. Liquefy the gum in twice its weight of hot water, and add it to the decoction. Dissolve the copperas in the remainder of the water, mix the liquors together, and finally stir in the creosote. It is very evident that in this recipe there is a great deficiency of

galls; otherwise, the quantity of sulphate of iron should be considerably reduced. The creosote is added as a preventive of mould, for which it is most efficient. BOOTH gives the following formulæ:—For superior black ink, take twelve pounds Aleppo galls, four pounds sulphate of iron, three and a half pounds of gum, and eighteen gallons of water. For a fine exchequer ink, forty pounds of Aleppo galls, nine pounds of sulphate of iron, ten pounds of gum, and forty-five gallons of water. In both these cases, it is directed that the bruised galls be exhausted by three consecutive boilings, each time diminishing the quantity of water, and supplying, by fresh addition, any loss by evaporation. The copperas and gum in solution are added to the strained decoction of galls, whilst both are yet warm, and the whole is allowed to repose for several weeks, when the fluid is drawn off from the sediment. A few cloves, or some drops of creosote are added, to prevent any parasitic growth.

REID gave, in the *Philosophical Transactions* of 1827, among many valuable observations which will subsequently be noticed in this article, the following proportions:—

Galls, bruised,.....	1 pound.
Sulphate of iron,.....	3 ounces, 64 grains.
Gum,.....	3 ounces, 64 grains.
Water,.....	3 quarts.

The galls are to be boiled with three pints of water till a quart of decoction remains; it is then poured off, the remainder of the water added, and ebullition continued until again a quart only is left. The two menstrua are then mixed, and the other ingredients dissolved in them; the whole is allowed to rest for twenty-four hours, when the fluid ink is poured off, and retained for use.

By another method, REID makes the decoction of galls as above directed, and exposes it freely to the air for ten days, agitating it two or three times each day. By this means much of the tannin is converted into gallic acid. To each quart of the decoction, add three and a half pints of water, nine ounces of sulphate of iron, and the same quantity of gum. The deposit which forms may, after three days, be separated, when the ink is fit for use.

Again, one pound of galls is exhausted as first directed, and the tannin of the decoction changed, by exposure, into gallic acid, as in the last instance. The menstruum is then mixed with a saturated solution of logwood, freshly made by boiling a pound and a half of the chips in five quarts of water, till the quantity is reduced to seven pints; eighteen ounces of sulphate of iron, and as many of gum, are dissolved in this mixed liquid; the whole is allowed to stand for two or three days, and the ink is then decanted from the sediment.

An attempt was formerly made to prepare ink by macerating iron filings in an infusion of galls; but though the resulting liquid was of the required hue, the writing produced with it was totally devoid of permanency, and was readily washed from the paper.

Japan ink is made as other inks, but the sulphate of iron is oxidised by roasting. This ink is intensely black when written with, but the color does not retain its depth or lustre. Besides these disadvantages, it

clogs the pen, and is, altogether, far from being worthy of recommendation.

Before giving the formulæ for, or notices of, inks prepared from other than the ordinary ingredients, it may be well to introduce here some remarks from a paper presented by Dr. BOSTOCK, in the year 1830, to the Society of Arts, which, though containing perhaps a few slight inaccuracies, is indicative of no small amount of research; and embodying, as it does to a great extent, the Editor's views, he does not consider any apology for its length to be requisite. Dr. BOSTOCK says:—

When the sulphate of iron and the infusion of galls are mixed, for the purpose of forming ink, it may be presumed that the metallic oxide enters into combination with at least four proximate vegetal principles, which constitute the bulk of the soluble portion of galls, namely, gallic and tannic acids, mucilage, and extractive matter. Two of these, the gallic acid and tannin, are more especially necessary to the constitution of ink, which is considered by some of the best chemists to be essentially a tanno-gallate of iron. It is also laid down, that the sesquioxide of iron alone possesses the property of forming the compound which constitutes black ink, and that the substance of the latter is mechanically suspended, rather than dissolved in it.

Ink, as it is usually prepared, is disposed to undergo certain changes, which considerably impair its value; of these the three following are the most important:—its tendency to moulding; the liability of the black matter to separate from the fluid, the ink then becoming what is termed *ropy*; and its loss of color, the black first changing to brown, and at length almost entirely disappearing.

Besides these, there are objects of minor importance to be attended to in the formation of ink. Its consistence should be such that it will easily flow from the pen, without being so fluid as to blur the paper, or so adhesive as to clog the pen, and to be long in drying. The shade of color is not to be disregarded; a black, approaching to blue, is generally preferred to a browner ink; and a degree of lustre or glossiness, if compatible with the due spissitude of the fluid, tends to render the characters more legible and beautiful.

With respect to the chemical constitution of ink, Dr. BOSTOCK remarks that although, as usually prepared, it is a combination of the metallic salt or oxide with tannic and gallic acids, mucilage, and extractive matter; yet the last three of them, so far from being essential, are, without doubt, the principal cause of the difficulty which is encountered in the formation of a perfect and durable ink. He illustrated this point by a series of experiments. Having prepared an infusion of galls, a portion of it was exposed to the atmosphere in a shallow capsule, until it was covered with a thick stratum of mould; this being removed by filtration, and the proper proportion of sulphate of iron added to the clear fluid, a compound was formed of a deep black hue, which showed no further tendency to foul, and which remained for a long time without undergoing any further alteration.

Another portion of the same infusion of galls had a

solution of isinglass added to it, until a precipitate was no longer occasioned; by adding sulphate of iron to the filtered liquid, a black compound was produced, which, although paler than that made from the entire fluid, appeared to be a perfect and durable ink.

Lastly, a portion of the infusion of galls was subjected to continued ebullition, by which means part of its contents became insoluble; the menstruum was filtered, and sulphate of iron added to the filtrate, producing a good and permanent ink.

Dr. BOSTOCK presumes that the three causes of deterioration in writing fluids, the fungoid growth, the subsidence of the black compound, and the loss of color, are dependent upon the operation of different proximate principles: the first change he ascribes to the mucilage; the second to the extractive matter, from the property which it possesses of forming insoluble compounds with metallic oxides; the third he believes to be owing to the tannic acid, which probably, in the first instance, forms a triple compound with the gallic acid and the iron, and that, in consequence of the decomposition of the tannin, this body is subsequently destroyed. Owing to the difficulty, if not impossibility of depriving the infusion of galls of any one of its ingredients, without, in some degree, affecting the others, the last-named authority was unable to obtain any results which could be considered decisive; but experiments led him to conclude that, in proportion as ink consists merely of the gallate of iron, it is less liable to decomposition, or to experience any kind of metamorphosis.

Dr. BOSTOCK's summary is as follows:—In order to procure an ink which may be little disposed either to mould or to deposit its contents, and which, at the same time, may possess a deep black hue not liable to fade, the galls should be macerated for some hours in hot water, and the fluid filtered; the filtrate should be then exposed for about fourteen days to a warm atmosphere, when any fungoid growth that may be observed must be removed. A solution of sulphate of iron is to be employed which has been boiled, or exposed for some time to the air, and in which there is consequently an admixture of sesquioxide of iron. If the infusion of galls be made considerably stronger than is generally directed, the ink formed in this manner will not necessarily require the addition of a mucilaginous substance to render it of a proper consistence.

Dr. BOSTOCK adds further, in the *Transactions of the Society of Arts*, that one of the best fluids for diluting ink, if it be, in the first instance, too thick for use, or if it afterwards become so by evaporation, is a strong decoction of coffee, which does not appear to occasion the decomposition of the ink, while it improves its hue, and gives it an additional lustre.

The black color produced by galls in union with sulphate of iron, although faulty from its disposition to precipitate and decompose, was, from its being the only known method of making a black tinctorial solution, the sole article used during a very considerable period for atramental purposes. To those whose chief employment consisted in writing, copying, *et cetera*, the least defect in the ink caused a more or less serious addition to their labor, and the improvements made in

this fluid may, therefore, be considered as real and valuable benefits.

A semi-colored solution, such as were the old ferro-gallic inks, requiring the addition of gum to prevent the deposition of the tinctorial matter, was especially liable to thicken, and flow tardily from the pen: this in sultry weather, when evaporation is rapid, became especially irksome. The introduction of the steel pen made these imperfections more manifest, causing a greater liability in the ink to concrete and deposit its coloring matter.

Writing inks were in this state when the improvements introduced by Mr. HENRY STEPHENS of London first appeared. This gentleman, applying the knowledge of chemistry which he obtained in his studies for the medical profession, to which he once belonged, engaged in extensive and successful researches upon atramental fluids.

The first improvement introduced by him consisted of a blue liquid, which had the startling novelty of becoming intensely black in a few hours after its deposition on the paper. It had the great recommendation of perfect fluidity, and the ease with which it was transferred from pen to paper, coupled with its ready but tenacious combination with the latter, were, at that time, considered really remarkable. This now celebrated writing fluid is a tanno-gallate of iron dissolved in sulphate of indigo; the common ferro-gallic writing inks consist of a liquid in which the tinctorial matter is suspended by means of gum, while in this the color is in complete solution.

RUNGE, after endeavoring for a long time to find a black fluid possessing the properties of forming no deposit, of adhering strongly to the paper, of being unaffected by acids, and, lastly, of neither acting nor being acted upon by steel pens, succeeded after many experiments. The composition has the advantages of being very simple and exceedingly cheap. It is prepared by adding one part of chromate of potassa to one thousand parts of a saturated solution of logwood, made by boiling twenty-two pounds of logwood in a sufficient quantity of water to give fourteen gallons of decoction; to this menstruum, when cold, the chromate is gradually added, and the mixture well stirred. The addition of gum is injurious. In the preparation of this ink, it must be remembered that the chromate, not the bichromate, of potassa is employed, and great care is requisite to insure the due adjustment of the relative proportions of the ingredients used. The best way is to make the decoction of logwood, and *gradually* add to it, well stirring the mixture, as much solution of chromate as will give the desired shade.

It appears astonishing, says RUNGE, what a small quantity of chromate of potassa is required to convert a large amount of decoction of logwood into a black writing fluid; the fact is, however, certain, and care must be taken not to allow the proportion of chrome salt to exceed one part for one thousand parts of decoction of logwood, as a larger quantity exercises a prejudicial effect in destroying the tinctorial matter of the liquid, whilst, in the proportion above mentioned, a deep blue-black writing ink is formed, which, unlike the ink made with tanno-gallate of iron, is perfectly fluid, forming no deposit. This fluid possesses another advantage; the paper which has been written upon

with it may be washed with a sponge, or be left twenty-four hours under water, without the marks being erased. Weak acids do not destroy the writing, nor do they even change the shade, whilst that made from galls is effaced, and the ink made with logwood and sulphate of iron is turned red.

It is especially necessary, in using this atramental fluid, that the steel pens should be well cleansed from the greasy matter with which, when new, they are always coated. This may either be done in the usual way, by moistening them with saliva, and subsequently washing them with water; or, preferably, by applying to them an alkaline solution. RUNGE used this ink for two years without his steel pens being in the least affected, either by being crusted, or clogged with solid matter, or by becoming rusty.

Professor TRAILL has proposed a formula for ink as follows:—Gluten, obtained in the ordinary way, is kept from twenty-four to thirty-six hours in water, and is then digested in acetic acid having the specific gravity 1.033 or 1.034, in the proportion of three parts of gluten to twenty parts of the acid. By the aid of a gentle heat, a greyish-white, saponaceous fluid, which may be kept for some time, is obtained. From eight to twelve grains of the finest lamp-black, and two grains of indigo, form the coloring matter for each fluid ounce of the vehicle, with which it must be thoroughly incorporated. An agreeable aroma may be communicated by digesting bruised cloves, pimento, or cinnamon, in a portion of the original acid. This ink may be used with a steel pen, but should not be left in it, and the pen should be washed after use; it is not calculated for writing on parchment.—*Edinburgh Philosophical Transactions*.

Mr. HENRY STEPHENS has invented an indelible carbon ink, which, if at all equalled, is certainly not surpassed. His process is as follows:—

Take common carbonated alkali, or the potassa or soda of commerce, or ammonia, or some other alkaline compound, and mix it with resinous matter,—as shell-lac or common resin,—in about equal proportions; then add water according to the required strength of the solution, and boil the whole until the resinous substance, or the greater portion of it, has dissolved; next mix the necessary quantity of fine lamp-black with this solution. A black liquid will thus be produced, which may be mixed with other suitable colored solutions, to form an indelible ink. Such tinctorial matter as is soluble in alkali, will best assimilate with this composition.

A recipe for an indelible carbon ink, published in the year 1845, by HERBERGER, is perfectly identical with that of Dr. TRAILL just given.

Dr. NORMANDY has suggested an indelible writing ink, which cannot be obliterated or defaced by any known chemical agent. Twenty-four pounds of Frankfort black must be ground with mucilage—formed by adding twenty pounds of gum to sixty gallons of water—and the mixture strained through a coarse flannel, or passed through a funnel the tube of which is closed by a sponge; four pounds of oxalic acid are then added, together with as much decoction of cochineal and sulphate of indigo as will give the required shade.

Many substitutes for galls, in the manufacture of ink, have been suggested—principally for the sake of economy. Those of Dr. NORMANDY and M. GIROND are most worthy of notice. The former chemist employs sumach, elm wood, elder, chestnut, beech, willow, oak, plum, sycamore, cherry, poplar wood, catechu, or any other ligneous matter or berry, or extract of vegetal substances, containing gallic acid and tannin, or either of these principles. In making ink by this method, which is patented, the bark, wood, or berry, as the case may be, is reduced to powder, and boiled with water until a sufficiently strong decoction has been obtained. The quantity of water must vary, of course, according to the sort of vegetal substance employed; thus sumach will demand more water than catechu, on account of the latter being almost wholly soluble. To the menstruum is added a certain amount of logwood, of acetate and hydrate of protoxide of copper, of sulphate of alumina and potassa, and of sulphate of protoxide of iron, in quantities which must be regulated according to the nature of the organic matter first made use of. Gum-arabic or a superior quality of gum-senegal is now added, in the proportion of eighty pounds or thereabouts for each three hundred and forty gallons of liquid; also a variable amount of sulphate. As the quantity of the ingredients must be regulated by the shade of the tint intended to be produced, it is impossible to indicate absolutely the proportions in which they are to be employed; this must be decided by the taste and fancy of the manipulator. Supposing, however, that a blue-black is desired, and that sumach is the vegetal substance to which preference is given, the annexed are the proportions for two hundred and forty gallons of the ink:—Sumach, from forty-eight to sixty bushels; logwood, about two hundredweight—the quantity slightly varying, according as new or old chip is taken; gum-arabic, from eighty to one hundred and twelve pounds; protosulphate of iron, one hundredweight; acetate and hydrate of protoxide of copper, four pounds; sulphate of alumina and potassa, thirty-seven pounds; sulphate of indigo, six pounds or more, according to the required intensity of the blue. Were catechu to be employed in this case, instead of sumach, one hundredweight would be required, the proportions of the other materials remaining the same.

The obstacles which have hitherto prevented the use of the above-named astringent vegetal substances instead of galls, are the variously-colored precipitates which they afford with salts of iron, some being quite green, others brown, while decoction of galls yields with sulphate of iron a dark purple. These hues may, however, be altered at will, by the use of sulphate of indigo in different proportions, from dark-blue to the most intense black, applicable to dyeing, staining, or writing, and which may be employed with every description of pen.

The substitute for galls, patented by GIROND in 1825, is denominated by him, *damajavag*, and consists of an extract from the shell, wood, or sap of the chestnut tree.

One hundredweight of chestnut shells, broken into fragments, is to be immersed in from one hundred and

eighty to two hundred gallons of water, in a vessel of copper or other material *except iron*; and after having been allowed to soak for about twelve hours, heat is applied, and ebullition maintained for about twelve hours. If the wood of the chestnut tree is employed, it is cut into small pieces or thin shavings, and treated in the same way.

The extract is drawn off from the boiler at the end of the time specified, and filtered through a fine sieve or cloth, after which the water is evaporated from it until it becomes of a pasty consistence, when it may be cut into cakes of any convenient size, and dried in an oven at a low temperature till hard, at which time it is ready for use.

In making ink with this substitute, it is merely necessary to reduce it to a coarse powder, and use it as galls.

One hundredweight of chestnut shells yields eight or ten pounds of the dry extract.

SCOTT, in the year 1840, patented the following method for the manufacture of ink:—

Take forty-eight pounds of logwood chips, and let them be saturated two days in soft water; then boil them in a closely-covered iron caldron, with eighty gallons of the last-named liquid, for one hour and a half, when the wood must be taken out, and forty-eight pounds of the best Aleppo galls added to the menstruum, which must be boiled for half an hour, and subsequently allowed to remain in the vessel for twenty-four hours, during which time it must be frequently agitated. When the principles of the galls have been sufficiently extracted, draw off the clear fluid into a vat, and add forty pounds of pulverized sulphate of iron; let these ingredients remain for a week, during which time they should be daily agitated; then pour in four gallons of vinegar. Next take seven and a half pounds of the best picked gum-arabic, and dissolve it in sufficient water to form a good mucilage, which must be well strained, and then by degrees be mixed with the fluid; let these stand a few days longer, then add twenty ounces of concentrated nitrate of iron. When the menstruum has attained a sufficient depth of color, it is carefully decanted from the sediment, and the following substances, each separately prepared and ground, added to it:—

First, grind half a pound of Spanish indigo by means of a muller and stone, till it is very fine, occasionally adding portions of the ink until it is made into an easily soluble paste; then take five pounds of well-washed and purified Prussian blue, which must be prepared as the indigo, except that distilled water must be employed instead of the partially-prepared writing fluid. Next take four ounces of *gas-black*,—that is, the carbon collected from the smoke of gas-burners on glass surfaces—and grind it with one ounce of the nitrate of iron. These several substances are allowed to remain for a few hours unmixed, when the whole may be incorporated with the fluid, which is daily agitated for a week. The clear ink, in quantity about eighty gallons, is then poured off for use.

The Rev. J. B. READE of Aylesbury took out patents in the year 1847 for various writing, marking, and printing inks. The first only will be here noticed; the second and third will be described in their proper

places in the subsequent part of the article. The only black writing ink which he has devised, is made by mixing soluble Prussian blue of a good quality—prepared by Mr. READE's own patent, and described in the manufacture of his blue ink—with ordinary gall ink. This addition of Prussian blue makes the ink, which was already unaffected by alkalies, equally proof against acids, and a writing fluid is thus obtained which cannot, according to the patentee, be erased from paper by any common method of obliteration without destroying the tissue.

Two or three black inks now remain to be noticed, which, from the nature of the ingredients, can hardly be classed with the common varieties, and have, on that account, been reserved for description to the last. The first, and not the least important, of these is BERZELIUS' indelible ink, prepared from the metal vanadium. Vanadic acid, when combined with ammonia, thus forming a vanadate of the volatile alkali, and mixed with an infusion of galls, forms a black fluid, which, according to the inventor, is the best writing ink that can be used. The quantity of salt necessary for a perfectly black ink is so small, that, to use the great chemist's own expression, it will not be worth considering when vanadium is more generally known. The writing obtained with this ink is perfectly black. Acids do not obliterate it, though they cause the color to become blue. Alkalies, when diluted so as not to act upon the paper, do not dissolve it. Chlorine, though it destroys the black color, does not efface the writing, even when water is suffered to run over it. Though this ink cannot be said to be absolutely indelible, yet it strongly resists reagents which cause common ink to disappear. It has also the advantage of being a solution, and not merely a precipitate suspended in a fluid by means of gum, so that it flows more freely from the pen.

COATHUPE has given a formula for an ink capable of resisting the action of all the substances usually employed for effacing writing. It is prepared as follows:—Boil, in a loosely-covered tin vessel, two ounces of shell-lac and one ounce of borax with eighteen ounces of distilled or rain water, stirring them occasionally until the whole is perfectly homogeneous; filter the mixture, when cold, through bibulous paper, and mix the filtrate—in quantity about nineteen ounces—with one ounce of mucilage of gum-arabic, made by dissolving the gum in double its weight of water, and add pulverized indigo and lamp-black *ad libitum*. Seethe the whole again in a covered vessel, and agitate the menstruum thoroughly in order to effect the complete solution of the gum and the admixture of the coloring matters. This agitation is continued during the cooling of the fluid, after which it is allowed to repose for a few hours, so as to permit the deposition of the excess of indigo and carbon, when it is decanted and bottled for use.

An *indelible safety ink*, patented by WHITFIELD in 1837, is prepared in the following manner:—Four gallons of linseed oil; two of cocoa-nut oil; one gallon of good molasses; five pounds of loaf sugar; two pounds each of ground sacre seed, ground cotton seed, Venice turpentine, ivory black, Antwerp black, finely-powdered

burnt horns, tartar, pulverized gum-kino, and anacardium nuts; four pounds each of very finely-powdered charcoal, dried bullocks' blood, and gum-arabic; one pound each of solution of caoutchouc, parchment-shavings, powdered seed-lac, and Indian borax; and three pounds each of Aleppo galls, pomegranate peel, fine glue, and walnut skins, all in fine powder,—are mixed and boiled in a large iron caldron. On the commencement of ebullition, the mixture is ignited with a bar of red-hot iron, and the smoke which is liberated is received into a capacious inverted cone made of the best sheet-iron. As soon as the whole of the oil is consumed, the carbon which adheres to the cone is collected and carefully preserved. The residuum is then removed from the boiler, and rubbed down on a stone slab to an impalpable powder. One pound of the carbon collected in the cone, and a similar quantity of the prepared residuum, are then mixed with a quart of the best French vinegar, two gallons of hot water, and four ounces of gum-lac, and these ingredients are then boiled for ten minutes, when one pound of Aleppo galls in fine powder, and two pounds of logwood chips are added. The mixture is stirred until cold, and is then poured into large flat pans, and exposed to the atmosphere for three weeks.

Whatever may be the qualities of this ink when manufactured, it is certainly prepared in a singular manner. A mere tyro in chemical science will at once perceive that the materials are selected and proportioned so as to form a rare *olla podrida*, while the subsequent treatment of them is, to say the very least of it, wasteful in the extreme.

Copying inks, or inks which, after having been transferred from pen to paper, and having become dry, will communicate a portion of their substance to a sheet of damped paper strongly compressed upon them, thus furnishing two, and, in some instances—by renewed application, with pressure, of clean moistened paper—even a third or fourth copy of the same manuscript, are generally prepared by adding a modicum of sugar or sugar-candy, with an increased amount of gum, to the ordinary ferro-gallic inks.

RED INK.—The red inks at present in common use are of two kinds, of which, however, there are some modifications.

The first variety is prepared by making a solution of the tinctorial matter of Brazil-wood in acetic acid, the color being *raised* by means of alum.

BOOTH gives the following formula for a red ink:—Brazil-wood, two ounces; chloride of tin, half a drachm; gum-arabic, one drachm; water, thirty-two ounces. These ingredients are subjected to continuous ebullition, until the quantity of fluid amounts to only sixteen ounces.

HEUSLER's recipe is here given:—Boil two ounces of Brazil-wood, half an ounce of pulverized alum, and the same quantity of crystals of bitartrate of potassa in sixteen ounces of distilled water, until the fluid is reduced to one-half. Strain the liquor, dissolve in it half an ounce of gum-arabic, then mix with it a tincture made by digesting a drachm and a half of cochineal in one and a half ounce of alcohol of specific gravity 0.839.

Red inks of the second class are prepared from cochineal or carmin; the most common modification is a simple solution of the latter in an excess of ammonia, the proportions being varied according to the depth of color required. Such ink is extremely fugitive.

The following recipe is given in the *Pharmaceutical Journal*:—Place in a porcelain vessel twelve grains of pure carmin, and pour thereon three ounces of solution of ammonia; heat over a spirit-lamp for a space of from five to eight minutes, carefully regulating the temperature so that ebullition shall not occur, and to the solution thus formed, add, continually stirring, eighteen grains of powdered gum-arabic. When this is liquefied, the ink is ready for use. Drop lake may be substituted for the carmin, as being more economical.

According to OHME, a good red ink may be made by macerating, for two days, six drachms of powdered cochineal, and one ounce and a half of pure carbonate of potassa, with sixteen ounces of water. Four and a half ounces of bitartrate of potassa and three drachms of alum are then to be added, and the fluid heated as long as carbonic acid is evolved. After the liquid has been filtered, the contents of the filter are to be washed in one ounce and a half of water, and one ounce of alcohol is then added to the resulting fluid, as an antiseptic. For most purposes, six drachms of gum-arabic should be dissolved in each sixteen ounces of this ink; but when used as a tinctorial agent in confectionery, for which it is well fitted, the addition of gum is unnecessary.

Mr. STEPHENS obtains an excellent red ink from cochineal by the following method:—Add to a quantity of common carbonate of potassa, soda, or ammonia, twice its weight of crude argol in powder. When the effervescence caused by the combination of the tartaric acid of the argol with the alkaline base, thereby expelling the carbonic acid, has ceased, decant or filter the solution from the insoluble matter; to this is added, by measure, half its quantity of oxalate of alumina, prepared by dissolving damp, newly-precipitated alumina in as small a quantity as possible of a concentrated solution of oxalic acid. The mixture thus prepared is next colored, when cold, with bruised or powdered cochineal, and after standing for forty-eight hours is strained, when it is fit for use.

The Rev. J. B. READE took out a patent for a red ink in the year 1847. Subjoined is his mode of preparing it:—Cochineal is first boiled in successive quantities of pure water, till it ceases, or nearly so, to afford tinctorial matter. It is then subjected to ebullition with dilute ammonia, which dissolves the remainder of the tint-giving principle, leaving the animal matter nearly white. These aqueous and ammoniacal decoctions are then mixed in an earthenware vessel, and the coloring matter is then thrown down by means of the double chloride of ammonium and tin. The compound thus formed is subsequently boiled in ammonia, and iodide of tin is then added, till the required degree of brilliancy of hue is obtained; this completes the process, the degree of body required in the ink being given by an *ad libitum* addition of water. This ink, says the patentee, is greatly superior to the com-

mon solutions from peach and Brazil-wood, not only in permanent richness of color, but also in its freedom from acid, and consequent fitness for use with steel pens.

BLUE INK.—There appears to have been no true ink of a persistent blue color, until Mr. STEPHENS introduced his *unchangeable blue writing fluid*.

Reflecting upon the durable nature of Prussian blue, as well as upon its beautiful and strong contrast to white paper, Mr. STEPHENS was led into an investigation of the means of dissolving it, so as to adapt it to atramentation, while, at the same time, it might be made serviceable to the dyer; and oxalic acid was found to answer the purpose. The ink is prepared as follows:—Take Prussian blue—whether it is that of commerce, or purposely prepared by a combination of a sesquisalt of iron with ferrocyanide of potassium, is immaterial—put it into an earthen vessel, and pour upon it as much strong acid as will cover it. Hydrochloric, nitric, and sulphuric acids are equally of service; but if the latter be used, it should be diluted with a quantity of water equal to its own bulk. The Prussian blue is allowed to remain in the acid from twenty-four to forty-eight hours, or even for a more extended period; the mixture is then diluted with much water, at the same time agitating it, for the purpose of washing from it the salts of iron. When in this state of dilution, it is permitted to rest until all the color has subsided, at which time the supernatant liquid is siphoned off, and a further quantity of water added. This process is repeated until ferrocyanide of potassium no longer evinces the presence of iron by giving a blue precipitate; and also until the menstruum ceases to redden blue litmus paper, thus proving that the acid has been entirely removed. The product is then placed upon a filter, and suffered to remain until all the liquid has drained away. The Prussian blue, by this treatment, has lost a considerable proportion of its iron, and is now more readily acted upon and dissolved than in any other condition. After being gently dried, oxalic acid is added to, and carefully mixed with, the Prussian blue; cold distilled water is then poured, in small portions at a time, over the whole, making it into a dense or dilute solution, according to the depth of color required. The amount of oxalic acid may be varied according to the quantity of water used. It will be found that Prussian blue which has undergone the process of digestion just described, requires but a small modicum of acid to dissolve it. For a concentrated solution, six parts of Prussian blue—weighed before the treatment with acid—will, after the operation, be taken up by one part of oxalic acid, and a proportional amount of water. Prussian blue, in its ordinary state, will require two or three times its weight of oxalic acid; and even then, it will be liable to precipitation after standing; when deprived of a portion of its iron in the first place, by means of acid, it remains a permanent solution.

The comparative durability of the ordinary black ferrogallie ink and that made from the sesquiferrocyanide of iron—Prussian blue—may be judged of by the following:—

Black ink is a combination of a protosalt of iron

with the active principles of galls; the tannogallate of iron thus produced is good whilst the metal remains as protoxide; but, as soon as the salt has passed into a higher state of oxidation, the ink has a tendency to decay; and as still more oxygen is attracted and combined, the vegetal matter is decomposed, until eventually there remains on the paper only oxide of iron of a reddish-brown hue, similar to that produced when the ink is acted upon by chlorine. If the writing is kept from the air, and all damp is excluded, the color of the ink will be unaffected for many years; but should the manuscript be placed in a damp position, the iron soon passes into the state of sesquioxide, and the vegetal portion of the ink becomes extinct.

The ink from Prussian blue has a reversed principle as regards its permanence. While the iron is in its normal degree of oxidation, the color is only partially developed, and it is not until the iron is further oxidised by means of an acid, or by exposure to the atmosphere, that the fine deep hue is fully developed. It is here that the uniform well-known tendency of the lower oxides of iron to absorb oxygen, instead of being an evil, is of positive service. As the state of sesquioxide is the true condition in which iron combines with ferrocyanogen to give Prussian blue, and as the inherent disposition of the iron is to assume this form, it is clear that the tendency of the elements is to be permanent. As a further proof of this, if writing executed with Prussian blue ink be exposed for a longer or shorter period to the action of strong light, a deoxidation of the iron occurs, and the color is to all appearance faded; but, on removing it from the influence of light, the iron reassumes the state of sesquioxide, and the color again becomes dark: this change may be repeatedly effected in the same manuscript, with an unvarying result. This repeated deoxidation by light, and the reverse action from want of solar or other rays, is generally known and well exemplified in the case of articles of external dress dyed with Prussian blue, which, being worn—and consequently exposed to the influence of strong light, not the less powerful because coming from its primary source, the sun—become pale, and lose that brilliancy for which Prussian blue, as a tinctorial substance, is so celebrated; but when these habiliments are again brought out, after being exposed for some time to darkness, the color is revived as by magic, and is again equal to new.

On adding a solution of ferrocyanide of potassium to ordinary black ink, a blue hue results; the affinity of the iron for the ferrocyanogen being so much stronger than that which it has for the tannic and gallic acids, the latter are displaced, thereby showing the greater force of combination in the blue, over that in the black ink. Many acids are destructive of the color of the latter, but the sesquiferrocyanide of iron is unaffected by any. Even chlorine has no action upon it, except that it perhaps deepens the shade a little. Of excess of moisture and light, and of the thousand and one physical causes which operate destructively upon black ink, only one affects the preparation of Prussian blue—light, and the action of this, as has been seen, is far from being permanent.

The Rev. J. B. READE has also patented a blue ink, which is manufactured as under :—

A solution of iodide of iron having been carefully prepared according to the usual method, a proportion of iodine amounting to half the weight already employed, is dissolved therein, and the mixture is then poured into a semi-saturated solution of ferrocyanide of potassium, employing of this salt a quantity about equal to that of the whole of the iodine used in the first-mentioned menstruum. A decomposition of the materials thus brought together immediately takes place, the ferrocyanogen of the potassium salt combining with the iron, and falling down in a solid form ; while the potassium and iodine unite to form an iodide of the alkali-metal, which remains in solution, together with a slight excess of iodide of iron. The whole is placed on a filter ; the retained deposit, caused by the union of the iron with the ferrocyanogen, and which is nothing more or less than Prussian blue in a soluble state, is well washed with, and is finally dissolved in water, which forms the blue ink desired.

Dr. NORMANDY has proposed a blue ink, which is made by operating upon Chinese blue, or ferrocyanide of iron. Three drachms of the ferrocyanide are macerated in seven ounces of water, with one drachm of binoxalate of potassa, adding one drachm of gum-arabic. A solution of tin may be added to these ingredients ; the binoxalate of potassa may also be substituted by an equivalent proportion of oxalic acid.

OHME recommends the following formula for blue ink :—Dissolve one scruple of iron in nitrohydrochloric acid—aqua regia—filter the solution, and dilute it with sufficient water to make eight ounces, which is mixed with four drachms of ferrocyanide of potassium, previously dissolved in eight ounces of water. The resulting subsidence is collected on a filter, and after the fluid has, as far as possible, been removed, the precipitate isedulcorated with pure water, until the latter passes through, having an azure tint. As soon as this occurs, the funnel and its contents are placed over a clean vessel, the filter pierced, and the blue compound washed with twenty-four ounces, by weight, of water. This latter menstruum constitutes the blue ink, the formation of which depends on the property of the precipitate to dissolve in pure water, and not in solutions of other salts.

PURPLE INK.—To produce a purple-colored ink, called the *King of Purples*, Dr. NORMANDY recommends the following method :—To twelve pounds of Campeachy logwood, add as many gallons of boiling water ; pour the infusion through a funnel with a strainer made of coarse flannel, on one pound of hydrate or acetate of copper—verdigris—finely powdered ; at the bottom of the funnel a sponge is placed ; then add immediately fourteen pounds of alum, and for each seventeen gallons of liquid, add four pounds of gum-arabic or senegal ; let these remain for three or four days, and a beautiful purple will be produced.

GREEN INK.—KLAPROTH directs for the preparation of green ink, that two parts of acetate of copper and one of bitartrate of potassa be boiled in eight parts of water, till the solution be reduced to half the bulk. It is then filtered through cloth, and after cooling, bottled.

WINCKLER has given the following recipe for a green ink :—Dissolve one hundred and eighty grains of bichromate of potassa in one fluid ounce of water ; add to the menstruum, while warm, half an ounce of spirit of wine ; then decompose the mixture with concentrated sulphuric acid until it assumes a brown color. The liquor is now evaporated till it is reduced in quantity to one-half, when it is diluted with two ounces of distilled water, filtered, mixed with half an ounce of alcohol, subsequently with a few drops of strong sulphuric acid, and then allowed to rest till, after some time, it assumes a beautiful green color. It is finally adapted for use by the addition of a small quantity of gum-arabic.

OHME has devised a green ink, made by triturating one drachm of gamboge with one ounce of the blue ink invented by him, and previously noticed ; but it is of little value.

YELLOW INK.—Yellow ink, according to Dr. URE, is prepared by dissolving three parts of alum in one hundred parts of water, adding twenty-five parts of bruised Persian or Avignon berries, boiling the mixture for an hour, filtering the liquor, and dissolving in it four parts of gum-arabic.

An extemporaneous yellow ink may be made by dissolving gamboge in water, but it is by no means permanent.

GOLD AND SILVER INKS.—Gold ink is prepared as follows :—Grind upon a porphyry slab with a muller, gold leaf and fine white honey, till the former is reduced to an impalpable powder. The paste is then carefully collected and diffused through water, which dissolves the honey, causing the deposition of the precious metal ; the water must now be decanted, and the sedimentedulcorated to free it from the saccharine matter. The powder exsiccated is very brilliant, and when required for use is suspended in mucilage of gum-arabic. After the writing executed with this ink is dry, it should be burnished with ivory.

Silver ink is prepared in the same manner, by substituting this metal, in leaf, for the gold.—*Ure*.

INDIAN OR CHINESE INK consists essentially of lamp-black formed into cakes by means of some glutinous or adhesive substance, such as gum-water. The lamp-black is said to be made in China by collecting the smoke of the oil of sesamé ; and M. MERIMÉE states that the Chinese do not use glue in the fabrication of their ink, but certain vegetable juices, which render it more brilliant and more indelible upon paper. Dr. URE remarks, that when the best lamp-black is levigated with the purest gelatin or solution of glue, it forms, no doubt, an ink of a good color, but wants the shining fracture, and is not so permanent on paper as good China ink. In the latter has been detected about two per cent. of camphor, which is supposed to improve it. On the other hand, PROUST says that lamp-black, purified by potash lie, when mixed with a solution of refined glue, and dried, formed an ink which was preferred by artists to that of China. A good Indian ink may be made with ivory black, ground to a fine powder, made into a paste with weak gum-arabic water, and then formed into cakes.

MARKING INK.—The fluids for writing on linen now known are widely different from those in vogue even

a few years ago. The latter always required a preparation of the tissue, previous to their application. The formulæ for a few of these are given, not so much on account of the likelihood of their being again useful, as to give an insight into their composition, thereby showing what science has accomplished even in such a limited sphere.

Marking inks are of two kinds: the first of these is applied with the pen, the second with types.

One of the older marking inks, in using which the linen required to be *pounded* or prepared, is as under:—Dissolve one hundred grains of nitrate of silver, two drachms of gum-arabic, and one scruple of sap green in one ounce of distilled water. The linen is to be wetted before applying this, with a pounce, consisting of a solution of one ounce of carbonate of soda in eight of distilled water.

GRAY directs that the ink be composed of two drachms of nitrate of silver, six drachms of water, and two of mucilage, while one ounce of carbonate of soda in sixteen of water, together with a little sap green, form the pounce. Another ink is a solution of one drachm of nitrate of silver, one of mucilage, in five drachms of distilled water, tinged slightly by means of sap green. The pounce consists of, carbonate of soda, one ounce; gum-arabic, one ounce; water, six ounces.

A form of ink known as Italian is merely terchloride of gold, the cloth being moistened before its application with a solution of chloride of tin.

The modern marking inks do not require the pounding of the linen previous to its being written upon; but instead, a hot iron is passed over the marks, or the cloth is held near the fire, till the color has been properly developed.

REDWOOD gives the following as the requisite properties of marking ink:—

1. That it shall flow freely from the pen, and form a well-defined mark, without running or blotting.
2. That it shall not require the application of a very strong or long-continued heat, by holding the article that has been written on to the fire, or by passing a hot iron over it, to develop the required hue.
3. That the marks produced by it, when brought out by heat or by exposure to light, shall be perfectly black.
4. That it shall not injure the texture of the finest cambric.

Subjoined is a very common formula for this kind of ink:—

Six drachms of nitrate of silver are dissolved in three ounces of distilled water, and as much ammonia is added as will liquefy the precipitate which it at first occasions. A little sap-green, ivory-black, Indian ink or indigo, diffused through four drachms of mucilage of gum-arabic, form the temporary tinctorial matter, and water is added to make up the quantity to four ounces.

Many marking inks, although black when first applied to the linen, become gradually washed out, and a yellowish stain only remains. JULES GUILLER has given three recipes for marking ink, which he believes to be free from these and some other prevalent evils. They are as under:—

For the first ink, twenty-two parts of carbonate of

soda are dissolved in eighty-five of distilled water, and twenty parts of pulverized gum-arabic are diffused through the menstruum. Eleven parts of nitrate of silver are then liquefied in twenty parts of ammonia, and this is commingled with the alkaline solution. The mixed fluids are next warmed in a flask, by which they become greyish-black, and partly coagulated; subsequently, brown and clear; then, when ebullition commences, very dark, and of such a consistence that it will flow readily from the pen. This ink, and that prepared from the next formula, have the advantages that no precipitates are formed in them, and that they insipitate by boiling, whereby their color becomes darker. For the second ink take,—

	Parts.
Nitrate of silver,.....	5
Distilled water,.....	12
Powdered gum-arabic,	5
Carbonate of soda,.....	7
Ammonia,.....	10

Treat these ingredients in the manner last described, and heat the resulting mixture in a flask until it has acquired a very dark tint, which is generally the case when its volume has diminished, by evaporation, about five per cent. By continuing the evaporation too long, a precipitate is occasioned in consequence of the loss of volatile alkali. The ink prepared in this manner is distinguished by producing very black characters upon linen, and is very suitable for marking with stamps or stencil-plates.

According to the third prescription, twenty-two parts of carbonate of soda are dissolved in twenty-five of distilled water; as also seventeen parts of nitrate of silver in forty-two parts of ammonia. Twenty parts of gum are then liquefied in sixty parts of water, and mixed with the soda solution, and afterwards with that of nitrate of silver, and lastly, thirty-three parts of sulphate of copper are added.

The large quantity of ammonia in this ink, says GUILLER, is accounted for by the presence of the cupreous salt. The latter might be replaced by nitrate of silver, but a much larger amount of this would be required to render the ink as dark as it is with the sulphate of copper. Whilst other marking inks have a dark-brown color, this ink possesses a rich blue. The proportions of the ingredients in these inks can be altered according to the consistency required, the uses to which they are to be applied, or the description and quality of the textile fabric on which they will be deposited.

REDWOOD's ink, which answers all the conditions—given above—that a marking ink ought to possess, is prepared in the following manner:—

Dissolve one ounce of nitrate of silver, and one and a half of crystallized carbonate of soda in separate portions of distilled water, and mix the solutions; collect the resulting precipitate on a filter, edulcorate it well with distilled water, and introduce it, while still moist, into a Wedgwood-ware mortar; add eight scruples of tartaric acid, and triturate the whole until effervescence has ceased: next add a sufficient quantity of ammonia to dissolve the tartrate of silver; mix in four fluid drachms of archil, four drachms of white sugar, and twelve of finely-powdered gum-arabic; and pour

in as much distilled water as will make six ounces of mixture.

The essential distinction between this and ordinary inks is the use of tartrate instead of nitrate of silver.

Long after REDWOOD had published his formula, generously laying his invention open for public use, the Rev. J. B. READE devised and patented two inks, the principle of which was identical with that of REDWOOD. Happening to meet with an ink made according to REDWOOD's recipe, he threatened the manufacturer with legal proceedings; but was prevented doing so by REDWOOD's showing with whom the invention originated. As other compounds are implied in Mr. READE's inks, the formula for each is appended:—

The first of these, which may be used with steel pens, and which is most readily developed on the application of heat, is prepared in the subjoined manner:—Nitrate of silver is triturated in a mortar with an equivalent of desiccated tartaric acid. Water is then added, which causes the separation of crystals of tartrate of silver, nitric acid being set free. The latter is neutralized carefully by adding ammonia, which also dissolves the metallic tartrate. Gum, tinctorial matter, and water are subsequently added in quantities which may be varied at pleasure.

By this process, remarks the patentee, the nitric acid, which is essential to a good marking ink, is retained, and the tartrate of silver formed is soluble in half the quantity of ammonia ordinarily required when nitrate of silver is the basis of the ink.

The second of the inks under this patent is made as follows:—

To a portion of ink formed by the process last described, is added an ammoniacal solution of an oxide, or salt of gold. The patentee has employed for this purpose the purple of Cassius—formed by precipitating a solution of the terchloride or other salt of gold by means of a tin salt—sulphide of gold, the iodide of gold and ammonia, and also the teriodide of gold and ammonia. The last two compounds, which Mr. READE considers to be *new*, he obtains by dissolving iodine in ammonia with application of heat; this operation must be conducted with great caution, in order to prevent the formation of that explosive compound, teriodide of nitrogen. The iodine solution thus obtained is a valuable solvent for gold. If this metal, in leaf, be placed upon it without the addition of water, a black deposition of gold is formed, which immediately dissolves; but, if the menstruum be diluted, the oxidation proceeds less rapidly, and the gold leaf assumes before solution, not a black, but a fine purple color. This salt of gold crystallizes in four-sided prisms, soluble in water. A few drops of this solution placed on a slip of glass, generally form arborescent, microscopic crystals, from which, by application of heat, the iodine and ammonia are volatilized, and arborescent metallic gold alone remains. If the heat be applied but moderately, only one equivalent of iodine is dispelled, and white crystals of iodide of ammonium and gold are left.

A *purple-red* marking ink consists of a solution of one drachm of bichloride of platinum in two ounces of distilled water. Before writing with it, prepare the

linen with a pounce made by liquefying three drachms of carbonate of soda and three drachms of gum-arabic in an ounce and a half of water.

SYMPATHETIC INK.—By sympathetic ink is meant a fluid which, being employed in writing, does not leave a trace of color upon the paper, but which, when exposed to moisture or heat, or when washed over with some vegetal or mineral solution, or subjected to some other agency according to its nature and chemical characteristics, becomes visible, the characters being then developed in a more or less apparent manner.

OVID mentions the method of writing with new milk, the characters being subsequently developed, even after the lapse of some time, by coal-dust or soot. The same means are proposed by AUSONIUS. It may be easily perceived that instead of milk, any other colorless and glutinous juice might be employed, as it would equally retain the black powder sprinkled upon it. PLINY, perceiving this, recommends the milky sap of certain plants.

Of all sympathetic inks, none, perhaps, is more remarkable than a solution of acetate of lead. The delineations made by this menstruum are rendered intensely black by means of sulphide of hydrogen—known also as hydrosulphuric acid, and as sulphuretted hydrogen—whether it be in a gaseous or liquid state. This effect, remarks BERGMANN, presented itself, perhaps accidentally, to some chemist; but the discovery is not of great antiquity. The first person who gave a receipt for preparing this ink, as far as the historian just quoted could learn, was PETER BOREL. In a work by him, printed in 1653, and again in 1657 at Paris, of which there were several subsequent editions, it is called a magnetic water which acts at a distance. In these days, phenomena, the causes of which were unknown, and particularly those which seemed to occur without any visible agency, were ascribed to *magnetic effluvia*. Others concealed their ignorance under what they called *sympathy*. The recipe for making these liquids, under the name of sympathetic ink, is first given by LE MORT, and that cognomen has not only been retained with reference to a solution of acetate of lead, but has also been applied to other fluids when employed for the same purposes.

Another and more beautiful sympathetic ink is that prepared from cobalt, the writing of which disappears in the cold, but appears again of a rich green color, as often as one chooses, after being exposed to a moderate degree of heat. This invention is generally ascribed, writes BERGMANN, to the French chemist HELLOT. He was, indeed, the first person who, after experimenting with it, made it public, but he was not the discoverer; he acknowledges that a German artist of Stolberg first showed him a reddish salt, which, when exposed to heat, became blue, and which, he assured him, was made out of Schneeberg cobalt with aqua regia—nitro-hydrochloric acid; but, if it be true that THEOPHRASTUS PARACELSUS could represent a garden in winter by this invention, it must unquestionably be older.

The development of chemistry in modern times, and the consequent discovery of an immense number of chemical compounds, have given rise to an almost infinite

variety of sympathetic inks. Some of the principal ones will be described:—

Black,—write with a solution of acetate of lead, or ternitrate of bismuth, and wash the writing over with an aqueous solution of sulphide of hydrogen, which causes the formation of sulphide of lead in the first instance, and of tersulphide of bismuth in the latter case. Or chloride of mercury may be used as the ink, to be developed by being placed in contact with chloride of tin; metallic mercury, in a minute state of division, being thus thrown down. A sympathetic ink, identical with common black writing fluid, consists of a solution of sulphate of iron; tincture or decoction of galls being employed as the mordant.

Blue,—employ nitrate of cobalt as the ink, with oxalic acid as a mordant—in this case oxalate of cobalt is formed; or sulphate of iron may be used for writing, which is to be washed over with ferrocyanide of potassium.

Yellow,—use chloride of antimony as the ink, and moisten the writing with decoction of galls; or inscribe the characters with subacetate of lead, and develop them by means of hydriodic acid. A dilute solution of chloride of copper forms a beautiful sympathetic ink, which is invisible until gently heated, when the letters assume a fine yellow color, which disappears as the paper cools.

Green sympathetic ink consists simply of a solution of chloride of cobalt, with a small quantity of a salt of nickel. Writing done with the colorless arseniate of potassa, and washed over with nitrate of copper, becomes beautifully green.

Purple is produced by edulcorating, with chloride of tin, writing executed with chloride of gold, the *purple of Cassius* being in this case formed.

The substances which may be employed as sympathetic inks, either *per se* or in conjunction with others, are exceedingly numerous; but they are so generally known that it is needless to describe them.

LITHOGRAPHIC WRITING INK.—There are two kinds of ink used in lithography,—that which is employed by the lithographic writer in tracing an inscription or design on paper with a view to its subsequent transference to the stone; and that which is employed in taking impressions on paper from engraved plates with a view to the same object. The composition of the latter will be stated under Printing Inks. The writing ink is composed of ingredients mixed in the following proportions:—For one and a half ounce of shellac, take two ounces of soap, three ounces of white wax, and about one ounce of tallow; add about three tablespoonfuls of a strong solution of gum-sandarach, and when ready color with lamp-black.

PRINTING INKS.—*Encre d'imprimerie*, French; *Buckdruckerfarbe*, German.—Printing ink, though of greater importance than that used for writing, has not engaged the attention of scientific men to any extent, and few works have been published respecting it. No printers of the present day make their own ink, although many add ingredients which they believe to improve the color or quality. It is an especial business, and demands considerable capital. Every manufacturer has his own secrets, both as to material and process; and

by long experience alone can printing-ink makers so select and apportion the various ingredients as to adapt it to its numerous requirements.

The commonest book-ink costs eighteenpence per pound, while the usual qualities are from two shillings and sixpence to four shillings; black ink for superior work is worth five to six shillings, while for the finest carmine ink as much as thirty shillings per pound is paid. In the latter case, the value of the tinctorial matter enhances the cost; but, when the care and labor required in the preparation are taken into consideration, it is evident that it is not the mere value of the ingredients which fixes its price.

PROPERTIES.—Printing ink, as every one must be aware, is a very different composition from that used for writing. It is a soft, glossy compound, having a certain amount of adhesiveness, and becoming, by exposure in thin layers, perfectly hard and firm. Besides these properties, which always belong to it, it possesses other and varying attributes according to the numerous purposes to which it is applied. Its preparation demands not only a tolerable proportion of scientific knowledge, but also very careful manipulation; and manufacturers have found that, to produce it of good quality, both experience and deep study are requisite. The very important use for which it is designed—the registering in a permanent manner the productions of the mind—indicates some of the properties it ought to possess. The most valuable of these is durability, or the capacity to resist successfully the obliterating influence of time; and it ought, at the same time, to have brightness and depth of tint. It must be a mutable preparation, passing from the soft adhesive state to that of a perfectly hard and dry substance, and this change of condition must have a certain rate of progress, and be to some extent under control. When prepared, some time generally elapses before it is used, and during this period it ought not to alter in the slightest degree; in fact, when the air is excluded from it, it should keep for almost any length of time. During its application to the types, its solidification ought to be as slow as possible, and unaccompanied by the emission of any unpleasant or deleterious odor. It ought not to affect the soft, elastic rollers which are employed to convey it to the type or woodcut *form*, and which, unless the ink be a perfectly innocuous preparation, are liable to considerable injury. The change of state should not be accompanied by the deposition of consolidated matter in the ink, as this impedes the workman, and proves a loss to the printer.

The trying circumstances, as regards the quality of printing ink, do not end here. Having been applied, its action must be confined to a very slight penetration into the paper,—just sufficient to prevent its detachment without materially injuring the surface of the latter. It ought to dry up, in a very short space of time, to a hard, inodorous, unalterable solid.

Printing ink should, moreover, have an oleaginous character; it ought to be very glossy, and perfectly free from any granular appearance. If, on the extraction of a small portion from a mass, it leaves but a short thread suspended, it is considered good; but the best

test of its consistency is the adhesion it shows upon pressing the finger against a quantity of it.

MATERIALS.—The ingredients of ordinary printing ink are *burnt* linseed oil, resin, and occasionally soap, with various coloring matters. A slight notice of these is required.

Linseed Oil.—The best quality of oil is used, and this is purified by digesting it in partially-diluted sulphuric acid for some hours, at a temperature of about 212°, allowing the impurities to subside, and then washing away the acid with repeated additions of hot water. The oil after this treatment is pale and turbid, and, if the edulcoration is complete, there is scarcely any odor. By rest the oil clarifies, and has then a pale lemon color. It now dries much more rapidly than before. For an experiment, four drops of oil were exposed on a slip of glass: the first was ordinary Baltic linseed oil; the second was East India oil; the third and fourth were two distinct oils which had been purified by means of sulphuric acid. In the course of a fortnight, the first was colorless and rather viscid, but no skin or pellicle had formed on its surface; the second was colorless, but had no apparent viscosity; the third and fourth were not only colorless, but a tenacious film covered the surface of each.

The purified oil is now partially resinated by heat. For this purpose it is introduced into large cast-iron pots, and boiled until inflammable vapors are freely evolved. These are ignited, and allowed to burn for a few minutes, after which they are extinguished by placing a tight cover over the boiler. Ebullition of the oil is continued until, on cooling, a firm skin forms on its surface, known by placing a drop on a slate or other smooth cold material.

According to SAVAGE,—who has written at considerable length on this subject, and whose inks gained the large medal of the Society for the Encouragement of Arts,—the linseed oil cannot be brought, however long boiled, unless inflamed, into a proper state for making printing ink. Certain it is, that by the ebullition and ignition just noticed, the original character of the oil is totally altered; it is at first turbid, but clarifies when allowed to repose; it is now viscid and more or less adhesive; it penetrates paper with difficulty; it dries much faster than when unburnt; and it has now a pyrogenous and not unpleasant odor, which soon passes off from a thin layer exposed to the air. Fragments of slightly charred bread are by some added to the boiling oil, but no marked benefit arises from such a procedure.

Other drying oils besides linseed are occasionally used, but their cost or other considerations prevent their general adoption. Resin oil is indeed pretty largely employed by some makers; but, apart from other disadvantages, its disagreeable and permanent smell prevents its entering into other ink than that intended for temporary or common printing, as newspapers, placards, *et cetera*.

Resin is an article of considerable importance in the manufacture of printing ink, since, when dissolved in the oil—after the latter has undergone ebullition and inflammation—it communicates *body* to the fluid, and the compound bears a great resemblance to Canadian balsam. For many inks, the quality of the common

black resin is sufficiently good; but some require the pale, clear, transparent resin, obtained by remelting and clarifying the residue of the distillation of turpentine with water.

THE COLORING MATTERS of printing ink demand great attention, as much of the beauty of the typography depends upon them.

Black.—The universal ingredient for this color is lamp-black. There are vast buildings, as a writer in the *Encyclopedia Britannica* remarks, appropriated to the sole purpose of burning oil, naphtha, spirit, coal-gas, *et cetera*, to produce this black, which is collected from the sides and ceilings of the chambers. It is imported from Germany and many other countries, and no expense is spared to get the most superior quality.

Other black substances are occasionally employed. Charcoal from various sources, when reduced to an impalpable powder, and mixed with the other ingredients, furnishes a deep blue-black ink that dries rapidly. Carbonized vine-stalks, wine-lies, woods of various kinds—in fact, carbonized lignin from any source, when ground sufficiently fine—sometimes a tedious and costly operation—answer well; as also does bone-black. The brown tint possessed by lamp-black is not unfrequently neutralized by the addition of blue compounds, as indigo, Prussian blue, *et cetera*.

For *red* ink, carmin, lake, vermilion, red lead— Pb_3O_4 —Indian and Venetian red, are employed.

A *blue* color is supplied by Prussian blue, indigo, Antwerp blue, *et cetera*.

Chromate and bichromate of lead—known respectively as lemon and orange chrome, or as chrome yellow and chrome red—yellow ochre, gamboge, and other pigments, furnish a *yellow* hue.

Green is obtained by means of arseniate of copper, or by a union of blue and yellow colors.

For *brown*, burnt sienna, umber, sepia, and mixtures of red with black, are employed.

PREPARATION.—In the manufacture of printing ink, the resin is dissolved in the burnt oil, in cast-iron pots or boilers, and the varnish, thus prepared, is introduced into what is termed *the mixing vessel*, which is cylindrical, and in the centre of which, bars or rods of iron, attached to a perpendicular shaft, revolve in a horizontal position. The black or other coloring matter is then added to the hot varnish, and the whole, when thoroughly mixed, is drawn off through an opening in the base of the vessel. The *pulp* is next very carefully ground, by being passed between hard stones of a very fine texture, driven by heavy machinery, the motive power being steam. Sometimes a second grinding is requisite, but this may generally be avoided by taking care that the varnish of resin and oil is clear and free from gritty particles, and that the black is in an impalpable state.

The proportions and conditions of the various ingredients vary considerably, and great experience is required before an ink can be prepared to suit any one purpose. The oil has to be rendered more viscid, by burning, in some cases than in others; sometimes the quantity or kind of resin requires to be varied; or, perhaps, different proportions of color are requisite. Newspapers printed by steam-power require an ink of

less substance than that employed for book-work, which must be tolerably *stiff*. For woodcuts, the ink must not only be stiff, but very fine. The qualities of the material to which the ink is applied, furnish an additional guide in this matter: thin paper must have a soft ink, which *works clearly*, and is not too adhesive. A fine stout paper, on the other hand, will bear a stiffer and more glutinous ink; and as resin supplies these properties, so does it in a great measure communicate brilliancy, and the most perfect and splendid effects are by these means produced.

URE gives the following directions for making printing ink:—

To one and a half gallon of linseed oil, burnt and boiled, as above described, till a portion, extracted from the pot by means of a pallet-knife and cooled, draws out between the fingers into strings of about half an inch in length—add gradually six pounds of resin. When this has dissolved, twenty-eight ounces of dry brown soap of the best quality, cut into slices, are introduced cautiously, for the combined water causes a violent intumescence. Both the resin and soap are well stirred in, and the whole is then ignited for a few moments, in order to complete the admixture of the constituents. Two and a half ounces each of ground indigo and Prussian blue, together with four pounds of the best *mineral* lamp-black, and three and a half pounds of good *vegetal* lamp-black, are placed in an earthenware pan, sufficiently large to contain the whole of the ink, and the warm varnish is then added by degrees, carefully stirring, to produce complete incorporation of all the ingredients; and the mixture is, finally, ground into a smooth uniform paste.

The two succeeding recipes are from the *Encyclopædia Britannica*, the first being that used by BASKERVILLE and BULMER, and giving excellent results:—

1. Dissolve a small quantity of black or amber resin in three gallons of fine old linseed oil, which has been boiled to a thick varnish, and cooled in small quantities; allow the mixture to stand for some months, so that all impurities may subside, then mix with the best lamp-black, and grind carefully.

2. One hundred pounds of nut or linseed oil are reduced by boiling and burning to one-eighth its bulk, and to the consistence of a sirup; two pounds of coarse bread and several onions (!) being thrown in to purify it from grease. Thirty or thirty-five pounds of turpentine are boiled apart, until, when the residue is cooled on paper, it breaks clean, without pulverizing. The former is poured nearly cold into the latter, and well mixed. The compound is then boiled again, a sufficient quantity of lamp-black is incorporated, and when the ink is well ground, it is ready for use.

One pound of printing ink may be made by the subjoined recipe of SAVAGE:—

Balsam of copaiba, nine ounces; lamp-black, three ounces; indigo and Prussian blue, ground together in equal proportions, one and a quarter ounce; Indian red, three-fourths of an ounce; dry, yellow turpentine soap, three ounces: this mixture is to be ground, by means of a slab and muller, to an impalpable smoothness. It is stated that this ink possesses a beautiful color, but appears to work foul.

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JOHN BIRD took out a patent for substituting a mineral found in Merionethshire and other localities, instead of lamp-black. The mineral is freed from *debris* by washing, when it becomes a very black paste; and subsequently, on drying, a fine, black, impalpable powder, composed of—

	Centesimally.
Silicic acid,	46·00
Alumina,	42·00
Carbonaceous matter,	12·00
	100·00

The preparation of printing ink with this pigment is, in other respects, according to ordinary methods.

A patent was granted in 1854 to THOMAS DE LA RUE, by which glycerin is employed as a vehicle for making a fugitive ink, peculiarly applicable for the printing of bankers' cheques and other similar documents. For this purpose he precipitates logwood and vegetal substances, suitable for producing coloring matters, and grinds them up with glycerin to the consistency of ordinary printing ink.

The Rev. J. B. READE'S patents for printing ink are as under:—

He describes two blue printing inks: the one is made by taking the soluble Prussian blue obtained in the manufacture of his blue writing ink, and rubbing it up with oil; or, by triturating with oil the residue obtained by evaporating his blue ink.

For the second blue ink, he prepares the soluble Prussian blue with bromine instead of iodine, and diffuses it in oil.

His first *black* printing ink is made in like manner from his black writing fluid.

A second black printing ink is made by boiling chips of logwood—for which an extract of logwood may be substituted—or other dyewoods containing coloring matter and tannin, with as much proto- or persalt of iron or of copper, as will be equal to about twice the weight of the tannin contained in the wood or extract employed; a black or bluish-black precipitate is thus obtained, the blueness of which is diminished, as required by the addition of a greater or less quantity of bichromate of potassa. The whole is finally triturated with oil; a little lamp-black, or other black coloring matter usually employed in the manufacture of printing inks, being added.

LITHOGRAPHIC PRINTING INK.—The composition of lithographic writing ink has been already given. That which is employed to take impressions on paper from engraved plates, with a view to their transference to the stone, may be composed as follows:—Tallow, wax, and soap, of each four ounces; shellac, three ounces; gum-mastic, two and a half ounces; black pitch, one ounce and a half; to which add lamp-black to color.

The Editor cannot conclude the present article without expressing his thanks to Mr. HENRY STEPHENS, for his kindness in supplying him with information respecting writing inks; and also to Messrs. BENJAMIN SMITH and Son—who make the ink with which this work is printed, and who have a world-wide fame for the excellence of their productions—for similar favors with regard to printing ink.

3 C

IODINE.—*Iode*, French; *Iod*, German; *Iodium*, Latin.—This body is one of those which chemists designate elements, from the circumstance, that by no means or agency at their disposal are they enabled to extract any other form of matter from it. It may be regarded as a new substance, being discovered by M. COURTOIS, manufacturer of saltpetre—nitrate of potassa—in Paris, in the year 1812-13; and of all the simple bodies which have attracted the attention of chemists, iodine seems to be the most interesting, as, since its isolation, it has never ceased to present wide fields of investigation to the chemist and physician; many of these have been diligently explored and cultivated, but still sufficient remain untrodden to keep alive that scientific interest with which iodine has been invested from the date of its discovery. It is well known that chemistry has extended her domain of research principally during the last forty years; but even anterior to that period, chemical knowledge was so far advanced that the discovery of iodine might have been expected to take place long before its announcement by COURTOIS. That this should not have been the case is the more surprising, when the wide range of its distribution is considered, and its presence, particularly in reagents which the chemists of 1800, and their predecessors, were in the habit of using and preparing in a state of comparative purity; moreover, its characteristic appearance in the form of vapor, its odor, and the remarkable reactions which it produces, render the circumstance of its having escaped observation the more striking. The discovery of iodine is interesting, inasmuch as it was not a result arrived at by unguided experiment, as in the case of many bodies which might be cited, but of patient research. The multiplied unsuccessful attempts of COURTOIS to isolate it would be tedious to relate; but some idea may be formed of his numerous experiments and failures, from the first observation he made relative to the destruction of his copper pans employed in the decomposition of nitrate of lime with the alkaline lie of the varec or kelp, till he succeeded in tracing the effect to the cause, and in preparing iodine in a very pure state from the mother waters of his various processes. This discovery was made, as already stated, in 1812, and was announced by M. CLEMENT DESORMES at the meeting of the Institute on the 29th November, 1813. At this period iodine was anxiously sought after and studied by the celebrities of the day. By degrees it came to be known that other substances besides the ashes of sea-plants contained it, and since then numerous researches have shown that iodine is one of the most widely-disseminated elements, although, it may be remarked, that its aggregate amount is comparatively small. In the mineral kingdom it is met with, combined with silver and mercury, in ores from Mexico; in Silesian galmei it is found combined with zinc; and it has been detected in species of lead ore from South America; it is contained as iodide of potassium or sodium in the nitrate of soda from Chili, and has been detected similarly combined in the rock-salt of Hall in the Tyrol. Many springs have been found to yield quantities of iodine, united, doubtless, with the alkali metals, potassium and sodium, and with mag-

nesium; of this description are the waters of Bex, Sülze in Mecklenburg, Rolberg in Pomerania, Salzuffeln in Königsbrunn, near Unna, Rehme, near Minden Schönebeck, Halle in Saxony, Dürrenberg and Kösen, Artern and Salzingen, Schonalkalden, Salzhausen and Kreuznach, Bolechow and Drochobycz in Galicia, Kenahwa in North America, Guaca in the province of Antioquia in New Granada. Its presence has likewise been proved in the following mineral waters; namely, in the thermal spring of Albano, in one near Sales in Piedmont, in several salt springs near Ascoli, in the hepatic waters of Castel Nuovo d'Asti, in the hot spring of Aix in Savoy, in the Bonnington water near Leith, in Bath water, in the water from Marienbad in Bohemia, and also in the waters from Carlsbad, Heilbrunn, and Kunzig in Bavaria; in the medicinal waters of Hall in Austria, used for the cure of goitre; in the hepatic water of Trutkawiec, and in the alkaline waters of Iwonicz in Galicia. Besides these, later investigations have proved its presence in several other waters of every description. A vast amount of iodine exists in the ocean; but, from the minute centesimal proportion in which it is present, DAVY, GAULTIER, FYFE, and others, failed to detect it. In the plants which grow in the sea, as well as on its shores, the iodine is, so to speak, concentrated, and consequently, when the ashes of these are submitted to the usual tests for its detection, its presence is readily manifested. The following plants were found by SARPHATI to contain iodine in the quantities mentioned:—

	Per Cent.
<i>Fucus filum</i> ,.....	0.0894
“ <i>digitatus</i> ,.....	0.1350
“ <i>saccharinus</i> ,.....	0.2300
“ <i>nodosus</i> ,.....	—
“ <i>vesiculosus</i> ,.....	0.001
“ <i>saccatus</i> ,.....	0.124
<i>Loriscus siliculosus</i> ,.....	0.142

DAVY, GAULTIER, and FYFE found iodine in the following:—*Fucus cartilagineus*, *membranaceus*, *rubens*, and *palmatus*; according to SARPHATI, it is contained in *Sphærococcus crispus*; he found it also in *Ulva Linza*, *pavonia*, *umbelicalis*; likewise in *Lactuca* and *Zostera marina*. *Lichen confinis*, *Statice armeria*, and *Grimmia maritima*, growing upon rocks on which sea-water has been blown by the wind, have yielded this element; but *Ramelina scopulorum*, growing in the same situation, gave no indication to DICKIE of the presence of iodine. *Pile marina* contains it; and it is obtained in large quantities from the ashes of various species of *Fucus*, *Ulva*, and other sea-plants, which constitute the varec of Bretagne, and the kelp of the Scotch and Irish. The ashes of several shore-plants, such as the different kinds of *salsola*, and such as are used for producing the barilla of Spain and the Sicilian soda, contain very little or no iodine.

The marine animals which yield iodine are:—The Common sponge, the Horse sponge, *Lapis spongiarum*, *Spongia oculata*, *Flustra foliacea*, various species of *Sertularia* and *Tubularia*, various kinds of *Rhizostoma* and *Cyana*, *Asterias rubens*, *Crogon vulgaris*, *Mytilus edulis*; oysters contain it, and likewise various species of *Dorus* and *Venus*. It is found in cod-liver oil; and the oil from the liver of the *Raja clavata* and *Raja*

balis give indications of its presence; and from the statements of JONAS, it appears that traces of it are afforded by Scotch salt herrings. Besides these, many other substances of the animal and vegetable kingdom contain small traces of this element. Lately it has been detected in the ashes of various coals and shaly matters; and from the researches of M. CHATIN and others, it has transpired that rain water, dew, air, rose leaves, *et cetera*, give to properly-regulated experiments appreciable traces of iodine.

PROPERTIES.—M. GAY-LUSSAC was the first who investigated and discovered the general properties of this element, being succeeded by Sir HUMPHREY DAVY, VAUQUELIN, and several others. To prepare iodine, varec or kelp is exhausted with hot water, which dissolves about one half of this substance; the liquid is filtered and concentrated, and the chief part of the chloride of sodium, sulphate of soda, chloride of potassium, and other salts, is crystallized out, leaving a mother-liquor which, besides the iodide of sodium, retains other bodies in solution, such as sulphide of sodium, hyposulphate of soda, and traces of those already mentioned. This liquid is treated with sulphuric acid in a retort, when the more unstable compounds are decomposed, and sulphates of the bases produced; and on the application of a gentle heat, the iodine passes over into the condenser. In this state it is rarely pure, but is contaminated with chlorine, sulphur, and saline matters; it may be purified from these, however, by washing with water, filtering, and pressing between folds of bibulous paper, then subliming it a second time. A better method is to dissolve the iodine in alcohol, filter from any residue, and precipitate with water. The deposit collected and dried in the usual way, is pure iodine.

So prepared, it presents a bluish-black appearance, and a metallic lustre very similar to that of black-lead or specular iron ore. It is generally obtained in crystals, which are modifications of an elongated octahedron with a rhomboidal base, the primary form be-

evaporation in very small quantity, but which is increased when the air is loaded with moisture. When in a thin stratum, the vapor of iodine presents a beautiful rich violet shade from which its name is derived; but if examined in layers a few inches thick, it no longer presents this appearance, but rather a black mass, impervious to diffused day or candle light. Vapor of iodine is the heaviest of all known gases, being, according to the investigations of DUMAS, of specific gravity 8.717, and by calculation from its atomic weight, 8.7077. Alcohol and ether dissolve it in all proportions, producing dark reddish-brown liquids; water takes up only one seven-thousandth of its weight of this element. The solvent action is increased, however, when there are other salts dissolved in the liquid, such as nitrates or chlorides. In either case a brownish liquid is formed, which, by long exposure, disappears, the iodine being transformed into iodic and hydriodic acids. It is capable of uniting with most of the non-metallic elements, producing with some—such as nitrogen—highly explosive compounds; and with others—oxygen and hydrogen—acids which are capable of neutralizing bases, and thus forming salts, many of which are very important. The mineral acids, chlorine and several other bodies, are capable of displacing and reducing these compounds of iodine, and of setting the latter free when it colors the liquid brownish-red. A characteristic and remarkable property of iodine discovered by MM. COLIN and GAULTIER DE CLAUVERY, is the blue coloration it affords when brought in contact with starch-paste disseminated in water. This is so delicate and characteristic, that it still remains the test for iodine in all investigations, affording, according to STROMAYER, a perceptibly blue tinge when not more than one four hundred and fifty-thousandth part of iodine is contained in the liquid. KERSTING has latterly discovered that, by the use of a palladium salt, so small a quantity as the millionth part of iodine may be detected in a liquid. This subject will

be referred to further on. The starch test should be applied with some caution, however, as a large excess of the amylaceous substance causes the blue coloration to vanish. Heat also destroys it; and hence, in testing for iodine, the liquids must be cold. This reaction is not produced by iodine when combined with other bodies; and, consequently, when such combinations of iodine are to be examined, they should be decomposed

by some strong mineral acid—sulphuric or nitric, which contains a little nitrous acid.

Iodine is a most valuable therapeutic agent, and, as such, was first brought into notice by COINDET, a distinguished physician of Geneva, who found it a most effectual remedy for goitre. Its application is very frequent, more especially in diseases of the skin, and for eradicating glandular enlargements, indurations, thickening of membranes and tumours, as well as in several other ailments. When applied to the skin, the cuticle becomes colored of an orange yellow, but this disappears after a short time. Iodine, in considerable doses, acts as an irritant poison, although to be fatal

Fig. 258.

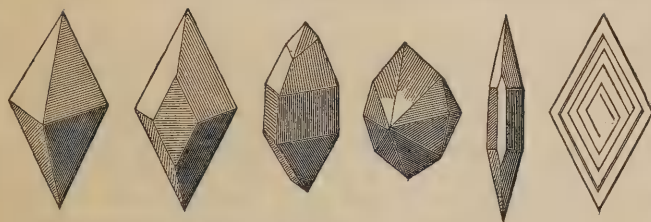
Fig. 259.

Fig. 260.

Fig. 261.

Fig. 262.

Fig. 263.



longing to the right prismatic system. See Figs. 258, 259, 260, 261, 262, and 263. The finest crystals are obtained from its solution in ether, or one of hydriodic acid exposed to the air. By sublimation it is obtained in laminae, or broad oblique tables, which, when thin, transmit light of a red color, according to GMELIN; but PAYEN states that the crystals which form under the microscope, and do not exceed in thickness the two-thousandth of a millimetre, or .000787 of an inch, are without translucency. Iodine fuses at 224.6°, and boils between 347° and 356°, giving off violet vapors, which condense upon a cold surface, producing crystals. At ordinary temperatures it is subject to spontaneous

it must be exhibited in large quantities. In the event of poisoning by this element, the pump and copious libations of amylaceous liquids should be resorted to.

MANUFACTURE.—The atomic weight of iodine has been estimated by BERZELIUS as 126; its chemical symbol is I.

Iodine has been a subject of manufacturing industry almost from the time of its discovery; and the first to prepare it on the large scale was the discoverer, but more as a *dernier ressort*, than for the sake of the advantages which it then offered. It has been stated in the foregoing, that COURTOIS was actively engaged in the manufacture of saltpetre, in which business he had invested the whole of his money; but on the throwing open of the French ports for foreign products, immense quantities of nitrate of potassa arrived from India, which at once superseded the old nitre beds, and by so doing ruined COURTOIS. In this dilemma he tried to extricate himself by manufacturing iodine; but the consumption of the article being at this time very limited, and the process of its manufacture being circuitous, rendered the enterprise an unsuccessful one. It was prosecuted, however, after COURTOIS by MM. COURNERIE of Cherbourg, in the North-East of France, who are the oldest manufacturers after the discoverer. With its extended application, as well in medicine as in printing, and latterly in photography, others were induced to turn their attention to the subject, and now several manufacturers of the article may be found, among whom may be mentioned Mr. WHITELOW of Glasgow, and Mr. JOHN WARD of the county Donegal, Ireland.

The course pursued in its manufacture is simple. The several *fuci* and *algæ* which contain it, are collected by inhabitants of places adjacent to the sea-shore, and dried in the air, after which shallow rectangular

pits are dug wherein the dried material is burned. The semi-vitrified ash that remains is broken up by sprinkling a little water upon it whilst hot. This is the *kelp* of the Scotch and Irish, and is the same as the *varec* of the Continental producers; it is purchased by the several manufacturers, in order to extract from it the iodine and other salts. For this purpose it is reduced to a coarse powder, which is placed in rectangular filters, having an inner perforated bottom of sheet-iron. These are arranged two and two, to the number of six pairs, so that whilst the one is being filled, the other is working. Water is let in upon the powder at the furthest end, till it has risen a few inches above the solid matter; and after allowing it to remain for a short time, the tap in the false bottom is opened, and the liquor drawn off as it slowly percolates through the mass.

From the receptacle in which the solution collects, it is raised by means of a pump to the second pair of filters, where it is allowed to act upon the powdered material as in the preceding instance. In the same manner the lie which is run off from each pair of filters is pumped on to the next pair, the matter in which it partly exhausts; thence it is removed to the others, and so on, till it has traversed the entire range. The solution thus obtained has a density of 1.257, and contains, for the most part, chlorides of sodium and potassium, with the iodides and bromides of these alkalies. After drawing off this first solution, the washing of the residuary mass in the filters is continued, using only as much water for this purpose as will afford a lie of 1.145 density. This is added to the other liquor, and the whole is evaporated in a series of three boilers, so disposed that the cold liquor flows into the first of the series, thence to the second, and is

Fig. 264.

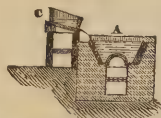


Fig. 265.



finally concentrated in the third, which is directly over the fire. Fig. 265 gives a longitudinal sectional view of the deposition of the evaporating pans, and Fig. 264 a transverse one.

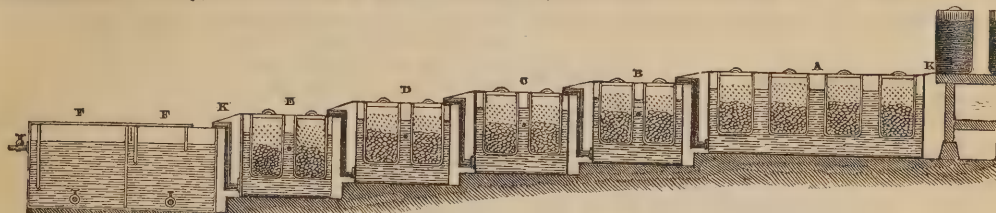
In the former of these, the pans are indicated by A, B, C, E, and F, the latter being situated over the fire, D, the flue from which passes under each in succession. After the evaporation has reduced the liquid to a density of 60° Twaddell, or 1.30 specific gravity, the chloride of sodium and sulphate of soda crystallize out in the heat, and are separated by a ladle, and thrown into an inclined drainer, C—Fig. 264—the drainings returning to the pan. When no more salt is deposited at this density, the fire is slackened, and the contents of the boiler allowed to repose for some time previous to siphoning off into wooden crystallizers lined with lead. By this a further quantity of chloride is separated in the pan, and the sulphates which are still retained are deposited in the coolers as incrustations on the sides and bottom. After removing these, and permitting the menstruum to repose for some time

longer, a crop of crystals of chloride of potassium is obtained. The period allowed for the formation of the latter deposit extends to about five days, at the termination of which, the chloride of potassium is found in large crystals at the bottom of the vessel. The mother-liquor is again pumped back into the evaporators, and reduced to 68° Twaddell, at which degree, sulphate of soda, chloride of sodium, and carbonate of soda deposit. It is customary to add sulphuric acid to the liquid in the first stages, to neutralize the carbonate of soda; the quantity of the latter which the kelp affords—about two per cent.—being thought too small to be separated from the other salts. When this is done, only sulphate of soda and chloride of sodium separate after the second concentration. The crystalline mass is then removed, and the liquor left to part with a further quantity of chloride of potassium, as in the preceding case. At this stage the mother-liquor is retained for further treatment, which will be presently described. The semi-exhausted mass is again mixed with water fractionally, till the solution marks 1.073; and the men-

strum is treated in the same manner as the first, only in a separate set of evaporators. As this contains more alkaline sulphates than the forementioned, and less chlorides, the crystallizations are effected much more readily, and when brought to about the same degree of concentration, the mother-*lie*, after the crystals have been deposited, is added to that from the first affusions. Finally, the washings of the residuary

mass are continued till the whole of the soluble matters are removed; these weak solutions are advantageously used to exhaust fresh portions of the kelp.

The kelp may be economically edulcorated by an arrangement such as that represented in Fig. 266, in which the parts, A, B, C, D, and E, are a number of rectangular plate-iron boxes, placed in gradation one step above another. Only five are represented in the



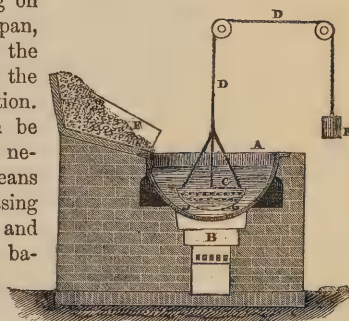
figure, but, if need be, a greater number may be employed. The last of these vases is a cast-iron wagon of double the size of the others, at the level of the rim of which a cast-iron plate, K, is placed in an inclined position, so that any liquid falling upon it may flow into the tank. By means of a pipe connected with A, at about six inches from its bottom, and which rises to the level of the next vessel, the liquid in A may be drawn over into B, which is similarly connected with the next, C, and so on to the vat, F, which, also by means of stopcocks, yields its contents to a series of plate-iron pans placed in gradation, like the others. The kelp or varec to be exhausted is put in small pieces into baskets of plate-iron, perforated in the manner of a skimmer, which are then introduced into the vats filled with water, by two men, who lift them by a wooden pole which passes through rings in the rim of the cylinder. After remaining in the first vat for the space of half an hour, they are transferred to the next vat, and their place replenished with two others, charged with fresh material. The same process takes place every half hour till the top wagon, A, contains two pair, at which stage those which have remained in it during an hour are taken out, and placed upon the inclined plate, K, to drain. At each succeeding half hour the transferring and charging takes place as before, the exhausted matter in the drained hampers being carried to the waste-heap. From the time, however, that the latter takes place, a portion of water, about double the volume of the perforated cylinder, is drawn off from the lower, and its place supplied from the next above it; the others in succession borrow from their superiors to the top one, which is replenished with water from the tank pipe. In this way, rapid and perfect exhaustion is insured, whilst the liquor which is drawn from E to the *settlers*, F F, has always a uniform strength. After the matter which had been retained mechanically in the liquid has deposited in F F, the *lie* is drawn off to the first of the evaporating pans which have been already mentioned, for concentrating the solution, in order to remove the sulphates and chlorides contained in it before recovering the iodine. Sometimes at this stage, especially when the ebullition has been quickly carried on, the chlorides and other salts which separate are in such small crystals, that they pass through the skim-

mer, and cannot be removed from the solution; hence, when the alkaline salts in kelp are procured for useful applications, there is considerable difficulty in their subsequent purification, for the sulphates and chlorides deposit promiscuously in the crystallizing pans. In order to have the separation as perfect as possible, PAYEN recommends a boiler such as that depicted in the drawing—Fig. 267—and indicated by A, having a fire beneath at B, and at the side an inclined case, F, from which the crystals are permitted to drain into the pan. A hemispherical vessel, C, of plate-iron, perforated at the sides, and resting on the walls of the pan, A, is placed in the liquid when near the point of ebullition. This vessel can be lifted out when necessary, by means of a chain, passing over pulleys, and attached to the basin at one end by branching chains, the other

being equipoised by a weight. Ebullition of the contents of A soon takes place, and the liquid being put into violent commotion, carries the small crystals about; but as they gravitate, they fall in the centre, owing to the absence of an upward current, and are received in the vessel, C, in which they are easily removed.

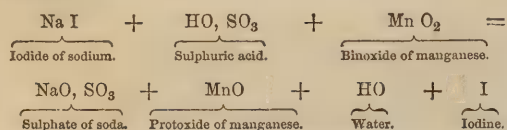
Whatever course is pursued to separate the mother-liquor from the salts, it generally happens that, in addition to the alkaline iodides and bromides, sulphide of sodium, hyposulphite of soda, with notable quantities of chlorides, are present in the solution, and which, owing to their solubility, cannot be removed. To obtain the iodine, the Scotch manufacturers add to the liquid a seventh of its volume of strong sulphuric acid, specific gravity 1.845, and, having agitated the whole, leave it to repose from thirty-six to forty-eight hours. During this period the sulphurous compounds are decomposed, sulphates being produced, whilst sulphide of hydrogen and sulphurous acid pass off, and sulphur becomes precipitated. At the end of this time the

Fig. 267.

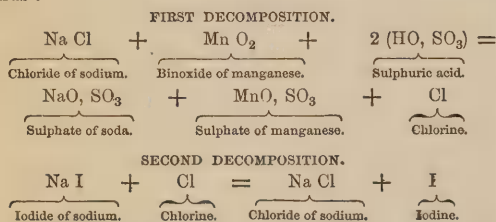


liquor is put into a retort which is adapted to a series of receivers, and heated to 140° . Having reached this temperature, a quantity of dry powdered binoxide of manganese is introduced through a tubulure in the head of the still, and the expulsion of the iodine effected at a temperature bordering on ebullition.

The chemical change which takes place in the course of the decomposition of the iodides by the sulphuric acid and binoxide of manganese, may be indicated thus:—



In this equation the oxygen from the manganese is represented as displacing the iodine, whilst the soda that is produced enters into combination with the sulphuric acid. Or it may be assumed that the binoxide of manganese, by acting upon the chlorides present under the influence of the excess of sulphuric acid, liberates chlorine, which in turn displaces the iodine thus:—



The distillatory apparatus employed is shown in Fig. 268, in which A is the still placed on an enclosed sand-bath over the fire, the door of which is shown at B. The head or capital of the retort is usually of lead, and is furnished with two apertures, *a* and *b*, which are closed

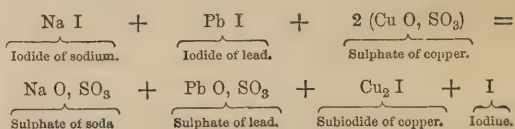
Fig. 268.



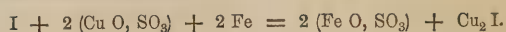
with stoppers. To the neck of the retort a series of spherical glass condensers, D D, are adapted, each of which has two apertures in its axis, one of which is drawn out so as to connect it to the next, as shown in the drawing.

After charging the retort, as already directed, with the liquor, and raising the temperature to about 140° , the peroxide of manganese is added in small portions through the stopper, *a*, and the temperature raised nearly to boiling; all the orifices and joinings being previously secured with the stoppers and pipe-clay, or other luting. The iodine passes over, and is collected in flakes in the receivers. The process is examined from time to time by opening the stopper *b*, and when the passage of iodine vapors slackens, more manganese—and acid, if necessary—are introduced through the stoppered aperture *a*, and the operation conducted till the whole of the iodine has separated. Such is the method pursued by Mr. WHITELOW of Glasgow, with this slight difference: he adds only an eighth part of sulphuric acid gradually to the liquor in a leaden boiler, and allows the sulphate of soda to crystallize out before introducing it into the still. It is important to retain the temperature at which the distillation proceeds at 212° , or nearly so, for above this the iodine is liable to pass over as chloride.

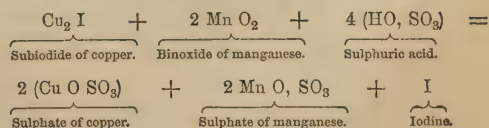
Sometimes, when the process is conducted in the manner just described, cyanide of iodine is produced, and is found in the third receiver in white needle-shaped crystals. The residue in the retort still retains some iodine in the form of iodide of lead and sodium. This can be recovered by the method proposed by SOUBEIRAN—namely, the addition of sulphate of copper, by which a subiodide of copper is formed. The precipitate is filtered, and the filtrate, which still retains some iodine, treated with a further quantity of the cupreous salt and iron filings, when another interchange takes place, and a further precipitation of iodide of copper occurs. The first of these changes may be expressed thus:—



And the second, by

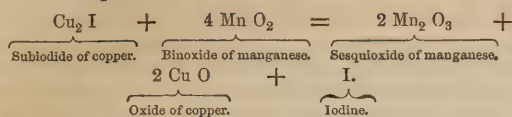


The proper period for arresting the addition of the cupreous salt and filings in the latter case, is when the characteristic smell of iodine disappears. No time should be lost in removing the precipitate from the ferruginous salt and filings by washing and decanting from the fragments of iron, and subsequently filtering through a cloth. Both portions of iodine are desiccated at a gentle heat, and the dry compound mixed with twice or three times its weight of peroxide of manganese, and as much strong sulphuric acid as will form it into a paste, and the mixture strongly heated in a subliming apparatus, when iodine passes off and is received in appropriate vessels: thus—



The use of sulphuric acid may be dispensed with in

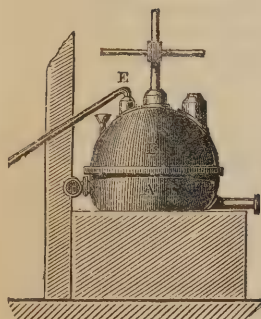
the above process, but the heat must be much more elevated when that agent is not employed. In this case, the binoxide of manganese is decomposed into sesquioxide of manganese and oxygen, which displaces the iodine combined with the copper, as shown in the annexed equation:—



According to SOUBEIRAN, this method is very economical, and affords as much as one per cent. of the mother-liquor operated upon.

At the Cherbourg Works the mother-waters are treated in slight excess with sulphuric acid, and the solution is afterwards boiled for some time; during this operation the sulphides, hyposulphites, and sulphites are decomposed, sulphurous acid, *et cetera*, being eliminated, and sulphur precipitated. Some time is now allowed, in order that the solution may clarify, and when this is effected, the supernatant fluid is drawn off from the precipitate and diluted till it marks 40° Twaddell, and then chlorine passed into it to saturation from a generating apparatus, such as that shown in Fig. 269. The chlorine passes off from the stills, A, B, where bin-

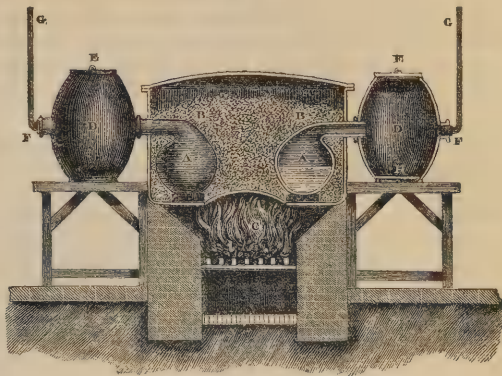
Fig. 269.



oxide of manganese and hydrochloric acid are made to act upon one another, or chloride of sodium, sulphuric acid, and binoxide of manganese, and proceeds by the conduit, E; into the vat, where it liberates the iodine from its combination in the mother-liquor. The end of this operation is the decomposition of the iodide present, or rather of the hydriodic acid, and the evolution of the iodine by the substitution of the chlorine; the iodine, being only slightly soluble, precipitates. In transmitting the chlorine through the liquid, it is necessary to guard against two evils: the first arising from the use of this agent in insufficient quantity, for in this case the iodine compound remains in part undecomposed; the second, produced by an excess of the gas, owing to the formation of chloride of iodine, which passes off in vapor, and is lost. Hence, to determine the exact point, it is necessary to test a part of the liquid as well with chlorine as with a solution of iodide of potassium, to prove, on the one hand, if there remains any further portion of the salt unacted upon; and on the other, if the agent be present in excess. Should the latter be the case, a further addition of mother-liquor is made to combine with the free chlorine. When the decomposition is complete, the contents of the vessel are allowed to settle, and after a time the clear liquor containing chlorides and sulphates is drawn off from the iodine. The latter is repeatedly washed by decantation, till the washing gives no indication by the hydrometer of the

presence of salts. The iodine is afterwards put and left to drain in a conical vase of pottery-ware, the bottom of which is perforated and rests upon a jar of freestone; it is then dried upon sheets of filtering-paper laid upon well-dried cinders, or upon porous tiles.

Fig. 270



The next step is the purification by a process of sublimation in an apparatus like that shown in Fig. 270. The iodine is introduced into the retorts, A A, which form a gallery of two rows, to the number of six; they are immersed in the sand of the cast-iron case, B B, which is heated by the fire, C. Into each of these about forty-five pounds of the crude iodine are introduced; they are then wholly buried in the sand, the neck as well as the body of the retort. This precaution seems necessary, to prevent the condensation of the iodine vapors in the neck, and the obstruction of the passage which would ensue. That this may be guarded against as much as possible, the necks of the retorts are short, and the receivers placed in connection with them as close to the sand-bath as possible. An elliptical cistern, D D, is used for this purpose, the beak of the retort entering at the side. It is furnished with a movable cover, E, to facilitate the removal of the iodine; it has likewise a perforated plate at the bottom, H, to allow any water which may condense to drain off. A tubulure, F, at the opposite side to that which receives the beak of the retort, allows the vapor of water to pass off by the pipe, F G, out of the range of the operation. In this way the iodine is obtained in fine large crystals.

When the bromine which is present is to be recovered, the liquor drawn off from the precipitate is evaporated to dryness, the residue compounded with sulphuric acid and binoxide of manganese, and distilled from a leaden vessel. Bromine passes over, and is received in strong sulphuric acid, in which it sinks, and is thus prevented from fuming, and injuring the health of the workmen.

IMPROVED PROCESSES.—BARRUEL'S process resembles the last in some of its operations. The remaining mother-liquor is evaporated to dryness, the residue mixed with about one-tenth of its weight of binoxide of manganese, and then heated to about incipient redness, the mixture being kept stirred all the time. The heat is continued till the sulphides and hyposulphites

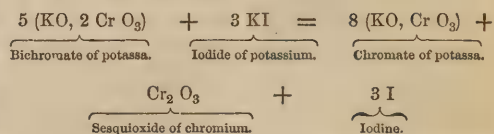
are thoroughly oxidised, which is known by treating a sample of the substance with sulphuric acid, and observing if sulphide of hydrogen be evolved. In this operation the heat should not be raised to such a degree as would cause the evolution of iodine, of which the characteristic violet vapor would be an indication. Water is added to the mass, and the sulphates and iodide of sodium are washed out; using only as much water, however, as will afford a solution of 36° Beaumé. Chlorine gas is now passed through the filtrate, and the iodine which is precipitated purified, as described in the preceding method.

In order to avoid the loss of iodine consequent upon the burning of the plants for the production of kelp, Dr. KEMP suggests a method whereby the iodine may be extracted, and the burning—as in the production of kelp, by which, doubtless, much iodine is dispersed—dispensed with. His suggestion is to crush the roots which contain the largest proportion of iodine, and to set them by in a heap, tank, or any convenient vessels, for a few days, and after the fermentation which ensues has subsided, to extract the soluble salts, among which will be the chief portion of the iodides, with cold water slightly acidulated with ordinary hydrochloric acid. This liquid is to be then treated with chloroxide of calcium—bleaching powder—in slight excess, so as to liberate the iodine, and the latter precipitated by adding to the liquid a sufficient quantity of amidacetate of lead—prepared by adding a solution of tribasic acetate of lead to well-washed potato starch—by which the whole of the iodine is carried down. The precipitate may be washed and dried, and in the hands of the manufacturer the iodine may be removed from it by adding a solution of sulphide of potassium, which precipitates sulphide of lead, leaving iodide of potassium in the liquid. After filtration the liquid may be concentrated, and the iodine extracted by one or other of the processes mentioned. The fluids from which the precipitated compound of iodine and amidacetate of lead is separated, may be useful in an agricultural point of view, either for mixing in the compost heap, or with other liquids in the manure tank. The cakes of cellular tissue which result from the pressure of the material after fermentation, may be dried and used as fuel; the ashes being preserved, on account of the portion of iodine they still retain, as well as for the other salts, which are valuable, both in an agricultural and manufacturing point of view.

Professor BECHI has indicated a process by which iodine may be economically obtained from river and other waters containing it in small proportion. His method of procedure is, to treat the waters with a mixture of one part of sulphuric acid and two of nitric, and to pass the acidulated liquor into a tank or vat, having a funnel-shaped bottom, and filled with lamp-black that has been heated to redness, or well-made ivory-black. The acids have the effect of removing the bases from the iodine, and on transmitting the solution through the charcoal, the latter is retained. When the lamp-black is charged with the iodine, and it is desired to obtain it, a solution of potassa is added, or what is better, the carbonaceous matter is mixed with hydrated protoxide of iron in a tub. After a

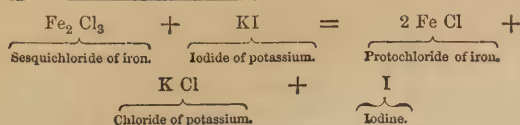
while the iodine is taken up, and an iodide of potassium or of iron produced. When the action has been sufficiently completed, water is allowed to flow upon the mass to dissolve these salts, the solution being drained off in another funnel-shaped vessel, which is stopped in the tube part with sponge or other porous material. The liquor is evaporated to dryness; and, in case of potassa being used, the iodide and iodate are decomposed by sulphuric acid and binoxide of manganese in the manner described in the foregoing. The iodide of iron may be operated upon in the same way; or, if it be thought better to dispense with the evaporations, a sulphate of copper solution may be added, and the precipitate of subiodide of copper, which falls after filtration and washing, distilled with sulphuric acid and binoxide of manganese, *et cetera*.

In a paper by SCHÖNBEIN—see *Chemical Gazette*, vol. viii., p. 166—several substances are described which are able to decompose the alkaline iodides, so as to liberate the non-metallic element in the dry way. Such are the metallic oxides and acids, containing two, three, and five equivalents of oxygen; but many seem to exercise an unequal degree of power in effecting this change. The most remarkable are arsenious acid, chromic acid, sesquioxide of iron, and protoxide of copper; but there is danger in employing the first of these, lest a portion of the poison might be driven off by an increased temperature with the iodine, and thus render its application dangerous as a therapeutic agent. When three parts of bichromate of potassa are ground and mixed with two of iodide of potassium, and the mixture is submitted to dry distillation in a stoneware retort, the whole of the iodine is set free, leaving in the vessel a greenish mass, which is a mixture of chromate of potassa and sesquioxide of chromium. The decomposition is represented by the following equation:—

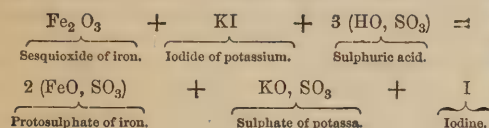


The iodine which is thus produced is very pure, and no loss either of it or the reagent is experienced; for the chromate, which is a residuary product of the distillation, is a valuable salt, and applicable for many purposes; whilst the green sesquioxide left after washing away the former, may be employed as a pigment in painting upon porcelain, *et cetera*; or by fusing it with an alkaline nitrate and carbonate, it may be reconverted into a bichromate of the alkali, which may be employed to decompose a fresh portion of iodide.

Iodine is also set free when anhydrous sesquichloride of iron is mixed with iodide of potassium, even at ordinary temperatures; and, on the application of heat, it passes off in dense vapors, which may be received in the usual manner. The change of the substances in this instance is due to the reduction of the ferruginous sesquisalt to that of a protosalt; the liberated equivalent of chlorine assimilating with the potassium, and thus setting the iodine free:—



Sesquisulphate of iron may be advantageously substituted for the preceding salt; for, when an alkaline iodide is moderately heated with it, dense vapors of iodine are liberated, quite free from sulphurous acid or other impregnation. Hence, by employing sesquioxide of iron and iodide of potassium in equivalent proportions, and adding to the mixture three equivalents of sulphuric acid, so diluted as not to be able by itself to liberate iodine, then moderately heating—the whole of the iodine passes over into the receiver, and the residuary matter is composed only of sulphates of potassa and of iron, as may be seen by the subjoined formula representing the interchange which takes place:—



COMBINATIONS OF IODINE.—Allusion has already been made to the compounds which iodine forms with some of the other elements; and a short description of the more important and useful products formed by combining this element with others, both of a metallic and non-metallic nature, will now be given.

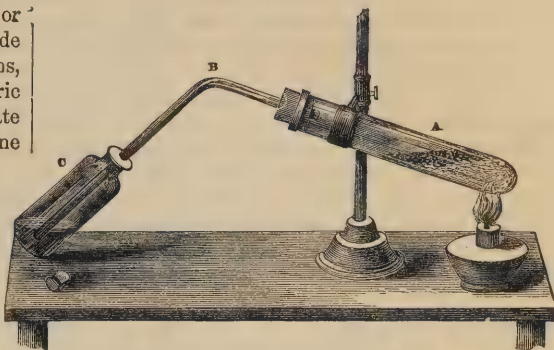
All the non-metallic elementary bodies, with the exception of fluorine, are capable of entering into combination with iodine, either in single or multiple proportions, and many of these compounds are so persistent as to offer considerable resistance to opposing affinities before being resolved into their elements. Like chlorine, sulphur, phosphorus, *et cetera*, iodine constitutes with hydrogen and oxygen acid compounds which, in their general characteristics, are analogous in every respect. With nitrogen and ammonia it affords a compound which is eminently explosive, but with the other simple bodies its combinations offer little interest beyond the precincts of the laboratory. Many of its compounds with the metals are very valuable, as well in medicine as in many branches of industrial art; and to the chemist they are in frequent demand as effective reagents both for ascertaining the presence and estimating the proportion of numerous bodies. Of these, however, reference will be made only to those of alkali metals, iron, silver, mercury, and a few others.

IODIDE OF HYDROGEN—Hydriodic Acid—Iodhydric Acid.—Next to oxygen, chlorine, bromine, and fluorine, iodine manifests the greatest affinity for hydrogen; consequently, it abstracts this element from its combinations of phosphide of hydrogen, sulphide of hydrogen, ammonia, as well as from alcohol, ether, and volatile oils; in each instance hydriodic acid results. A similar metamorphosis with regard to the iodine takes place when it is mixed with water in the presence of a body capable of abstracting oxygen from the latter; and by this means hydriodic acid is sometimes prepared. Thus, when a mixture of nine parts of iodine and one of phosphorus is introduced into a tube,

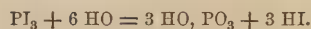
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A—Fig. 271—and covered with moist quartz, sand, or powdered glass, and heat applied, decomposition of iodide of phosphorus, which is at first formed, takes place, as it comes in contact with the thin stratum of moisture, and hydriodic and phosphorous acid are produced; the former being volatile, may be conducted by

Fig. 271.



a tube, B, to the receiver, C, in which it may be collected. The change of elements in the reaction alluded to may be expressed thus:—



Only a slight heat should be applied to produce this decomposition, for, if the temperature be elevated, some terhydride of phosphorus is apt to form and pass over into the receiver, and contaminate the hydriodic acid. Another method is to compound one part of phosphorus, fourteen of iodide of potassium, and twenty of iodine, with a little water, and submit the mixture to heat in a retort or distillatory vessel fitted up on the principle of the apparatus in the preceding figure. When the evolution in this case becomes too rapid, the retort should be cooled by plunging it in cold water; and, on the other hand, when it slackens, the heat must be reapplied.

Several modes may be adopted for preparing this acid in the liquid state: thus, iodide of barium or of lead may be decomposed by an equivalent proportion of sulphuric acid, and the liquid, after filtering off the insoluble precipitate of sulphate of baryta or of lead, concentrated; this product will be aqueous hydriodic acid. Iodine is diffused in water, and sulphide of hydrogen transmitted through it, when decomposition of the latter takes place, sulphur being precipitated, and hydriodic acid produced. A difficulty is, however, experienced in this process, notwithstanding its being effectual—namely, the evisceration of a portion of iodine by the depositing sulphur, by which the whole of the former cannot be conveniently transformed in its hydracid. DUMAS proposes to remedy this defect by merely saturating a given volume of water with iodine, and, after allowing the insoluble portion to subside, and decanting the brownish fluid, he directs that the sulphide of hydrogen should be passed through it till it becomes colorless. The deposited sulphur is then filtered, and the filtrate again charged with the iodine, and the portion which dissolves again acted upon as before. In this way the whole of the iodine may be

3 D

converted into the acid; for at each succeeding saturation, in consequence of the portion of hydriodic acid that is formed, the liquid acquires the property of dissolving a larger quantity of the iodine. The process is troublesome, however, from the repeated filtrations and solutions. Hydriodic acid might be obtained with considerable facility by passing the gas through a solution of iodine in alcohol, were it not that some sulphide of carbon would be produced by the action of the sulphur on the spirit, and which could not be conveniently removed.

Hydriodic acid, prepared according to the first of these methods, is a colorless gas, soluble in water, and capable of strongly reddening litmus; it has an acerb taste and very pungent odor, somewhat similar to hydrochloric acid. When allowed to escape into the air, it produces dense white vapors, which are very suffocating when inhaled. Its density is 4.3757, according to THOMSON, but GAY-LUSSAC gives it 4.4429, air being taken as unity; it is neither a combustible body nor a supporter of combustion. Steam, sulphurous acid, chlorine, bromine, and a few other bodies, are capable of decomposing hydriodic acid with the separation of iodine in every instance. The gas is composed of half a volume of iodine and half a volume of hydrogen. In the liquid state hydriodic acid is colorless, and of a specific gravity 1.700. It is highly acid, and possesses an odor similar to that of the gas. Upon exposure it gradually suffers decomposition, being converted into hydriodous acid with the evolution of hydrogen; but, with prolonged contact with the air, the oxidised portion reacts upon the remainder, and causes the liberation of the iodine, which separates in fine lamellar crystals.

Sulphuric acid, when concentrated, sets free the iodine, a portion of the agent being at the same time broken up into sulphurous acid and oxygen. Hydriodic acid has been solidified by FARADAY at a temperature of -59.8° Fahr. In this state it is perfectly transparent and colorless, but intersected with fissures like ice. The tension of the vapor at 0° is 2.9 atmospheres.

This acid is capable of decomposing the oxides of most of the metals affording metallic iodides and water. Its symbol is HI, and its atomic weight 127.

Iodine forms, with oxygen, compounds of various degrees of oxidation, the lowest being iodic oxide— IO , and iodous acid— IO_2 ; the highest iodic acid— IO_3 , and periodic acid— IO_4 . The latter three constitute salts with the metallic bases, which are called iodites, iodates, and hyperiodates respectively. To enter into a description of the processes by which they are prepared, would not be warranted by the uses which they serve—namely, of forming the links of analogy between iodine and chlorine, bromine, *et cetera*.

With sulphur, phosphorus, chlorine, and bromine, it produces several compounds, which are very interesting to the chemical student. The combination of iodine with nitrogen is remarkable, in being analogous to the chloride of this element, although the explosion which it produces is much less violent.

Iodide of Nitrogen.—If dry iodine and ammonia are brought together in close vessels, they form a brownish liquid, which is simply a combination of the two sub-

stances, and which may be represented by the formula $3(\text{NH}_3) \text{I}_2$. When, however, the iodine is digested with a strong solution of pure ammonia, the compound in question falls as a black powder. The same change takes place when carbonate of ammonia is substituted for the caustic alkali, or chloride of iodine for the pure element. To favor the reaction in this case, the mixture of the ingredients should be effected with a gentle abrasion in a mortar. The powder should be washed on a filter with water, to remove the excess of ammonia and the iodide of ammonium which forms. Another method for preparing the compound with equal facility, but without incurring the risk of spontaneous explosion, is to dissolve the iodine in alcohol 54.5° Twaddell, and, after decanting the tincture, saturating it with a strong solution of caustic ammonia. After briskly agitating, the mixture is diluted with water upon which the iodide of nitrogen precipitates, and may be washed in the cold with this liquid either by subsidence and decantation, or on the filter. The iodide thus produced is not spontaneously decomposed; but SERULLAS remarks, that if the iodine be precipitated from the alcoholic solution by water, and the solid thus recovered treated with ammonia, a compound results which is very apt to explode even during the preparation. Subsequently to the affusion, the compound is dried carefully upon bibulous paper at the ordinary temperature. In performing this operation, care should be taken to divide the mass into small portions, which ought to be placed at a distance from one another, in order to preclude the possibility of an explosion of any considerable quantities of the salt.

MILLON states that it may be desiccated with safety in a bell surcharged with ammoniacal gas, and no decomposition occurs even after lengthened exposure, provided the atmosphere is one of ammonia.

The slightest cause is adequate to decompose the iodide of nitrogen with a violent explosion, and the evolution of a violet light which is visible in the dark. The feather of a quill drawn over the powder is sufficient to produce this effect, and if contained in a dish in moderate quantity, the force is such as to shatter it in pieces. Even if rubbed strongly under water, an explosion takes place; but the causes which determine this change in the air are incapable to effect the decomposition when it is mixed with large quantities of water. It is not liable to explode by mere contact with oils and fats, like the chloride of nitrogen. The products of the decomposition of this peculiar salt, so far as they have been examined, seem to be pure nitrogen, finely divided iodine, and hydriodic acid; but some assert that iodide of ammonium is produced. MARCHAND found that traces of the latter salt were formed upon the sides of a glass jar, in which portions of the nitrogenous compounds had been successively exploded. Water gradually dissolves the iodide of nitrogen with the formation of iodide and iodate of ammonia, free iodine, and the evolution of small quantities of nitrogen. By the action of heat, or sulphuric or nitric acid, the action is considerably expedited. Sulphide of hydrogen effects an immediate decomposition of this compound, the products being iodide of ammonium, hydriodic acid, and sulphur; the alkalies, lime, *et cetera*, operate in a

similar way with the liberation of ammonia, and the formation of an alkaline iodide and iodate.

Composition of Iodide of Nitrogen.—The composition of this body is as yet somewhat doubtful, being regarded in the several lights of iodide of nitrogen— NI_3 , iodide of amidogen— NH_2I , or as a mixture of the former of these with an equivalent of ammonia. The following are the data furnished by the calculations of the investigators whose names are attached:—

GAY-LUSSAC.

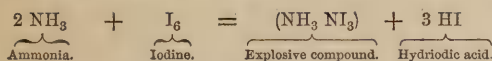
A.		Centesimally.	
1 Eq. of Nitrogen.....	14	=	3·57
3 Eqs. of Iodine.....	378	=	96·43
	392	=	100·00

1 Eq. of Nitrogen.....	14	=	10
1 Eq. of Iodine.....	126	=	90
	140	=	100

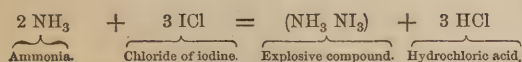
MILLON.

1 Eq. of Amidogen	{ 1 Eq. N = 14	=	986
	{ 2 Eqs. H = 2	=	1·41
1 Eq. of Iodine	= 126	=	88·73
	142	=	100·00

According to the recent analysis of BUNSEN, however, it appears that the composition of the compound is NI_3 , NH_3 , but that another compound of these elements exists, presenting the composition indicated by the formula $4(\text{NI}_3)$, NH_3 , and which results from the precipitation of an aqueous solution of chloride of iodine by ammonia. In either case he regards these iodides as ammonia compounds, in which the hydrogen is entirely replaced by iodine, and which unite with an equivalent of undecomposed ammonia, as expressed by the formulæ. He gives the equation representing the formation of this explosive body by the mutual action of iodine and ammonia, thus—



And by the effects of ammonia upon chloride of iodine, thus—

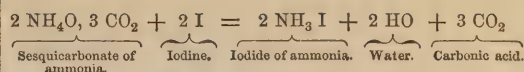


Combination of Iodine with Metals.—With most of the metals iodine enters into combination, producing metallic iodides, but, in forming such, very diverse phenomena are exhibited; some are produced instantaneously, on account of the force of the affinity which exists between the elements, whilst others require very careful and circuitous manipulations, in order to effect the union of both substances.

Only a few of these combinations have been brought into use in the arts and sciences, consequently it will be unnecessary to pursue their description beyond those compounds which are available in medicine, photography, *et cetera*. Such are the alkaline iodides, iodides of iron, of mercury, and of silver, with a few others.

Iodide of Ammonia.—When dry ammoniacal gas and iodine are brought in contact, combination takes place, and a heavy blackish-brown, very tenacious

liquid is produced; the same compound is obtained on gently heating equal weights of sesquicarbonate of ammonia and iodine in a retort or porcelain tube, water and carbonic acid being formed. The change may be expressed thus—



The compound is easily decomposed in part when heated, ammonia being set free; the chief portion of the iodine salt, however, sublimes in violet-colored vapors. It indicates the presence of ammonia and iodine. Its composition, according to MILLON and BINEAU, is—

MILLON.

	At. weight.	Centesimally.
1 Eq. of Ammonia,.....	17	= 11·89
1 Eq. of Iodine,.....	126	= 88·11
NH_3I ,.....	143	= 100·00

BINEAU.

	At. weight.	Centesimally.
3 Eqs. of Ammonia,.....	51	= 18·02
2 Eqs. of Iodine,.....	232	= 81·28
$3\text{NH}_3 2\text{I}$,.....	283	= 100·00

Iodide of Ammonium.—The compound which is met with in commerce, and intended chiefly for the photographer, is prepared by neutralizing a solution of ammonia with hydriodic acid gas, and subsequently decomposing any iodate of the alkali, by transmitting a slight excess of sulphide of hydrogen through the liquid, evaporating the liquor in a water-bath, and afterwards filtering off any deposited sulphur. When the evaporation is conducted carefully under the bell jar of an air-pump, the salt crystallizes in cubes and is colorless; but if exposed to the air, it readily deliquesces, and turns brown, owing to a portion of the iodine being set free. It may be prepared likewise by bringing ammoniacal and hydriodic acid gases in contact, or by decomposing iodide of iron by carbonate of ammonia, filtering off the ferruginous precipitate, and evaporating the solution till the iodide crystallizes.

The iodide of ammonium thus prepared is a very deliquescent salt, very soluble in water and alcohol. By keeping, even in diffused daylight when out of contact with air, it decomposes, turning brownish-yellow, ammonia being evolved. It may be represented as NH_4I , or NH_3HI , and its per centage composition as—

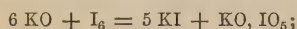
	At. weight.	Per cent.
1 Eq. of Ammonium,.....	18	= 12·50
1 Eq. of Iodine,.....	126	= 87·50
NH_4I ,.....	144	= 100·00

Iodide of Potassium.—This salt is one of the most valuable compounds of iodine; its importance is derived from its medicinal effects chiefly; but as a reagent in the laboratory and in photography it is, especially for the latter, in general use. There are several recipes for preparing it, the most appropriate of which will be here noticed.

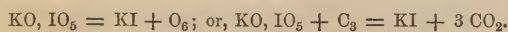
When potassium and iodine, or iodine vapor, are

brought together, rapid combination takes place with a considerable rise of temperature, and the evolution of a violet light. If the combination be aided by heat, the union of the two elements is often attended with a violent explosion. The result is iodide of potassium.

To prepare this body with materials which are more easily obtained, and at less expense and trouble than potassium, other processes are adopted. The simplest of these appears to be the following:—Powdered iodine is agitated with a solution of caustic potassa as long as the former dissolves. Its point of saturation is known by the liquid acquiring a brownish tint. When this happens, any excess of iodine is removed by subsidence and decantation of the liquor, or it is acted upon by a proportionate quantity of the alkaline lie. By evaporation there is obtained a white residuary mass, consisting of iodide and iodate; the latter is decomposed by heating the mass gently for some time, when iodide of potassium only remains. There is need, however, of giving particular attention to this part of the operation; for if the temperature be too elevated, some loss of iodide of potassium by volatilization is sustained; and, on the other hand, if too low, portions of iodate remain undecomposed and contaminate the salt. To avoid this, ORFILA, and latterly SCANLAN, recommend to mix the dry residue with charcoal-powder before submitting it to the action of the heat; this has the effect of bringing about a more perfect decomposition, and at a lower temperature, than could be effected without it. No iodine is liberated, and the whole of the oxygen of the iodate is taken up by the carbon, which is thereby converted into carbonic acid. After heating, the mass is exhausted with water, which dissolves out the iodide. Alcohol may be substituted with advantage when a very pure product is desired, for this takes up only the iodide and leaves the carbonate of potassa, which is nearly always present. By distillation the spirit may be removed, and the iodide crystallized from the concentrated alcoholic solution, or from water. If the residue, after the first evaporation, be treated with alcohol only, the iodide of potassium dissolves, the iodate and any carbonate which might have been present in the alkaline liquor remaining behind. This residuary salt may be afterwards heated with charcoal, and the iodide to which it is reduced extracted as above. In both cases the changes which occur may be thus symbolized:—



the final product by the application of the heat becoming iodide of potassium, thus:—



The method of saturating a solution of potassa, or of carbonate of potassa, with hydriodic acid, offers very good results, were it not that the preliminary operation involved in the preparation of the hydriodic acid renders the course rather circuitous. By forming an iodide of zinc, as recommended by LE ROYER and DUMAS, the operation is shortened and simplified. Zinc turnings, water, and iodine are agitated together in a close vessel, and the metallic salt which is thus produced is afterwards decomposed by addition of carbonate of potassa

to the liquid as long as a precipitate appears. The carbonate of zinc is filtered, and the solution evaporated to the crystallizing point. This method is objected to on account of the difficulty which is experienced in removing the last traces of iodide of zinc. In order to obtain a pure salt by this process, GIRAULT gradually pours the cold solution of the iodide of zinc into a boiling hot one of carbonate of potassa as long as there is any effervescence observed; cold water is then added to the mixture, and the whole filtered, and the carbonate of zinc washed twice with water. The trace of zinc still held in solution is removed by the cautious addition of carbonate of potassa, the precipitate filtered, and the liquid concentrated and set by to crystallize. By many iron is substituted for the zinc, but the further steps in the process are decidedly the same. Two parts of iodine, one of iron, and ten of water are agitated together in a close vessel till the liquid loses its brown color; as soon as this happens, the liquid is filtered, and precipitated by a solution of caustic or of carbonate of potassa heated to the seething point. Care must be taken that the air is as much as possible excluded during the production of the iodide of iron, so as to prevent the formation of a basic iodide of this metal, which could be decomposed only by an excess of alkali.

The Dublin college directs the conversion of the iodine into hydriodic acid by sulphide of hydrogen, and the neutralization of this product either by potassa or carbonate of this alkali. TADDIE employs an alcoholic solution of iodine, or iodine diffused in water, and adds to it an aqueous or alcoholic solution of sulphide of potassium till the whole becomes colorless. Sulphur which separates in this operation is removed by filtration, and the liquid evaporated to obtain the salt in a crystalline state. It may be observed that in this process, when alcohol is employed, the iodide of potassium is always more or less of a brown color. Further, when the sulphide of potassium is present in excess the liquid becomes cloudy, to remove which a greater quantity of iodine must be added. Notwithstanding these precautions, it appears, that the iodide of the alkali produced is, to some extent, impregnated with sulphur; for upon heating, it turns grey, and evolves sulphide of hydrogen. The process recommended by STEPHANI is merely the old one of TURNER, mentioned above, modified. Into a bath of the caustic alkali, iodine is introduced in small portions at a time until the liquid begins to be tinged. The weight of iodine necessary to effect this is found by having a determined quantity of iodine to begin with, and weighing what remains. After the point of incipient coloration is observed, as much more iodine as is already contained in the liquid is to be added, and the whole agitated until it dissolves. Iodide of potassium and iodate of potassa are thus produced, and by treating the liquor with sulphide of sodium, prepared by saturating a solution of an equal quantity of alkali to that to which the iodine was added with sulphide of hydrogen; both liquors are mixed and left to repose, when, by mutual decomposition, the contents of the vessel become muddy in consequence of the deposition of sulphur; after a short interval this sulphur falls to the bottom, when the whole is passed through a filter, and the percolating liquid concentrated so as to obtain the salt.

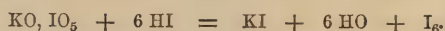
STEPHANI states that very beautiful transparent crystals are obtained in this way, and which are quite different in this respect from the salt met with in the market.

Iodide of potassium crystallizes from its aqueous solution in the form of cubes, parallelopipeds, pyramids, or octahedrons; and, according to KANE, sometimes in forms belonging to the square prismatic system. The crystals are soluble in about three-fourths of their weight of water at ordinary temperatures, and in six parts of alcohol of 0·85 specific gravity. By this solution in water the temperature is reduced about 75·2°. The boiling point of the saturated solution is about 248°. The salt melts at a temperature below redness, and forms pearly crystals on cooling; if air be admitted to it whilst in a state of fusion, a portion volatilizes undecomposed. SCHINDLER found, when performing the experiment in glass tubes, that the volatilization does not take place below the fusing point of the glass. Chlorine, sulphurous acid, sulphuric and nitric acids, are capable of decomposing iodide of potassium, yielding iodine in the free state; or, in the case of sulphuric acid when diluted, hydriodic acid, as noticed under the manufacture of iodine. According to GAY-LUSSAC, it may be represented by KI, being composed of—

		Centesimally.
1 Eq. of Potassium,.....	39	= 23·63
1 Eq. of Iodine,.....	126	= 76·37
1 Eq. of Iodide of potassium,...	165	= 100·00

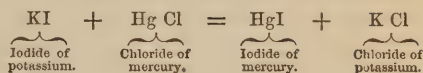
The iodide of potassium is liable to much adulteration, as well from the nature of the processes followed in its manufacture, as from intentional additions of other bodies of less value. Those bodies, the presence of which is consequent upon the method of manufacture, are carbonate of potassa, chloride of potassium, sulphate of potassa, iodate of potassa, and, under particular circumstances, traces of a substance known as xanthate of potassa. Carbonate of potassa, derived from the imperfect neutralization of the iodide or hydriodic acid, in the first instance, may be discovered by the effervescence which succeeds the addition of hydrochloric acid to a portion of the salt, and also by its solution giving a precipitate with lime water; this impurity remains undissolved when the salt is treated with alcohol. Traces of alkaline chlorides may be derived from its being contained in the alkali taken to prepare the salt. Their presence is detected by its giving a precipitate with nitrate of silver, which is soluble in ammonia, and is reprecipitated from this solvent in the state of white chloride of silver by nitric or sulphuric acids. Sulphuric acid is detected by adding to a weak acid solution a few drops of chloride of barium. Alkaline sulphates are also left undissolved when a portion of the sample is treated with alcohol. Xanthate of potassa is produced when the iodide is prepared by the action of sulphide of potassium or of barium upon iodine dissolved in alcohol. When this body is present, the taste of the salt is like that of asafetida; it turns greyish-brown on being heated, and evolves sulphurous acid; when the heated residue is treated with water, a substance remains undissolved

which is composed chiefly of carbon, but traces of sulphates are found in the solution. Iodate of potassa is detected by adding a weak acid, by which hydriodic acid is liberated; this effected, the liberated hydracid exercises a deoxidizing effect upon the iodate, its hydrogen combining with the oxygen of the iodic acid of the latter, and setting the iodine free. Thus—

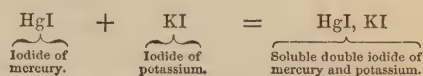


Such disengagement of iodine is indicative of the presence, not only of an iodate, but likewise of any other of the higher oxygen acids. Exclusive of the substances mentioned, and which are never contained in greater proportion than one to two per cent., adulteration of this salt has been known and detected to the extent of seventy and eighty per cent.

Besides the process, which will be detailed at the end of this article, for the analysis and determination of iodine, as well in the commercial article as in the iodides of the metals, a simple process, applicable for the estimation of the amount of iodide in the alkaline salts, may be here mentioned. It is founded upon the behavior of the alkaline iodides with chloride of mercury, whereby an equivalent of either the potassium or sodium salt precipitates exactly an equivalent of chloride of mercury in the form of iodide. The insoluble compound thus formed is, however, redissolved by a second equivalent of the alkaline salt, in consequence of the production of a soluble double iodide of mercury and potassium. The reactions may be expressed thus:—



And secondly—



To test the salt, two equivalents—330 parts—and one equivalent of chloride of mercury—135·5 parts—or any less weight of each, provided this ratio is retained, are weighed and dissolved in equal measures of water, say one thousand grains. To the solution of the iodide the mercurial liquor is to be added till a permanent precipitate appears. Should it happen that no turbidness arises, even when the whole of the latter liquor has been added, it is a proof that no adulterant exists in it; but if a precipitate should occur when only the one-half or one-fourth of the mercurial liquor has been poured in, it is evident that the iodide must be adulterated with one-half or one-fourth of some spurious matter. When iodide of sodium is to be tested in this way, it will be clear that the weight of the salt to be taken will differ from that specified for the potassium salt, in proportion as its equivalent weight is less; that is, only two hundred and ninety-eight grains are required.

Iodide of potassium is used in the laboratory as an agent for producing metallic iodides, and by the photographers largely, in preparing the silver baths wherein the plates are immersed; its chief application

is in the latter art, and in medicine. Its medicinal properties are, in a great measure, similar to those of iodine itself. For further information on its physiological properties, the reader is recommended to consult the able work of the late Dr. PEREIRA.

Iodide of Sodium.—The description given for the obtaining of the preceding iodide will fully answer for the manufacture of this compound. The crystals, however, retain four equivalents of water when they form in an aqueous solution of the salt; they are larger than those of iodide of potassium, and present the appearance of oblique rhombic prisms; they melt in their water of crystallization when heated, giving the anhydrous salt; if the temperature be maintained, they dissolve in 0.6 parts of cold water. According to MITSCHERLICH, it is composed of—

		Centesimally.	
		Theory.	Mitscherlich.
1 Eq. of Iodide of sodium	= 149	= 80.21	= 80.6
4 Eqs. of Water	= 36	= 19.79	= 19.4
	182	100.00	100.0

Symbol, Na I, 4 HO.

Iodide of Iron.—This salt, as already intimated, is prepared by agitating water and iron turnings, or fine wire, and iodine together, taking the precaution to retain the presence of an excess of the metal. The iodine attacks the metal, and combines with it, forming a soluble iodide of iron. The compound, though readily prepared in the state of solution, is more difficult to obtain as a solid, owing to its tendency to decompose, yielding free iodine and a basic iodide, which is but sparingly soluble. During the concentration of the solution of iodide of iron this change occurs, unless it be guarded against by the evaporation being conducted in an iron vessel, or in contact with iron wire, which prevents the oxidation of that portion of the salt which is already formed. Carefully concentrated thus, the compound may be obtained, on cooling, in the state of a crystalline mass; but in this condition it cannot be long preserved, especially when air has contact with it, iodine being set free, as just indicated, and an oxide of iron mixed with iodide remaining. This salt is of no very great importance; it is sometimes employed in medicine, with other substances; it is also occasionally used as a photographic agent. Its symbol is Fe I, and the atomic weight, 154.

Iodide of Mercury.—Mercury is capable of forming several combinations with iodine, but that which will be noticed more particularly here, is the iodide or protiodide of the metal. If two equivalents of mercury and one of iodine are triturated together in a convenient vessel, moistening the whole with alcohol, a subiodide of mercury is obtained in the form of a greenish powder; the same compound is formed when a solution of subnitrate of mercury is precipitated with one of iodide of potassium. The resulting mass is composed according to the formula $Hg_2 I$.

If iodine be added to the solution of iodide of potassium, and the brownish liquid which results be mixed with a solution of subnitrate of mercury, a precipitate falls which differs in composition from the foregoing. It may also be procured by adding the iodide of potassium

to an acid solution of the mercurial salt, but the first is the surer method. It forms a yellow powder, which is apt to vary in its composition, according to the conditions in which the two salts are brought together. When treated with an acid, a red salt—the iodide—deposits. According to BOULLAY, this compound is composed of four equivalents of mercury and three of iodine, and is represented by the symbol $Hg_4 I_3$. The most remarkable of the mercurial compounds with iodine, owing to its fine scarlet hue, is that which is thrown down when dissolved chloride of mercury—corrosive sublimate, $Hg Cl$ —is added to iodide of potassium. If the iodide of potassium has been added only sparingly, the tinge will be duller, in consequence of a portion of chloride of mercury being carried down; on addition of a further quantity of the reagent, however, this is displaced, and the whole of the quicksilver is converted into the brilliant-colored precipitate. The operator should guard against the opposite extreme of using too great an excess of the iodide, which would have the effect of redissolving it, and producing a soluble double iodide of mercury and of potassium.

The red iodide of mercury may likewise be obtained by triturating iodine and the metal together in the ratio of their equivalents, alcohol being added. This, however, should be done with only small portions at a time, for, when large quantities are operated upon, the temperature becomes so elevated as to volatilize much of the iodine. A duller-tinted compound is produced in this way, than that which results from precipitation with iodide of potassium or hydriodic acid.

When the iodide of mercury thus prepared is heated, it fuses, and a dark yellow mass remains, which, on solidifying, retains the yellow hue. As the temperature lowers, however, the original color is regained. The composition in both cases remains unaltered, consequently the dimorphous effect must be attributed to a molecular arrangement which is produced by the increased heat. Iodide of mercury is slightly soluble in water, alcohol, and ether, but hydrochloric acid, and various alkaline salts, dissolve it completely, producing soluble double salts with it. Its composition is—

		Centesimally.	
1 Eq. of Mercury,	100	44.25	
1 Eq. of Iodine,	126	55.75	
1 Eq. of Iodide of mercury,	226	100.00	

agreeing with the formula $Hg I$.

Iodide of mercury might be used as a pigment. It has been stated by several French chemists, that its employment was contemplated some few years ago by English dyers and printers, for giving a bright color to cloths, but the Editor has not been able to learn anything of its application in this way.

Iodide of Silver.—This salt is easily prepared by adding to a solution of a soluble silver salt, an aqueous one of hydriodic acid, or of a soluble iodide. It forms a yellowish-white precipitate, which, when dried and heated, fuses to a reddish liquid mass, but changes to a dirty yellow.

The same salt is formed when iodine is made to act upon silver foil; or, according to M. ST. CLAIRE DE-

VILLE, when concentrated hydriodic acid is poured upon the metal, hydrogen being abundantly eliminated. It is found native, as specified in the beginning of this article. Iodide of silver is soluble in an excess of the alkaline iodide to some extent, but is only sparingly dissolved by water; it is not dissolved wholly by ammonia, like the chloride of this metal. In the presence of moisture, chlorine decomposes the iodide of silver, yielding a chloride of the metal and free iodine, which may be expelled by slightly raising the temperature. This reaction does not take place at a high temperature, as ascertained by M. ST. CLAIRE DEVILLE, but, in fact, hydriodic acid is capable of expelling hydrochloric acid from chloride of silver, and producing an iodide instead, contrary to the received opinion of the force of the affinity of these elements. He also found that on making a mixture of hydrochloric and hydriodic acids, and adding it to a solution of a soluble silver salt, only iodide of silver was produced. Chlorides of potassium and of sodium, dissolved in a small quantity of water, dissolve iodide of silver freely. Strong nitric and sulphuric acids are capable of liberating iodine from the iodide of silver, a nitrate or sulphate of the oxide of the metal being formed; this does not happen, however, when water is present, or the diluted acids are employed. Iodide of silver contains—

		Centesimally
1 Eq. of Silver,	108	46.15
1 Eq. of Iodine,	126	53.85
1 Eq. of Iodide of silver,	234	100.00

consequently, its formula is Ag I.

The chief use which is made of this body is in Photography, and the various other systems in use for taking impressions of objects by the influence of light. As, however, in a future article this beautiful and very interesting art will be fully discussed, the action of light upon the salt in question will not be further pursued here.

Estimation of Iodine when uncombined and in combination.—The minute proportion of this element, which has often to be sought in plants, bituminous and other shales, waters, and even in the air, has taxed the inventive powers and researches of chemists for methods, of which the accuracy might be commensurate with the evident difficulty of the task undertaken. Fortunately, iodine comports itself with a few bodies in such a characteristic way, offering indications so marked as not to be surpassed in this respect by any other substance known. These are starch, silver, and palladium; and by proper modifications in the applications of only these three bodies, the methods for the estimation of iodine, as well when free as when combined, are not exceeded by any other class, either in their accuracy or extent.

Some of these methods are of recent invention, whilst others date from the first researches made upon this element by GAY-LUSSAC and others. Iodine in quantitative determinations is never weighed alone, but in combination with another body, with which it is chemically united—silver or palladium. These offer the greatest security for accurate results, since they produce compounds with the iodine which are unaffected by most

other substances. As a preliminary to the estimation either by silver or palladium, it is necessary to convert the iodine into hydriodic acid or into an alkaline iodide; and for this purpose a sample is weighed, and treated by any of the convenient methods already detailed for the production of hydriodic acid or iodides of the alkalies. If the iodine is mixed with potassa sparingly, and the brownish liquid treated with sulphide of hydrogen till it becomes colorless, iodide of potassium results; but in adopting this process, the last traces of the sulphide of hydrogen must be expelled, so as they may not interfere with the subsequent precipitation with nitrate of silver. A solution of the latter salt with a little nitric acid is then added as long as any precipitate is formed. By placing the beaker in a warm situation, the yellow iodide of silver falls, and the supernatant clear liquid may be decanted; the residue in the beaker may be washed either by adding water to it, agitating, and after it has subsided pouring off the clear solution, or it may be thrown upon a filter, washed thoroughly, and dried in the water-bath. The bulk of the precipitate is detached from the filter, and introduced into a porcelain crucible; the paper being burned on the lid at as low a temperature as possible, and the ashes added to the matter in the vessel. Subsequently, the whole is heated to a low red heat, and when cold, weighed. From the weight of the substance, minus that of the filter-ash, that of the iodine is calculated—234 parts of iodide of silver being equivalent to 126 parts of iodine.

In conducting this operation, it would be better to wash the precipitate by decantation, and afterwards to transfer it into the crucible, evaporating the water from the latter in the bath, and finally slightly heating over the lamp and weighing. No loss would be incurred in this by reduction of any part of the compound, as is done when a filter is employed. In either case, however, the results are very accurate. When a palladium salt is at hand, the mode introduced by LASSAIGNE is still better, and is now almost in every instance preferred to that just described. It is the more certain and convenient, as it offers a means of determining the iodine, even in the presence of chlorine and bromine, which the use of silver does not. The following is the method:—The liquid containing a weighed portion of the iodide under examination, or of the iodine converted into an iodide or hydriodic acid, is to be slightly acidulated with hydrochloric acid, and a solution of the protochloride of palladium added as long as a precipitate continues to form; the vessel is then placed in a warm situation for twenty-four or forty-eight hours, at the end of which time the clear liquid is passed through a filter, and the russet-black precipitate collected; it is washed with warm water, and subsequently dried till the weight remains constant, and the iodine calculated from the quantity of iodide of palladium thus found. As it is somewhat difficult and tedious to dry the precipitate when washed with water, it would be well to pour some alcohol upon the filter, after all the impurities have been first removed by the hot water, and after the spirit has passed through, to replace it with a little ether. When exposed to heat, the volatile liquid will readily escape, leaving the mass quite dry. FRESSENIUS

recommends to exsiccate the compound in *vacuo* over sulphuric acid. As the iodide of palladium is decomposed into iodine and metal by heat, the weight of the compound is taken after driving off all moisture by long exposure to a low temperature, or as above described; and as this is done in contact with the filter, the latter ought to be tared before collecting the salt, and after being exposed some hours to a heat of a water-bath. One hundred and seventy-nine parts of the dried salt—palladium 53 + iodine 126—contains one hundred and twenty-six of iodine. According to ROSÉ, the iodide after desiccation may be heated in the usual way in a platinum or porcelain crucible, and from the weight of the palladium which is left, the iodine calculated. LASAIGNE found that the $\frac{1}{400,000}$ th part of iodide of potassium could be determined in a liquid by this means, and the modifications, to which reference will be made presently, show that this is fully corroborated.

Upon the reaction of chloride of palladium with hydriodic acid or a soluble iodide, KERSTING has founded a volumetrical method of analysis for determining this element. He prepares for the purpose a number of test liquors with pure iodide of potassium and protochloride of palladium; the iodide of potassium solution is made of such a strength as to contain one part of iodine in a thousand of the liquid. This is done by dissolving 13.1 parts of the ignited salt in ten thousand parts of distilled water.

The palladium test liquor is prepared by dissolving one part of the metal in nitrohydrochloric acid with the aid of heat, evaporating the solution to dryness in a water-bath, and adding to the residue fifty parts of concentrated hydrochloric acid and two thousand parts of water, agitating the whole, and then allowing it to rest, to part with any insoluble matter. The value of this liquid is to be ascertained by adding to a given volume of it the iodide of potassium solution in successive portions, till the whole of the metal is thrown down. If the iodide test liquor be poured from a burette holding one thousand grains of water, and divided into one hundred divisions, the amount of palladium in the volume of solution operated upon may be readily ascertained from the number of measures of the other added, since each division contains exactly 0.1 grain of iodine, which is equivalent to 0.042 of palladium, since $126 : 0.1 :: 53 : 0.042$.

Having thus ascertained the quantity of materials in the two test liquors, the iodide to be examined is dissolved in water, if it admits of this treatment; a certain measure is then taken and operated upon qualitatively, as it were, in order to arrive at a knowledge of the probable quantity of iodine contained in it. For this purpose a number of measures of the palladium liquid is taken in a flask and heated in the water-bath; the measures of the liquid under examination are diluted till the ten make one hundred or a thousand grains. After the palladium solution is warmed, the other is dropped in from the burette in portions, taking care not to add too much at once, and also to shake the flask after each addition. The precipitate readily falls, and by drawing off, by means of a pipette, two portions of the liquid into two tall narrow foot-glasses, and adding to one a few drops from the burette and comparing

it with the other, it will be readily ascertained whether the whole of the palladium has been thrown down. If not, a further addition is to be made to the solution in the flask, to which the portions taken out for trial-tests must be put, and the whole left for a short time in the bath, heated as before from 140° to 212°, and as soon as the solid has settled to the bottom, a similar trial-test made. It is needless to say, that as the precise point is approached, the solution of iodide of potassium must be added more sparingly, and, when gained, the two liquids ought to be tested with the iodide of potassium and with the palladium liquor, using the former in one of the test-glasses, and the latter in the other. If no indication is obtained, it is proof that the whole of the palladium has been precipitated. Should, however, an excess of the iodide be added, the operator ought to introduce a few measures of the palladium test, and proceed more carefully in the precipitation till the desired point is attained. From the number of measures of the metallic solution operated upon, it is easy to ascertain the iodine, calculating from the data given in the preceding. A second test may now be performed, employing a given number of measures of the solution containing the iodine, and adding the other test solution till there is no further separation of iodide of palladium, in order to arrive at the true amount of iodine with greater certainty.

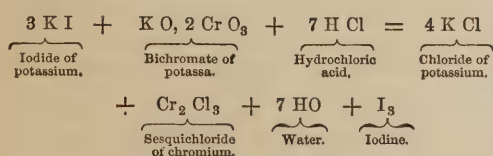
If the iodide under examination should be insoluble in water, or not well adapted for immediate solution, on account of admixture with foreign substances, it must be distilled from a small retort, with the neck turned upwards, with sulphuric acid, using for this purpose about twenty measures of the burette of strong acid, free from iodine, and from twenty to a hundred measures of water. The distillation must be continued till fumes of hydrated sulphuric acid begin to be evolved. Should the distillate contain free iodine and hydriodic acid, a few drops of starch paste, prepared by boiling one part of starch with one-tenth part of strong sulphuric acid in twenty-four of water, and then sulphurous acid, till the blue coloration occasioned by the free iodine and starch disappears, or is on the point of disappearing; on the other hand, if the substance distilled with the acid contains organic matter, causing, during the operation, an evolution of sulphurous acid, which condenses in the receiver, a few drops of the paste must be introduced, and then a solution of bleaching powder, till a faint bluish tinge begins to appear. This is an indication that the whole of the sulphurous acid has been converted into sulphuric acid; it is necessary, however, to destroy the azure tinge in the liquor by a few drops of solution of the sulphurous acid. After this, the testing with the palladium liquor is proceeded with in the manner detailed.

According to KERSTING, dilute hydrochloric, sulphuric, nitric, phosphoric, and acetic acids, and also the neutral salts of those acids with the alkalies, have no influence upon this method; neither have chloride of calcium or of zinc, acetate of lead, sugar, uric acid, and the distillate of urine with sulphuric acid, alcohol, ether, starch paste, oil of lemons, and bromide of sodium, in the presence of acetic acid. The test is interfered with, however, by the presence of alkaline

bromides with free mineral acids, especially upon heating; free alkalis, free chlorine, bromine, iodine, and cyanogen; large quantities of nitric acid at a high temperature, and sulphurous acid; for all these bodies prevent the precipitation of the iodide of palladium.

KERSTING has devised another mode, which is in application less complex than the foregoing, and affords, when none of those substances which interfere with the reaction are present, very trustworthy results. It is founded upon the behavior of chloride of mercury with a metallic iodide, tinged blue by the addition of a little starch paste and bromine water, in which case coloration is perceived as long as any of the iodide remains undecomposed by the mercurial salt, but by the decomposition of the last traces the blueness disappears. A test liquor, containing a certain known weight of chloride of mercury in a given volume of it, is prepared as in the preceding case, and the iodide to be examined is dissolved, and the liquor so diluted that it will contain about one part of iodine in a thousand, being previously blued by a little bromine water and starch paste, as previously mentioned. By adding the test liquor to this solution, iodide of mercury and chloride of the metal, in combination with the iodide, will be formed; but in consequence of the solutions being so diluted, the mercurial iodide dissolves, and so does not prevent the observation of the blue shade. When this disappears, the number of measures of test liquor required are read off, and from them the iodine is calculated. 135.5 parts of chloride of mercury are equivalent to 126 of iodine, and so in this proportion will any weight of the former salt in the solution added to destroy the color, be to its equivalent of iodine. When chlorides and bromides are present, also free mineral acids, acetic acid, and the acetates, the results afforded by this method are not exact.

Dr. FREDERICK PENNY has published a process for testing the quantity of iodine in iodides, volumetrically, by means of bichromate of potassa, which gives rise to the annexed reaction:—

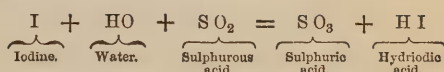


When heat is not applied, this is the only reaction which takes place, and by it three equivalents of iodine are set free by one of the bichromate of potassa. The manipulations are as follow:—Ten grains of pure bichromate of potassa are dissolved in about seventy measures of the burette, holding one thousand grains of water up to zero on the divided scale, and the remainder up to 0, filled with strong cold hydrochloric acid. The liquor is agitated and set aside. A weighed quantity of the salt to be examined is taken and dissolved in like manner in about a thousand grains of water, and to this the liquor from the burette is added cautiously till the whole of the iodine is precipitated. This is ascertained by letting a drop from the end of the glass-stirrer fall upon another of a freshly-prepared solution of protochloride of iron, mixed with sulpho-

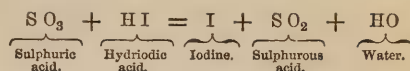
cyanide of potassium, and observing if a red coloration be produced. The bichromate solution is carefully added, stirring after each addition till this result is arrived at, and then the number of measures read off. Knowing that every ten divisions of the test solution contains one grain of the bichromate, and that their quantity effects the liberation of 2.437 grains of iodine from the sample, it is easy to estimate the weight of iodine in the quantity operated upon by the proportion:

$$10 : 2.437 :: x : y \text{—the iodine.}$$

Before leaving this part of the subject, which must be interesting to every chemical student, it may be well to lay BUNSEN'S volumetrical method before the reader. It is founded on the behavior of sulphurous acid with iodine, which, in the presence of water, converts the iodine into hydriodic acid:—



This reaction is one among the many that the chemist and manufacturer encounter, and which at first sight appears inconsistent, since the converse can be effected as freely, namely:—



The state in which the substances are presented to one another has a great influence upon the nature of the change, and, consequently, demands careful study. In this case, the one or other of these reactions which result, is dependent upon the state of concentration of the materials which are taken to produce the effect. By careful experiments, BUNSEN found that the first reaction only is produced when a solution of sulphurous acid, containing 0.04 to 0.05 of real acid, is brought into contact with iodine; hence, when this condition is supplied, one equivalent of sulphurous acid is converted into sulphuric acid by an equivalent of iodine.

This comportment suggests, that when an unknown quantity of iodine is mixed with an excess of sulphurous acid of the above strength, by testing how much of the reagent remains in excess after the former substance has disappeared, the difference will afford data for calculating the quantity of iodine present. By means of a solution containing a known amount of iodine, the latter part of the reaction is performed.

Standard solutions of sulphurous acid, of the fore-mentioned strength, also one of iodine, one of iodide of potassium, and some starch paste, are required for performing the analysis by this method. The iodine test liquor is prepared by dissolving five grammes of the purest iodine in a concentrated solution of pure iodide of potassium, in a flask holding twenty thousand grains measure—twenty measures of burette—up to a certain mark, and diluting the liquor with distilled water till this mark is reached. A perfect homogeneity of the liquid should be effected by agitation, and care taken that it does not show any brown tinge. As each hundred divisions of the burette of this liquid contains 0.25—2000 : 5 :: 100 : 0.25—it is evident that

each division will contain a quantity of iodine equal to $\cdot 0025$ of a gramme. Lest impurities might be contained in it, it is necessary to subject it to a corroborative test to be certain of its value.

A sulphurous acid test liquor is prepared by saturating distilled water with sulphurous acid at the common temperature; this liquid should be kept in well-stoppered bottles inverted in water. From seventy to eighty divisions of this saturated liquor should be added to every hundred burette measures of distilled water.

The iodide of potassium test liquor is prepared by dissolving one part of pure iodide of potassium in ten parts water; it should form a colorless liquid, and give no tinge even on the addition of hydrochloric acid.

It is necessary to prepare the starch paste fresh for each testing. Before proceeding to operate upon samples of unknown composition, it is requisite to find the relative proportion between the iodine and sulphurous acid solutions; and also what quantity of the respective agents is present in a given volume of them. To effect this, it is required, in the first instance, to measure off two burette measures, that is, two hundred burette divisions of the diluted sulphurous acid solution, and add thereto six or eight divisions of starch paste; then a solution of the iodine is dropped in from the burette, and the flask agitated till there is a slight excess of the iodine, and the starch acquires in consequence a persistent blue color.

Operating in this way, and supposing that, to convert the two hundred divisions of sulphurous acid into sulphuric, one hundred and eight of the iodine liquor were required, it is evident that these numbers will stand in the same relation to one another when the iodine is to be determined, as when it is wished to estimate the sulphurous acid. The next step is to find how much pure iodine is contained in each degree or burette division of the iodine test solution, and likewise its effect upon the sulphurous acid. This is done by weighing off $0\cdot 40$ gramme of dry and pure bichromate of potassa, and treating it in a small retort with concentrated hydrochloric acid, and conducting the evolved chlorine into a solution of iodide of potassium. For this end the bichromate and acid are put into a flask, to which a tubulure and tube are adapted, and secured by passing a tube of caoutchouc over the neck, cork, and portion of the tube; a small glass bulb, with its long neck closed by the blowpipe, is put into the end of the eduction tube, and then introduced into an inverted retort, containing the solution of iodide of potassium. Heat is applied by means of a lamp, and, after a few minutes' ebullition of the contents of the flask, the whole of the chlorine will have passed over. There will be liberated from the iodide of potassium, by the chlorine evolved from the quantity of bichromate operated upon, $1\cdot 024$ of iodine—that is, an amount proportionate to three equivalents of iodine for one of the former salt, as stated at page 400. To the solution containing the mixture of iodine and iodide of potassium, the diluted sulphurous acid liquid must be added from the burette till the brown color of the fluid has completely disappeared, and the quantity is noted, which, for example's sake, may be taken at sixteen hundred divisions. It is needless to say that there has

been an excess of the acid employed on this occasion, and which is to be determined in the next operation, by introducing a little starch paste, and as much of the standard iodine solution as is requisite to communicate a blue color to the fluid. If for this purpose twenty divisions of the burette are taken, from the following calculation, founded upon the preceding tests, the value of the solution as to the iodine it contains, and the sulphurous acid it changes into sulphuric, is arrived at. As by the previous experiment it was found that fifty-four divisions of the iodised solution were necessary to oxidise two hundred of the sulphurous acid liquor, it follows that four hundred and thirty-two of the former will be required to oxidise the one thousand six hundred measures taken of the latter; but, as the experiment shows that the iodine liberated from the iodide of potassium is equivalent to this volume of test liquor, minus the twenty divisions required for the excess—that is, $432 - 20 = 412$ divisions, corresponding to $1\cdot 024$ of iodine—it is evident that each burette division of the iodised test liquor contains $\cdot 00248$ of a gramme of iodine. Of course, each degree of the entire quantity of the test liquor possesses this value.

To test the iodine in a sample submitted, a portion is to be weighed off in a flask, and dissolved in iodide of potassium of the strength specified in the foregoing, using about ten divisions of the burette for each one-tenth of a gramme of the iodine. The dilute sulphurous acid liquor must now be added in measured quantities from the burette, till all color in the solution disappears; the quantity thus used is noted; a few divisions of starch paste are stirred with the menstruum, and the iodine test liquor carefully dropped in, stirring well after each addition till the blue iodide of starch appears. The volume of sulphurous acid and the number of divisions of the iodised test liquor which are required to oxidise the excess of the acid above what was necessary to convert the iodine in the sample to hydriodic acid being known, it is easy to find, by the following mode of calculation, the proportion of iodine in the sample. Thus, supposing that a thousand divisions of the acid solution were taken in the first instance, and that to oxidise the excess which remained of this, ten divisions of the iodine liquor were required, it follows that the weight of the sample taken, supposing it a gramme, contained $0\cdot 6448$ of iodine, and, consequently, $64\cdot 48$ per cent.; for, as found by the foregoing experiments, fifty-four divisions of the iodine liquor were equivalent to the oxidation of two hundred of the sulphurous one; hence $200 : 54 :: 1000 : 270$, and $270 - 10 = 260 \times \cdot 00248$ —the amount of iodine in each division—gives $0\cdot 6448$, as stated.

For the detection of the grosser adulterations of iodine, which are mentioned as being practised, although they have not come within the range of the Editor's experience—such as plumbago, sulphide of antimony, and the like—a rough estimate may be formed of the amount, by heating a weighed sample of iodine in a porcelain crucible to redness, till the whole of this element is volatilized, and weighing the fixed residue. This, though not so precise as those other methods which have been detailed, does not require that accu-

racy of manipulation which is presupposed to be possessed in the other instances.

When small quantities of iodine have to be found—as, for instance, in the ashes of plants, the residuary matter left after the evaporation of spring or river waters, and the like—the methods by which they are to be detected must evidently insure all possible accuracy, if the investigator is anxious to arrive at the truth. For a long time the tests known, such as decomposition of the iodide by sulphuric acid, and addition of starch paste, were found insufficient to determine the minute traces of iodine which, as appears by late researches, are contained in several bodies. Without entering upon the general description of all the tests proposed, a few of the more remarkable may be briefly noticed.

At the head of investigations of this kind stands the test of PRICE, detailed in the Transactions of the Chemical Society for 1851. It consists in operating upon the solution which is supposed to contain the iodide with hydrochloric acid and starch paste, and then adding a few drops of a solution of nitrite of potassa, when a blue coloration from the iodide of starch makes its appearance. The hydrochloric acid liberates the iodine from its basic combination, and is retained in the liquid in the form of hydriodic acid; this body is decomposed by the nitrite, the acid of which is set free by the excess of hydrochloric acid—the hydrogen being converted to water, and the iodine liberated. When much iodide is present, the color of the liquid is dark blue, and appears immediately; but when only a small quantity is contained in the substance operated upon, the shade is lighter, and a few seconds elapse before its appearance. This chemist states that he has detected iodine in a solution containing not more than the four-millionth part of it, and that there is no difficulty in ascertaining the presence of iodine in cod-liver oil, and in the mother-liquor from a few pounds of sea-water, by its aid.

M. GRANGE's method is analogous to that just described, only that he directs the transmission of a few bubbles of fuming hyponitric acid through the solution to be tested, and already impregnated with starch paste; the reaction is instantaneous; and when the iodine forms about the five-millionth part of the fluid, a pale rose color, inclining to violet, is produced. With a larger proportion, say the one three hundred thousandth, this chemist asserts that the characteristic blue appeared; but when only the one-millionth of iodine is present, he states that no satisfactory results can be attained by this test *per se*. Coupling it, however, with another method published by RABOURDIN, founded upon the property of chloroform, of dissolving iodine, and becoming reddish-coloured thereby, it can be rendered so accurate as to satisfy the minutest inquiry. Should a portion of the fluid afford no indication with starch paste and hyponitric acid, the latter is to be transmitted through the bulk of the solution at hand, till it manifests an acid reaction; a small quantity of chloroform is agitated with it, and then drawn off with a pipette; the reddish color is removed by the addition of a little potassa, and the aqueous solution then decanted. The hyponitric test is then applied, when it does not fail to produce the characteristic blue color.

In this way, the one-five millionth of iodine is easily detected. GRANGE found that bromides do not interfere with the accuracy of these reactions, for they are not decomposed by the hyponitric acid.

M. MORIDE has proposed a substitute for the chloroform in the preceding method, which offers advantages in giving a solution which is more highly colored than the chloroform becomes under similar circumstances. According to this chemist, wherever iodine is indicated by starch paste, it may be proved also by the employment of benzine more satisfactorily. This agent is rendered more valuable from the fact, that the water which is present, or which may be used to wash it, carries away any bromine or chlorine, thus leaving the iodine isolated.

Chlorine, though capable of setting iodine free from its combinations in aqueous solutions, is now rarely employed to detect iodine, since an excess of the agent converts the iodine into a colorless combination of chloride of this element. Bromine comports itself differently, for although it is capable of liberating it, still none of the iodine is redissolved. DE LUCCA has made this behavior the basis of a method for the analysis of iodides by means of a standard solution of bromide, coupled with the use of sulphide of carbon, which takes up the iodine as it is liberated by the bromine liquor. From the volume of the latter which is expended in setting free the whole of the iodine—ascertained by the sulphide of carbon being colorless when drawn off with the pipette—its quantity is found.

To show that iodine is contained in the air, *et cetera*, modifications of the processes above described have been successfully employed by CHATIN, HERAPATH, and others; but to enter into further details upon this subject, although highly interesting, appears unnecessary.

IRON.—*Fer*, French; *Eisen*, German; *Ferrum*, Latin.—Iron is a metal of a bluish-grey color, but acquiring a brilliant surface by polishing; its fracture is fibrous, and it is the hardest and toughest of all the ductile metals; it cannot be hammered into very thin plates, but may be rolled into thin sheets, and drawn into very fine wire.

The iron of commerce is seldom or never pure, containing small portions of carbon, sulphur, silicium, phosphorus, arsenic, *et cetera*; its density varies a little according to its purity and the mode of its manufacture. Purified by fusion with smithy scales, it gave in some experiments a specific gravity of 7.8439, which is increased by rolling and drawing into wire. Pure soft bar-iron, containing only a trace of carbon, has a density of 7.79; that of ordinary bar-iron is 7.788.

When iron is subjected to a red heat, it softens and becomes tough, a circumstance which adds much to its value in the manufacturing arts; and its property of welding at a white heat, gives a facility in working it which no other metal possesses. When heated above the welding point, it crumbles under the strokes of the hammer.

The melting point of iron has been variously given as 1550° C.—*Pouillet*; 1587°—*Daniell*; 6346° C. or 175° Wedgwood—*Morveau*; 158° Wedgwood—*Mackenzie*. Any impurity in the metal makes it more easily fused,

and might account for small discrepancies in the melting point; but the remarkable differences shown in the above results enable us to appreciate the great difficulty of obtaining accurate measurements of very high temperatures.

Iron is attracted by the magnet, and is itself easily rendered magnetic, but does not retain this property except when converted into steel.

HISTORICAL NOTICE.—Iron, wherever known, has universally taken the lead amongst the metals in point of usefulness, and its possession by any people has invariably proved the means of advancing them in the arts of civilized life, and of raising them in the scale of nations. It is strange that, notwithstanding the difficulties in its manufacture, iron is amongst the first metals mentioned in history. MOSES tells us that TUBALCAIN, the great-grandson of CAIN, ADAM's son, was an instructor of every artificer in brass and iron, that iron furnaces were in use in ancient Egypt, and that the hills of Palestine produced ferruginous ores. JOB says,—Iron is taken out of the earth;—and throughout the whole sacred volume this metal is referred to as being in common use, both for weapons of war and manufacturing instruments.

HOMER mentions a mass of iron as one of the prizes at the funeral games given by ACHILLES in honor of PATROCLUS, a circumstance showing the great value attached to it in ancient times, when it was so much less common than at the present day:—

Then hurl'd the hero, thundering on the ground,
A mass of iron—an enormous round—
Whose weight and size the circling Greeks admire,
Rude from the furnace, and but shaped by fire.

* * * * *
Who furthest hurls it takes it as his prize.
If he be one enriched with large domain
Of downs for flocks, and arable for grain,
Small stock of iron needs that man provide;
His hinds and swains whole years shall be supplied
From hence; nor ask the neighboring city's aid
For ploughshares, wheels, and all the rural trade.

There are also notices in HOMER and HESIOD of the methods of reducing and forging iron; but cast-iron was then unknown, an imperfectly malleable iron being produced at once from the ores in the furnace. It is conjectured that the Greeks obtained most of their iron through the Phœnicians, from the shores of the Black Sea and of Laconia. DIODORUS SICULUS refers to the Island of Elba as yielding ores of iron, which the natives were accustomed to dig and cut out of the ground, subsequently melting the mass to obtain the metal. PLINY in his Natural History enters at great length upon the manufacture of iron; he says the ores are to be found almost in every country, and that they are easily discovered by the color of the earth which breedeth the iron, and that they are tried by fire like other veins of metal. He speaks of it also as being applied to all the uses for which it is commonly employed in the present day. It is remarkable, however, that although in all the Latin writers, *ferrum*, iron, is the most common name for a sword, the weapons and cutting instruments discovered in the ruins of Pompeii and Herculaneum are almost invariably found to be made of bronze.

The furnaces which were first employed for smelting

iron were probably simple conical structures, with small openings below for the admission of air, and a large one above for the escape of the products of combustion, erected on high grounds that the wind might assist combustion. Similar rude furnaces, known as *air-bloomeries*, are still used in some countries at the present day. Successive layers of ore and charcoal being placed over the fire, the heat would be regulated by opening and closing the apertures. Subsequently, an artificial blast would be introduced, and the advantages of this appear to have been known at a very early period; for HOMER represents HEPHÆSTUS as throwing the materials from which the shield of ACHILLES was to be forged, into a furnace urged by twenty pair of bellows. This blast-bloomery would ultimately be developed into the *catalan forge*, in which malleable iron is produced directly from the ore by heating it in contact with carbon—a process still adopted in some places where wood is abundant for making charcoal, as in the Pyrenees, in Corsica, and some parts of Spain. Finally, it assumed the form of the *blast-furnace*, now in general use, and which, by completely fusing the ore in contact with the fuel, results in producing cast-iron—a compound of the pure metal with carbon.

The transformation of the blast-bloomery into the blast-furnace is supposed to have taken place in the early part of the sixteenth century; for proof exists that in the seventeenth the art of casting had arrived at considerable perfection. The more efficient operation of the blast-furnace allowed the reduction of the heaps of scoriæ, which had been gradually accumulating during the period that the blast-bloomeries had been in operation. In the Forest of Dean in Monmouthshire, in Yorkshire, and other counties, these were found in immense beds, among which were discovered Roman coins and other specimens, inscribed to the god who presided over iron. There is ample evidence of the industry of the Romans in working the iron mines of Britain, until their final abandonment of the island about A.D. 409. It is supposed, also, that the Danes, during their occupation of England, carried on the smelting of iron extensively, and hence many of the heaps above-mentioned are called in certain localities *Danes' cinders*. A portion, only, of the ore was reduced by the imperfect methods of smelting then known; and, in the Dean Forest alone, it is computed that twenty furnaces, for a period of nearly two hundred years, were supplied chiefly with the bloomery cinders as a substitute for iron ore.

Up to the beginning of the seventeenth century, charcoal was the only material employed in smelting operations. An enterprising ironmaster in Worcestershire, named DUDLEY, was the first who attempted the operation with pit-coal, and the trial was so successful, that about the year 1620 he applied for a patent for his invention, which was granted for thirty-one years. For some time he succeeded in producing considerable supplies of iron, which could be sold with good profit at a much reduced price; but this very success was the cause of his ruin, by exciting the animosity of his rivals, from whom he encountered incessant opposition, and, by combinations among masters and men, he was ultimately turned out of his works. With DUDLEY

died for a time the art of making iron with pit-coal; but the rapid destruction of the forests, not only to supply the great consumption of the blast furnaces, but also the wants of a constantly increasing population, induced at length special enactments prohibiting the cutting down of timber for the use of the ironworks. The first effect of this prohibition was greatly to reduce the number of furnaces; so much so, that in 1740 the annual production, which had previously amounted to one hundred and eighty thousand tons, was diminished to seventeen thousand three hundred and fifty tons.

The change from charcoal to coke as fuel necessitated a more powerful blast, and a longer subjection of the materials to the heat. The latter was effected by an enlargement of the height of the furnace, and the former by the introduction of large cylinders, with closely fitting pistons, instead of the common forge-bellows. The earliest blowing cylinders of any magnitude are supposed to have been those erected by SMEATON at the Carron Ironworks in 1760. These improvements speedily effected an astonishing increase in the production of iron. About the year 1780, the furnaces still worked with charcoal produced only eleven tons of iron weekly, while those in which coke and coal were used averaged a weekly product of seventeen and a half tons. DR. URE gives the quantity of cast-iron produced in 1788 as follows:—

	Tons.
By means of coal,.....	48,800
By means of charcoal,.....	13,100
Constituting a total quantity,.....	61,900

In 1796 the wood-charcoal process was all but entirely given up, and the gross produce of one hundred and twenty-one blast furnaces was one hundred and twenty-four thousand eight hundred and seventy-nine tons, being near to twenty tons weekly for each furnace; and in ten years after this, 1806, there were two hundred and twenty-seven blast furnaces in this country, one hundred and fifty-nine of which were in active blast at once, and produced two hundred and fifty thousand tons of iron.

The blast furnaces were distributed as follows:—

In the principality of Wales,.....	52
In Staffordshire,.....	42
In Shropshire,.....	42
In Derbyshire,.....	17
In Yorkshire,.....	28
In the counties of Gloucester, Monmouth, Leicester, Lancaster, Cumberland, and Northumberland,.....	18
Scotland,.....	28

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Nearly simultaneous with the earliest improvements in the manufacture of cast-iron by means of pit-coal, were others of an equally important kind for converting the cast-iron into malleable or bar-iron. Hitherto this had been effected by means of wood charcoal in what are termed refiners, as is still practised in the South of France; but owing to the scarcity of wood fuel in this country, the charcoal was mixed up with coke for the refining operation; the iron produced from this was hard and of an inferior quality, and much time was required for the conversion of a ton of cast into malle-

able iron. England was therefore greatly indebted to Sweden and Russia for iron of good quality, and not less than seventy thousand tons annually were imported from these countries. In 1783, MR. RICHARD CORT, after many trials, succeeded in converting cast-iron into malleable iron, by the use of pit-coal in a reverberatory, instead of a blast furnace, and thus introduced what is known as the *puddling process*. For some time much difficulty was experienced in puddling, from the loss of iron, and irregularity in the quality of the metal produced and the fuel used. To avoid this, the iron was subjected for a short period to a process of refining with the blast and coke fuel, previous to being transferred to the puddling operations in the reverberatory furnace. The original puddling furnace, patented by MR. CORT in 1784, says MUSHET, is now, *without the intervention of the refining*, producing tens of thousands of railway bars all over the world. This invention placed England in an independent position as respects iron, and so facilitated the manufacture of malleable metal, that before many years one work could turn out annually as much bar-iron as was made previously by the whole iron trade of the kingdom. Notwithstanding the value of these improvements, MR. CORT did not benefit by his inventions. After spending thousands in experimenting, and giving to the world his results, those who were the gainers repudiated his claims while they adopted his processes, leaving him to drag out the rest of his days in poverty; and it was only in the course of last year that the Government granted a small acknowledgment of fifty pounds per year to the widow of the great benefactor of his country, while the children and grandchildren have been appealing to the sympathy and charity of the ironmasters, for what they should have received through their father as a right.

The general introduction of the steam-engine, as improved by WATT, contributed also to initiate a new era in the history of the iron trade, as in almost every branch of industry. Its application to pumping enabled the mines to be sunk to a greater depth, and accelerated the process of raising the coal and ores; by employing it as the motive power for urging the blast, refractory ores were reduced with facility, and the processes of rolling, forging, *et cetera*, were now effected with a rapidity previously unknown.

Lastly, the discovery of the hot-blast process, for which a patent was taken by MR. NELSON of Glasgow in 1824, and by which three or four times the quantity of iron can be produced with little more than one-third of the fuel that was required with the cold-blast, effected another complete revolution in the iron trade, and may be regarded as marking the last era in the history of this all-important metal. The high expectations at first formed from BESSEMER's new and remarkable refining process, of which an account will be given, have not yet been realized.

SOURCES.—In admirable harmony with the universal application and innumerable uses of iron, is its almost universal presence in nature. It is by far the most widely diffused of all the metals; there being few substances in the material world that do not contain it in greater or less amount; and yet the variety

of ores from which the metal is manufactured is very limited.

Native Iron.—For a long time native iron was unknown, and its existence in nature questioned; it has been found, however, in several localities both on the Continent of Europe and in America. In this country it has been met with in minute quantity in trap rocks, but on all occasions it is found only in small portions, and is considered more in the light of a chemical or mineralogical curiosity than as a useful source of the metal. Native iron is almost pure white, more resembling silver than ordinary iron, is generally softer and less dense, and, unlike meteoric iron, contains no nickel. A mass was found with magnetite at Grass Ramsdorf, not far from Saalfeld in Thuringia, which, according to KLAPROTH, consisted of:—

	Centesimally.
Iron,	92·5
Lead,	6·0
Copper,	1·5
	100·0

It is said, however, to be found in considerable quantity in Liberia. The natives use it for instruments; it is soft and flexible, and can be easily cut with a chisel. An analysis of this gave:—

Iron,	98·87	98·40
Silica,	1·63	1·60
	100·00	100·00

This is the purest yet described from any locality. In 1786, a mass of native iron, weighing upwards of thirteen tons, was found in South America, a sample of which was sent to the British Museum. It is described as being soft and compact, although the internal part of the mass is full of cavities; it had every appearance of having been in a fused state, and was considered the product of a volcanic irruption. No analysis of this sample has been made.

Small quantities of native iron have been obtained in the immediate vicinity of a coal seam which had been spontaneously ignited, and was doubtless the result of reduction by the coal; samples of this sort are excessively hard and fine-grained, and give a fracture resembling cast-steel, from which circumstance it has been named *native steel* or *steely iron*. A mass of this mineral, weighing sixteen pounds six ounces, was discovered some years since near Nexy, in the department of the Allier.

Meteoric Iron.—Large masses of metallic iron have been discovered from time to time, in different parts of the globe, embedded in the soil and also lying upon the surface; others of a similar kind have been known to fall from the atmosphere, and are hence termed meteorites. These masses are generally covered over with a kind of black enamel, which protects the metal from the action of the atmosphere. The iron forms usually a sort of network round a crystallized metallic mineral of a complicated composition. These meteoric masses are sometimes so large, and the metal which they contain so pure, as to furnish the inhabitants of the neighborhood with ample material for knives and spearheads. When examined chemically, there seems

a considerable similarity in the composition of different specimens, although some of them contain ingredients which others do not. In the following table this similarity is very apparent, although the samples were obtained from localities widely apart:—

No.	Iron.	Nickel.	Cobalt.	Copper and tin.	Manganese.	Phosphorus.
1	92·47	5·67	0·23	—	—	—
2	93·77	3·81	0·21	—	—	—
3	88·04	10·73	0·45	0·66	0·13	—
4	88·23	8·52	0·76	—	—	—
5	66·56	24·70	—	—	—	—
6	83·57	12·66	—	—	—	—
7	89·78	8·88	6·67	—	—	—
8	85·61	12·27	0·89	—	—	—
9	90·88	8·45	0·66	—	—	—
10	88·98	10·35	—	0·56	—	0·11
11	85·00	13·01	1·42	0·57	—	—
12	86·64	13·04	—	0·27	—	0·05

These are but a few of many analyses that have been given, all showing a remarkable sameness in composition. Besides these ingredients, the meteoric mass is sometimes found to contain silica, alumina, lime, potassa, chromium, magnesia, soda, arsenic, carbon, sulphur, chlorine, *et cetera*.

Protoxide of Iron.—This oxide has never been found in nature except in combination with other matters, forming distinct minerals. Its great tendency to combine with more oxygen, obtained either from the air or other substances, prevents it existing as protoxide for any length of time, unless it is entirely excluded from the presence of oxygen. This compound may be prepared by precipitating a solution of protosulphate of iron, by a caustic alkali, and carefully filtering; but it is impossible to obtain it in the dry state by this method, from its affinity for oxygen. It may be said that protoxide of iron does not exist in a separate state in nature; its composition is—

	Centesimally.
Oxygen,	8
Iron,	27
	35
	100·00

Magnetic Oxide of Iron.—When the protoxide combines with more oxygen, it does not pass at once into the highest state of oxidation, but into a mixture of protoxide and sesquioxide, which is permanent and magnetic, and is hence termed magnetic oxide. This compound, when found as a mineral, has a black color, and is hard. It exists abundantly in nature in different rocks; in granite, mica-slate, clay-slate, syenite, hornblende, chlorite, and also in some of the limestone formations. Much of it is found in the Island of Elba, and it has been obtained from that island for making iron from the earliest times. It also abounds in the United States of America; and mostly all the Swedish iron is manufactured from the magnetic oxide. This ore occurs in crystallines, of which the primitive is a cube: its general forms are the octahedron and dodecahedron. Its density varies from 5·00 to 5·10; it fuses before the blowpipe with difficulty. In powder it is perfectly soluble in warm hydrochloric acid. Its chemical composition is—

		Centesimally.
3 Eqs. iron,.....	81	71·68
4 Eqs. oxygen,.....	32	28·32
1 Eq. magnetic oxide,..	113	100·00

corresponding to the formula Fe_3O_4 , or $\text{Fe}_2\text{O}_3 + \text{Fe O}$. The last is considered to be the true formula, expressing a combination of one equivalent of sesquioxide and one of protoxide. The analyses obtained of magnetic oxide of iron give—

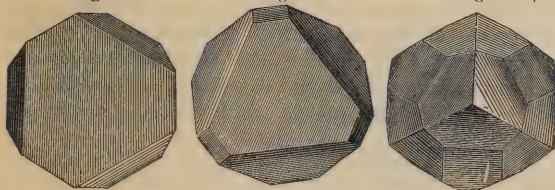
Iron,.....	71·86	71·91
Oxygen,.....	28·14	28·09
	100·00	100·00

Specular Iron Ore—Red Hematite.—This is a sesquioxide of iron existing in great abundance, and found in a variety of shapes, both massive and in crystals. The following are a few of the crystalline forms in which it is found—Figs. 272, 273, 274. The crystals are of

Fig. 272.

Fig. 273.

Fig. 274.



a dark steel-grey color, but leave a reddish-brown streak upon a stone or any hard substance; they have a specific gravity varying from 4·8 to 5·3; and are a pure sesquioxide, composed as follows:—

		Centesimally.
2 Eqs. iron,.....	54	69·34
3 Eqs. oxygen,.....	24	30·66
	78	100·00

This same oxide exists in a variety of other forms, such as a fibrous mass, with the fibres radiating from a centre, in which state it is termed the *red hematite* or *fibrous iron ore*. When the ore is an amorphous mass, it is termed *compact iron ore*; when mixed with clay and other earthy matters, *red ochre*; when hard, and combined with silica, *jaspers ore*; when in scales of a black metallic lustre, it is known as *micaceous iron ore* or *iron glance*.

This ore occurs both in the primitive and secondary rock; it abounds in the Island of Elba, Norway, Sweden, and Switzerland. Fine specimens are met with in the fissures of rocks in the volcanic districts. The red hematite, found in masses, having an unctuous feel, and readily soiling the fingers and everything with which it comes into contact, exists in many parts of England, particularly in Cornwall and Ulverston. This variety has generally from eight to ten per cent. of

silica. It is wrought in great quantities along with poorer kinds of iron, and produces a strong metal. When subjected to a high heat alone, such as the jet of the blowpipe, it yields a portion of its oxygen, and is converted into the magnetic oxide. It is very slowly soluble in hydrochloric acid. The following are several analyses of this ore from different localities:—

Iron,.....	70·42	70·27	69·85	69·22	69·	68·96
Oxygen,..	29·58	29·73	30·15	30·78	31·	31·04
	100·00	100·00	100·00	100·00	100·	100·00

Another form of the same oxide, in combination with water, is very abundant as a mineral known as *brown iron ore*. It has a brownish color, produces a yellow streak, and, when crushed, a yellow powder; it is thus easily distinguished from the anhydrous oxide, which yields a red-brown powder. It is of lower specific gravity than the red, varying in density from 3·8 to 4·2. It usually occurs in a massive state, and is composed of—

		Centesimally.
4 Eqs. iron.....	103	59·0
6 Eqs. oxygen.....	48	26·3
3 Eqs. water,.....	27	14·7
	183	100·0

This corresponds to the formula which is always given for the ore, $2\text{Fe}_2\text{O}_3 + 3\text{HO}$. The following are the results of three analyses:—

Peroxide of iron,..	80·25	90·53	86·34
Water,.....	15·00	9·47	11·66
Silica,.....	3·75	—	2·00
Loss,.....	1·00	—	—
	100·00	100·00	100·00

Brown iron ore is found both in amorphous masses, and in crystals of a variety of forms, according as the ore may have been produced either by the decomposition of iron pyrites, or substitution and oxidation of carbonate of iron. It also occurs in small rounded pieces, either loose or conglomerated, in which state it is known as *pea iron ore*. When mixed with clay and other earthy matters, and of a soft texture, in which state it is found in great beds, it is termed *yellow ochre*. It exists in great quantities in Normandy, Berry, Lorraine, Burgundy, and constitutes the principal supply of ore for many of the French ironworks.

BOG IRON ORE.—This ore is amorphous, having a vitreous lustre, yellowish and dark-brown in color; it is of very recent formation, and is produced from the decomposition of certain rocks over which water passes; it is therefore always found in low marshy places, and hence its name. The following are the results of analyses of this ore from different localities:—

Sesquioxide of iron,.....	78·57	43·4	66·0	66·33	51·0	70·05
Protoxide of iron,.....	—	—	—	3·60	—	—
Lime and magnesia,.....	—	—	—	—	—	2·43
Oxide of manganese,.....	—	15·0	1·5	0·75	—	1·78
Phosphoric acid,.....	—	—	8·0	0·12	10·99	0·34
Water and organic matters,.....	21·43	15·0	23·0	26·40	28·80	15·87
Silica,.....	—	23·0	—	2·80	9·20	8·03
Alumina,.....	—	3·2	—	—	0·41	1·50
	100·00	99·6	98·5	100·00	100·40	100·00

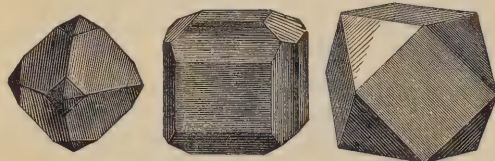
IRON PYRITES.—The affinity between iron and sulphur is equal to that between iron and oxygen, varying according to the circumstances in which they are placed; under one condition, oxygen will take the iron from the sulphur, and again, under other circumstances, iron will leave the oxygen for the sulphur. That these conditions may have determined the different combinations in nature is a probable hypothesis. Sulphur and iron are combined in a great variety of proportions, and give rise to an important series of minerals, the most abundant being what is termed iron pyrites or bisulphide of iron. This mineral varies in tint, according to its exposure, from a yellow bronze to a silver white; the high bronze yellow hue may be familiar to every one in what is termed the sulphur in coal, which is iron pyrites; it has a metallic lustre, and is very hard, being capable of striking fire with steel, and therefore occasionally termed firestone; it is very brittle, and has a specific gravity of from 4·8 to 5·1. It occurs in beautiful cubical and octahedral crystals, some of which are represented by the following figures.

Different localities are known to give pyrites with a certain definite form of crystal peculiar to each, as for

Fig. 275.

Fig. 276.

Fig. 277.



instance, the Island of Elba, which yields pyrites in crystals extremely large, and often of a pentagonal dodecahedron form, while some of the Cornish mines abound more in cubical crystals. A familiar instance of this form is seen in the common slate, and is popularly termed, *slate diamond*; these are true cubes of iron pyrites. The composition of this mineral is:—

		Per cent.
1 Eq. of iron,	27	45·76
2 Eqs. of sulphur,	32	54·24
	59	100·00

expressed by the formula Fe S_2 .

The various analyses of this mineral have given a composition which exhibits the following relations to the theoretical numbers above indicated:—

Iron,	47·85	46·08	46·53	46·5
Sulphur, ..	52·15	53·92	53·39	53·5
	100·00	100·00	99·92	100·0

Pyrites is very widely diffused through rocks. It has not yet been used as a source of supply for the manufacture of iron, but is most extensively employed for the making of sulphuric acid and alum—see Vol. I., p. 156. The residue of the heaps in making acid or alum is a sesquioxide of iron, with some remaining sulphur and earths, and is used as a coarse pigment for out-door purposes, under the name of *colcothar* or *purple brown*.

There is a certain kind of pyrites very common

in the mineral districts, and found in round and sometimes curiously-shaped nodules in clay, which when broken has a radiated appearance of fibres proceeding from the centre, or sometimes from various centres, and is often either compact or granular. This sort is termed *white pyrites*, it being lighter in the color. It is also termed *cockscomb pyrites*, from its radiations. It has a density varying from 4·69 to 4·90. When analysed it is found to have the same composition as the other sort, but is much more liable to spontaneous decomposition. When exposed to a damp atmosphere, it often crumbles to pieces; the sulphur is oxidised and converted into sulphuric acid, which combines with the iron to form sulphate of iron or copperas, and appears as an efflorescence of minute crystals on the surface of the mineral. This sort of pyrites is very plentiful in Anglesea and several of the copper mines of this country. White iron pyrites is more liable to be impure than the ordinary kind, and when found in mines of other metallic ores, it is often impregnated with some of the other metals. That of Anglesea often contains both copper and zinc, and frequently small portions of silicious and argillaceous matter. A specimen analysed by BERZELIUS gave:—

Iron,	45·07
Sulphur,	53·35
Manganese,	·70
Silica,	·80
Loss,	·08
	100·00

Magnetic Iron Pyrites.—This is a sulphide distinct from the common pyrites. It is found mostly in masses filling up fissures of rocks, is seldom crystallized, and is not very abundant. Occasionally it is met with associated with common pyrites, but is distinguished from the latter by being of a deeper color, and also, as its name implies, magnetic. It has a density of 4·6, and is composed of—

		Centesimally.
7 Eqs. of iron,	189	59·63
8 Eqs. of sulphur,	128	40·37
	317	100·00

represented by the formula, $\text{Fe S}_2 + 6 (\text{Fe S})$, which expresses a combination of bi- and proto-sulphide of iron.

The following are several analyses of this mineral which agree with the formula—

Iron,	59·29	56·38	59·61	59·72	59·8
Sulphur,	40·71	43·62	40·43	40·32	40·2
	100·00	100·00	100·04	100·04	100·0

Another iron pyrites is also found, which differs little from the common, except in the form of crystal; generally, however, it has a little of another matter in it, which is present more as an impurity than as forming a part of its constitution. This mineral is known as *marcasite*, and its composition by analyses is—

Iron,	45·07	45·60	45·66
Sulphur,	53·35	53·05	54·34
Manganese, ..	0·70	—	—
Copper,	—	1·41	—
Arsenic,	—	0·93	—
Silica,	0·80	—	—
Loss,	0·08	—	—
	100·00	100·99	100·00

ARSENICAL IRON PYRITES—Mispickel.—This mineral is met with abundantly in Cornwall and upon the Continent. It is often associated with other metals, as tin. It is found in crystals, but more generally as an amorphous mass. It has a grey, silver-white color and metallic lustre, is very hard, and has a specific gravity of from 5·7 to 6·2. It is easily known from the strong smell of garlic it emits when struck by the hammer or rubbed on anything hard or heated. It is a combination of sulphur, iron, and arsenic, and is composed of—

		Centesimally.
2 Eqs. of Iron,.....	54	33·54
2 Eqs. of Sulphur,.....	32	19·87
1 Eq. of Arsenic,.....	75	46·59
	161	100·00

agreeing with the formula $\text{Fe S}_2 + \text{Fe As}$.

Another variety of arsenical pyrites is known under the technical name *Danaite*, differing from the above in having cobalt as a constituent. Its analysis from different localities does not vary much, as the following two examples show:—

Iron,.....	26·54	33·28
Cobalt,.....	8·31	6·52
Sulphur,.....	17·57	18·02
Arsenic,.....	47·55	41·86
Loss,.....	·03	·32
	100·00	100·00

Besides the few which have been described, there are several other sulphides of iron well known to mineralogists, either from their peculiar form of crystal or the state in which they are found combined. There are likewise a great variety of other minerals, being combinations of iron with other metals, as cobalt, nickel, *et cetera*; also with other matters, forming arseniates, silicates, and the like, some of which will be noticed in another part of this article. Amongst these may be specified copper pyrites, composed of copper, iron, and sulphur, but which is never wrought for the iron it contains, although yielding more of it than the ore which is generally worked for that metal.

CARBONATE OF IRON.—This is the most common ore of this country, from which the greater part of the iron is manufactured, and of which there are several varieties. The true carbonate, or *spathose iron ore*, often occurs crystalline, generally in well-shaped six-sided prisms, and rhombohedrons, similar to carbonate of lime; although more generally the ore is obtained in a massive state, with a foliated structure. It is mostly of a light-brown or grey color, having a pearly lustre, varies in specific gravity from 3·0 to 3·85, and is composed of—

		Centesimally.
1 Eq. protoxide iron,.....	35	61·4
1 Eq. carbonic acid,.....	22	38·6
	57	100·0

It is, therefore, represented by the formula Fe O, CO_2 .

This mineral, however, often contains small portions of manganese and earthy matters, as the following analyses of samples from different localities will show:—

Oxide of iron,....	53·06	49·61	59·63
Carbonic acid,....	38·41	38·44	38·04
Manganese,.....	4·20	0·10	1·89
Magnesia,.....	2·26	5·18	—
Lime,.....	1·12	6·67	1·20
Silica,.....	0·48	—	—
Loss,.....	·47	—	—
	100·00	100·00	100·76

The most of the ores from which British iron is made consist of a carbonate found in beds in the coal formation, often alternating with the seams from which the coal is taken. This circumstance gives great facility to the manufacture of iron in this country, and is at once the cause of the superiority and cheapness of the metal. The great deposits of this kind of iron ore in Britain are those of Dudley in England, those of Wales, and of Lanarkshire and Ayrshire in Scotland. These ores are always massive, and generally contain several impurities, which, if not extracted, affect more or less the quality of the iron. They may be divided into two sorts:—

The first is the argillaceous or *clay-band* ores which contain a considerable quantity of earthy matter or clay, and these, when wrought by themselves, yield a weak and inferior quality of iron. They have a dark-grey color, nearly black, and a specific gravity varying from 3·17 to 3·41. The following analyses give a fair average of their composition taken from different districts:—

Protoxide of iron,....	32·22	38·80	35·0
Carbonic acid,....	32·53	30·76	25·5
Manganese,.....	—	0·07	0·3
Lime,.....	8·62	5·30	—
Magnesia,.....	5·19	6·70	1·6
Silica,.....	9·56	10·87	26·5
Alumina,.....	5·34	6·20	11·8
Sesquioxide of iron,....	1·16	0·33	—
Carbon,.....	2·13	1·87	—
Sulphur,.....	0·62	0·16	—
Loss,.....	2·63	—	—
	100·00	101·06	100·7

Black-band.—The second variety of this kind of ore, which is known as *black-band*, was for a long time unknown, and was first pointed out by the late D. MUSHET. It differs from the clay-band in having less earthy matters, and being much blacker in color. Some kinds of this ore have a homogeneous appearance, while others have coaly seams running between, and round light-brownish matter, stratified or in nodules; the whole mass or seam of this sort being of a mixed brown and black. The following analyses of a few samples of black-band exhibits the difference between it and the clay-band or argillaceous carbonate:—

Protoxide of iron,....	49·4	49·6	46·6
Carbonic acid,.....	35·2	30·4	30·1
Magnesia,.....	4·0	8·1	—
Alumina,.....	1·8	1·8	—
Lime,.....	—	—	6·3
Silica,.....	—	—	5·4
Coaly matter,.....	9·6	9·6	8·4
Loss,.....	—	0·5	3·2
	100·0	100·0	100·0

This class of ore is exceedingly valuable to the manufacturer, as the presence of the coal assists in some of the preliminary operations. These two ores, the

black and clay band, are generally wrought together, and give iron of excellent quality.

A most valuable addition to our knowledge of the iron ores of the Northern and North Midland Counties of England has been recently given to the world, in the *Memoirs of the Geological Survey of Great Britain*. These are to be further extended, and the completion

of the work will be hailed as a great boon by chemists and iron manufacturers. At the same time, unless these analyses of the ores be followed up by a similar investigation into the flux and fuel used, and the iron produced from the ores, the directors of the Museum of Practical Geology will only tantalise the manufacturers by an unfinished work:—

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.
Sesquioxide of iron,.....	49.57	—	95.16	90.55	86.50	94.23	1.77	1.45	2.39	1.69	1.30
Protoxide of iron,.....	10.77	49.47	—	—	—	—	35.38	36.14	41.77	39.38	39.87
Protoxide of manganese,.....	3.06	2.42	0.24	0.10	0.21	.23	.94	1.31	1.13	.95	1.38
Silica,.....	6.64	4.93	5.66	7.05	6.18	4.90	19.13	17.37	8.93	12.16	13.50
Alumina,.....	.84	.06	.06	1.43	.30	.63	7.63	6.74	4.79	6.42	6.13
Lime,.....	5.69	3.47	.07	.71	2.77	.05	3.35	2.70	2.55	2.26	2.12
Magnesia,.....	1.21	3.15	—	.06	1.46	trace	2.33	2.17	3.85	3.89	2.77
Carbonic acid,.....	14.49	37.71	—	—	2.96	—	25.41	26.57	31.39	29.38	28.47
Phosphoric acid,.....	.01	trace	trace	trace	trace	trace	.48	.34	.75	.47	.69
Sulphuric acid,.....	trace	trace	trace	trace	.11	.09	trace	trace	trace	trace	trace
Bisulphide of iron,.....	.03	.08	trace	.06	—	.03	.18	.10	trace	trace	.05
Water,.....	8.44	—	—	—	—	.56	1.85	1.77	1.70	2.09	1.80
Organic matter,.....	trace	trace	—	—	—	—	.23	2.40	.86	.54	.83
Potassa,.....	.05	—	—	—	—	—	.78	.65	.43	.37	.18
	100.80	100.29	100.19	99.86	100.49	100.50	99.46	99.71	100.34	98.80	99.09

	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.	XIX.	XX.	XXI.	
Sesquioxide of iron,.....	.79	1.49	2.18	2.16	1.47	1.42	2.30	2.69	3.49	3.60	
Protoxide of iron,.....	33.72	37.99	35.74	33.56	38.97	28.27	40.01	33.31	39.55	39.92	
Protoxide of manganese,.....	1.01	1.51	1.23	.96	1.09	1.02	1.26	2.18	1.50	.95	
Silica,.....	16.02	10.04	16.06	17.13	11.90	3.55	11.19	17.24	10.22	8.62	
Alumina,.....	6.41	5.57	7.09	8.49	5.93	2.31	5.91	8.85	5.65	7.96	
Lime,.....	3.99	4.59	3.01	3.17	1.62	13.94	2.78	2.32	3.38	7.44	
Magnesia,.....	5.49	3.37	2.96	3.06	4.82	9.27	2.85	2.44	2.88	3.82	
Carbonic acid,.....	28.14	29.92	26.74	25.63	30.14	37.61	29.72	24.83	28.63	22.85	
Phosphoric acid,.....	.41	.80	.66	.75	.48	.74	.34	.62	1.12	1.86	
Sulphuric acid,.....	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace	
Bisulphide of iron,.....	.13	.06	.05	.26	.05	.04	.09	.13	.05	.11	
Water,.....	1.44	2.21	2.17	2.25	1.66	.90	1.57	2.57	1.75	2.97	
Organic matter,.....	.36	1.42	.76	1.57	.30	.92	1.38	1.85	1.14	trace	
Potassa,.....	.47	.55	.66	.74	.67	.16	.34	.49	.68	.27	
Titanic acid,.....	—	—	—	—	—	—	—	—	—	.03	
	98.88	99.52	99.31	99.77	99.10	100.15	99.74	99.52	99.84	100.37	

OVERMANN has the following remarks on the clay-band of America:—

The compact carbonate of iron, sphaerosiderite, argillaceous iron ore, has no relation externally with the sparry variety; it comprehends most of the clay ironstones of the coal measures, particularly those which occur in flattened spheroidal masses, varying in size from the dimensions of a small bean to pieces weighing a ton. The color of this ore is commonly a dirty blue or grey-brown, reddish-brown, and yellowish-brown; fracture close-grained, hard, streaked white or brown, blackens before the blowpipe, and if calcined, is attracted by the magnet. This carbonate of iron, though belonging to the coal formation, is found in various places in the tertiary strata. It is the principal ore from which iron is smelted in England and Scotland, and yields usually from thirty to thirty-three per cent. of iron. It is largely distributed over the United States—Pennsylvania abounds in it. It exists in Maryland, Virginia, Ohio, Illinois, North Carolina, and Kentucky. The difficulty of working this kind of ore in the blast furnace, may be assigned as the reason why it is not more generally employed. England and Scotland use it extensively, and work scarcely any other kind.

VALUATION OF IRON ORES.—The value of the ore depends upon two conditions:—first, the quantity of iron it contains, and, second, the amount of impurities or matrix. The character and properties of the impurities, and the extent to which they will interfere with the quality of the iron when manufactured, must also be considered. To ascertain these points, the ore must be subjected to testing or assaying. There are two methods of assaying, termed respectively the wet and dry.

Wet Method.—What is termed the wet assay is the most accurate, and may be performed by any ordinary operative, after a short experience. Although, in the first instance, the operator wishes only to ascertain the quantity of iron in the ore, still, that being only a part of the process for obtaining the whole of the ingredients, it will be better to describe here the complete analysis required for practical purposes. The mineral being ground, weigh fifty grains and put them into a flask or beaker; add pretty strong aqua regia, and then digest the whole on a sand-bath at a boiling heat for fifteen or twenty minutes; remove the vessel from the heat, and add a little water; after allowing it to stand several minutes, decant the clear

solution; add to the undissolved residue as much acid and water as at first, and repeat the digestion; then put the two solutions together, pour the whole into a porcelain basin, and evaporate to dryness; next add two ounces hydrochloric acid, and two ounces water, digest for ten minutes, and pour the whole upon a paper filter, taking care not to lose any of the liquid; wash the residue upon the filter till the liquor passing through is free of acid; dry the filter, heat the contents in a crucible to redness, and then weigh. This gives the insoluble matter. The filtrate is now carefully divided into two equal proportions; to the one is added caustic ammonia in excess, and then filtered; the contents of the filter are well washed, and then dried; the liquid filtered through with the washing is to be kept. To the other half of the solution add caustic potassa till the iron is precipitated, then add a considerable excess, and boil the whole for ten minutes, filter while hot, and wash the precipitate with warm water till the alkali is all removed; the iron precipitate is then dried. These two iron precipitates are now heated to redness in a crucible, and weighed separately; the weight of the one obtained by potassa will be that of the sesquioxide of iron; the weight of the other will be the sesquioxide of iron and alumina, if any of that substance has been dissolved; the difference of weight will therefore indicate the alumina, which is noted down. The quantity of iron which the sesquioxide contains is known by calculating their equivalents, which are as ten to seven:—thus, if the sesquioxide obtained be 12·5 grains, then $10 : 7 :: 12·5 : 8·75$, and this being in twenty-five grains, will make the percentage of the ore thirty-five.

To the solution filtered from the precipitate by ammonia, there is added oxalate of ammonia, so long as a precipitate is formed, if there be any; this is stirred well, and after heating the solution it is again filtered, and the precipitate washed and dried. This is the lime in the state of oxalate, which is converted into carbonate of lime by subjecting it to red heat in a crucible, and then weighed. As the carbonate is the condition in which the lime would exist in the mineral, no calculation is required. To the solution filtered from the lime is added a little solution of phosphate of soda; the mixture is well-stirred for seven or ten minutes, and then allowed to stand for an hour; if a precipitate is formed, it is filtered, well washed, dried, and burned at a red heat; this precipitate is the phosphate of magnesia. When burned and washed, the quantity of magnesia present in the mineral is known from the fact, that every 237 parts of the precipitate are equal to 85·4 magnesia.

When the ore is to be tested for sulphur, it is better to take a separate portion of the mineral—say twenty-five grains—and digest in two parts hydrochloric and one nitric acid, for half an hour, then dilute and filter, and add to the filtered solution chloride of barium—allow it to stand for an hour; any precipitate formed is sulphate of baryta, which is obtained by filtering, washing, and then drying and burning; every one hundred and sixteen parts of this precipitate is equal to sixteen parts of sulphur. If only the quantity of iron be required, then the operator need go no further than the first

precipitate, but he will have to take potassa only, and proceed as directed above.

The preceding method is applicable to any of the ordinary classes of iron ore, such as the hematite, brown oxide, magnetic, *et cetera*. Sulphides are never used for the manufacture of the metal; but even these, such as the common pyrites, may also be tested in the same way.

A few years ago Professor FUCHS recommended, for ascertaining the value of iron ores, the following process, founded upon the fact that copper reduces sesquioxide of iron to the state of protoxide:—Take fifty grains of the powdered ore to be operated upon, and digest in strong hydrochloric acid till all the iron is dissolved—say about half an hour; then add by degrees about twenty-five grains of chlorate of potassa to oxidise the iron—neither nitric acid nor nitrate must be used for this purpose. When the iron is oxidised, the solution is brought to boil, then a clean slip of pure copper is added, which must have been previously weighed, and the solution is kept in ebullition to prevent access of air. After ten minutes' boiling, and previous to removing the undissolved copper from the solution, hot water is to be added till the vessel is quite full; this is to be poured off, and the vessel again filled with fresh hot water. The copper, which is generally covered with a brownish coating, is then carefully washed in cold water, dried at a gentle heat, and finally weighed; every four grains of copper dissolved indicates five grains of sesquioxide of iron present in solution; the quantity of metallic iron may then be calculated as already stated.

The advantages of a process of this kind are not only that it is simple and easy to perform, but the presence of any of the earthy matters, as silica, lime, alumina, or other metals, does not interfere with it; only, if the ore contains arsenic, this process will not answer. Much care must be taken not to prolong the operation, as copper is dissolved by the acid present in small quantity, and in that case the results cannot be relied on; yet many are able from experience to perform the analysis in this way with great accuracy.

Another simple process for testing the quantity of iron in an ore, based upon the reaction of the protosalts of iron upon permanganate of potassa, has been proposed by MARGUERITE:—When a solution of permanganate of potassa is poured into a very dilute acid solution of protosalt of iron, the protosalt becomes converted into the sesquioxide at the expense of the oxygen of the permanganate, decoloring the solution. As long as any protosalt of iron remains, it is immediately decomposed in proportion as the solution of the permanganate is gradually poured into it, the liquor assuming a very pale yellow color, due to the sesquioxide of iron produced; but as soon as all the iron is oxidised, one single drop of permanganate suffices to impart a distinct pink color to the liquor, which indicates that the experiment is finished.

Permanganate of potassa is prepared as follows:—

	Parts.
Binoxide of manganese,.....	2
Chlorate of potassa,.....	1
Caustic potassa,.....	3

Mix the whole thoroughly, introduce the mixture into

a Hessian crucible, and keep it at a low red heat for about two hours. The mass, which is of a dark-green color, is then reduced to coarse powder, and mixed with three or four times its weight of water; after stirring the whole, nitric acid, diluted with half its weight of water, is gradually added until the liquor assumes a fine violet color; it is then filtered through pounded glass or asbestos, and preserved in a glass-stoppered phial. The reason of filtering through asbestos or glass is because contact with organic matter, such as paper or linen, decomposes the permanganate. The salt is very stable, and may be preserved for a long time without alteration, provided always that it be kept in a glass-stoppered bottle, and contact with dust or any organic matter carefully avoided.

To make the permanganate of the proper strength, dissolve twenty-five grains of pianoforte wire—which may be considered pure iron—in about 1·500 grains by measure of pure hydrochloric acid. When dissolved, and the disengagement of hydrogen gas has ceased, dilute the solution with about one pint and a half of water. It is necessary to dilute the solution to this extent, and to operate in the cold, in order to guard against the excess of hydrochloric acid reacting upon the permanganate and disengaging chlorine; one thousand grains-measure of the solution of permanganate of potassa, prepared as before described, being introduced into an alkalimeter, it must now be gradually poured therefrom carefully, drop by drop, into the hydrochloric acid solution of iron just alluded to, stirring the liquor all the time in order to insure complete action, exactly as in alkalimetry.

On adding the solution of permanganate of potassa, the operator will perceive that, at first, it is decolorized as fast as it is poured in; but the rapidity of action gradually diminishes, and, at last, it imparts to the liquor a pinkish tint, which indicates that the whole of the iron in the liquor is oxidised. The number of divisions which have been required to obtain that result is carefully observed; and supposing, for example, that fifty divisions of the alkalimeter have been required to oxidise the twenty-five grains of pianoforte-wire employed, it is evident that each division of the permanganate of potassa test-liquors represents half a grain of metallic iron.

But whatever may be the strength of the solution of permanganate, it is always easy to adjust it to any desired standard; if too weak, by concentrating it by evaporation at a gentle heat; if too strong, by diluting it with a suitable quantity of water, so that it may be brought as near as possible to such a strength that one measure of the alkalimeter may indicate half a grain of metallic iron.

Take twenty grains of the iron ore and reduce them to very fine powder by levigation; put them into a flask capable of holding about a quart of water, and pour into it about one thousand grains-measure of pure and fuming hydrochloric acid. The mixture is now moderately boiled until the ore has dissolved. Water is then poured in, so as to fill up about one-third of the flask; and the salt of iron is brought entirely to the state of protosalt, by adding about one hundred grains of pure zinc, or about sixty grains of sulphite

of soda. After boiling for a few minutes, and as soon as the liquor no longer evolves an odor of sulphurous acid, and has become greenish or almost colorless, all the iron has passed into the state of protosalt. The solution is then diluted with a fresh quantity of water, so as almost to fill the flask, and the test-liquor of the permanganate of potassa is poured in, drop by drop, until the characteristic pink color is produced. The operator then reads off the number of divisions employed.

Let it be supposed, for example, that the test-liquor is of such a strength that each division represents half a grain of pure iron, and that twenty-two divisions have been required to oxidise the metal contained in the twenty grains of ore operated upon. It is evident that these twenty grains contain eleven grains, and consequently fifty-five per cent. of iron.

This process is obviously much more rapid than any of those previously described, and the presence of any other metal or earth does not interfere with the results—except two, namely, arsenic and copper. Should either of these be present, they may be separated, previous to applying the test, by a bar of zinc, which precipitates them. Then filter the solution, and proceed as described.

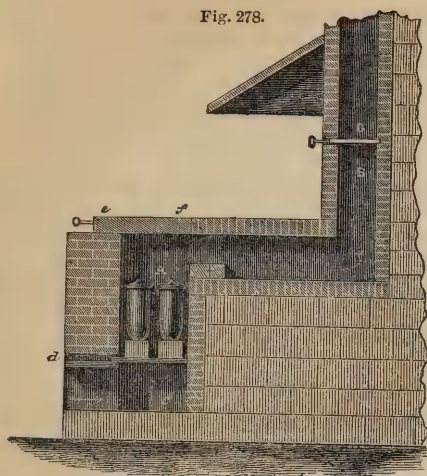
The Dry Method.—By the preceding methods, it will be observed that it is the quantity of pure metal that is estimated; whereas, by the process of smelting, the metal is not obtained pure. Some metallurgists prefer using a process more analogous to the smelting operations for testing the value of the ore and the quality of the iron, and for this purpose practise what is termed the dry assay; this is performed by taking a sample of the ore and fusing it in a crucible, to obtain the iron in the metallic state. It will have been observed, that the ores generally contain small portions of silica, alumina, *et cetera*. Such matters are by themselves infusible; but at a high temperature they combine with the oxide of iron, and form a fusible compound; so that were the ore put into a crucible alone and fused, iron would not be obtained, but a combination of oxide of iron. It is necessary, therefore, to mix with the ore some matters that will combine with the substances named, and set the iron free. Such are termed fluxes and reducing agents; but even by the aid of these, the operation of assaying by the former requires great care, and necessarily a very high heat, the apparatus and operations for which are as follow.

The common assay furnace is of a very simple form. It is generally constructed upon the floor of the room, close to where there is a chimney, so as to insure a good draught. The following sectional sketch—Fig. 278—will give the best idea of its construction. A is the fire-place containing two crucibles; B, the chimney; c, ashpit open from the front for the admission of air; d, the grate bars; ef, cover for fire; g, damper for regulating heat.

The grate bars are loose pieces of bar-iron half an inch square, leaving an intervening space of the same size, and laid loose, so that they may be removed and the fire-place cleaned out, as the coals and bricks are apt to cake and choke up the fire-place. The latter should be lined with the best fire-brick built in with fire-clay,

and should be from sixteen to eighteen inches square, and from twenty-four to thirty inches deep. The fire is fed from the top, which is covered by a fire-clay

Fig. 278.



tile, furnished with a rim of iron. The whole furnace should be strapped round with belts of iron, to prevent its splitting or falling to pieces by the expansion; or a very common method, and the most secure, is to fit them round with a cast-iron casing, which is a great preventive against the furnace rending and admitting currents of air. The most suitable fuel is a mixture of coal and coke. The furnace should be at a good heat before the crucibles are put into it. Some assayers place a small piece of tile or brick upon the bars on which the crucibles stand, while others embed them in the fire, which is the best method for obtaining an equal heat round the crucible. In a furnace of the size stated, two or three crucibles may be placed in the fire at a time, and this is often recommended; but the Editor prefers to use only one at a time, as giving the most certain results, though requiring a little longer for the operation. The most refractory kind of crucibles should be used; those termed the Cornish and Hessian answer very well. A good assortment of them, laid in a warm place, should be kept on hand by the assayer. Covers are also prepared for them, by baking a piece of fire-clay into the required shape and size.

For the purpose of inserting or removing the crucibles from the furnace, a number of different-shaped tongs are wanted. There are also required the following fluxes and reagents—pounded charcoal, slaked lime, potassa and soda, tartar, borax, and ground glass. If the assayer has a knowledge of chemical operations, he will, before making an assay, ascertain by means of tests, as already referred to, an approximate idea of the quantity of lime, silica, and alumina present, so as to regulate his fluxes; but it often happens that the assayer is ignorant of this, and he consequently judges of the quality of the ore and the fluxes to be used by the appearance of the ore when ground and burned. The assay is then proceeded with, by first taking a sample of the ore and grinding it fine in an iron mortar, weighing out two hundred grains, and placing it, mixed with an equal quantity of dry slaked lime and fifty grains of powdered char-

coal, upon a clean piece of glazed paper; but if the ore be a refractory one, a little carbonate of soda or potassa may also be added.

The crucible should be previously prepared by filling it with pounded charcoal, moistened with water; this should be pressed into the crucible, and dried. A hole is scooped out in the centre of the charcoal, so as to leave about one quarter of an inch of charcoal all round. The mixed ore and flux are put into this cavity; the crucible is covered and luted with clay, and then placed in the centre of the furnace, the fire of which should have been allowed to burn low. When the crucible is properly embedded, coal and coke are packed all round and over it, filling the furnace nearly to the top; the crucible being as nearly as possible in the centre of the fire. For a time the fire is allowed to burn slowly, so as to drive off all damp from the ore and crucible. After a while the fire is covered, and the heat raised to the highest pitch and continued for about half an hour, when the cover of the furnace is removed, and a portion of the fire is taken out from the top, to expose the crucible, which is then withdrawn by a pair of tongs, giving it a gentle tap upon the floor, to shake down any particles of fused metal. When cool, the lid is taken off and the contents examined. For this purpose the crucible is generally broken; if the temperature has been sufficient, a small button of metallic iron will be found under the slag; if the heat has not been high enough, or a proper supply of flux has been wanting, the slag is full of small metallic beads, or the whole forms an agglutinated mass; in the latter case, the only remedy is to repeat the operation. If the process is successful, the small button of iron is carefully detached and hammered, to drive off any scoria adhering. The success of the whole operation is judged of by the appearance of the slag; it should be a greenish or greyish glass. This should be ground fine and spread upon paper, and a magnet drawn over it to detect any little prill of iron which may have remained in the slag. The whole iron is then weighed and the per-centage calculated. Iron thus obtained is not perfectly pure, but in general it is as pure as cast-iron, and may therefore be taken as the true valuation, if cast-iron is to be made from the same ore.

MUSHET, in his work upon iron and steel, enters extensively into the assaying of different ores by the furnace; he arranges the ores for assay into three classes—*argillaceous*, *calcareous*, and *silicious*—according to the earthy matters that prevail, so that there may be a proper distribution of flux, and each class is divided into two varieties, as follows:—

	First variety.	Average proportion.	Second variety.	Average proportion.
<i>Argillaceous iron ore</i> ,	Clay,	9	Clay,	10
	Lime,	6	Silica,	7
	Silica,	3	Lime,	3
		18		20

For every four ounces troy of this class of ore, he recommends as flux the following ingredients well mixed:—

	First variety Ounces.	Second variety. Ounces.
Bottle-glass,	4	4
Chalk,	3	4
Charcoal,	0.50	0.75

Second class of ores:—

	First variety.	Average proportion.	Second variety.	Average proportion.
<i>Calcareous iron ore</i> ,.....	Lime,.....	14	Lime,.....	10
	Clay,.....	6	Silica,.....	6
	Silica,.....	4	Clay,.....	4
		24		20

The flux recommended for this class is—

	First variety. Ounces.	Second variety. Ounces.
Bottle-glass,.....	5	4
Chalk,.....	1.50	2
Charcoal,.....	0.75	0.50

Third class of iron ores is—

	First variety.	Average proportion.	Second variety.	Average proportion.
<i>Silicious iron ore</i> ,.....	Silica,.....	12	Silica,.....	10
	Lime,.....	8	Clay,.....	7
	Clay,.....	5	Lime,.....	5
		25		22

Flux recommended for four ounces of ore:—

	First variety. Ounces.	Second variety. Ounces.
Bottle-glass,.....	3.50	3.50
Chalk,.....	3	2.50
Charcoal,.....	0.75	0.50

For hematite and such like ores that contain small portions of silica, the best flux for four ounces is—

	Ounces.
Chalk,.....	1.50 to 2
Charcoal,.....	0.50

Many assayers use slaked lime alone; others add with the lime small portions of the alkaline carbonates, or borax, which often facilitate the fusion, especially with such ores as contain much silica and alumina, and are, consequently, very refractory.

The button of iron obtained in the assay is subjected to the following test:—It is placed between a fold of thin tin-plate, to prevent it flying away on being struck, it is then hammered upon an anvil and broken; if the button flattens before breaking, and the fracture have a greyish appearance, the quality is considered good;

Fig. 279.



but should it split on the first blow of the hammer, and show a crystalline fracture, whitish in appearance, it is not good, and the ore is judged unfit for the best quality of iron.

MANUFACTURING OPERATIONS.—Iron is produced for the purposes of the arts in three different states—as *crude* or *cast-iron*, *steel*, and *malleable* or *bar-iron*. These three modifications are the results of several and separate operations, undertaken for the express purpose of obtaining the quality of iron desired; although, when each is tested separately, they are found to differ only in the quantity of carbon or charcoal in their composition. Malleable iron is the purest, and has very little carbon in it; to have it quite pure is the aim of the manufacturer, but this is never accomplished in practice. Steel contains more carbon than bar-iron, and cast-iron generally more than steel; but there is no fixed proportion of that ingredient in either by which a line may be drawn between them; they seem to merge into one another, so that some kinds of steel may be called cast-iron, and some cast-iron may be considered steel. The difference is often more dependent upon the mode in which the carbon is combined with the iron, than on the exact quantity present. Ordinary crude or cast-iron contains, also, other impurities, as silica, which render it very inferior; and the variable amount of silica and carbon found in different kinds, gives rise to a great variety of qualities of cast-iron, distinguished by technical names, such as *grey*, *mottled*, *white*, *silver*, *et cetera*.

The manufacturing operations succeed each other in the following order:—1. The calcination of the ores, by which the carbonaceous and volatile matters are burned off, and the whole reduced in bulk to prepare them for the smelting furnace; 2. The extraction or reduction of the metal in the form of cast-iron by smelting; 3. The conversion of the cast-iron into malleable or wrought iron by puddling and rolling; and 4. The reconversion of the comparatively pure malleable iron into that particular carbide which is known as steel.

CALCINATION OF THE ORES.—The carbonated ores of this country are generally prepared for the blast furnace by a process of calcination which burns away all volatile matters, and concentrates the metal. For this purpose the ores are accumulated in large heaps, generally in an open field, and mixed with carbonaceous matters, such as small coal. Some of the black bands have sufficient coal in their composition to effect their calcination. After a heap of several hundred tons is collected, a fire is kindled at the windward end, which gradually passes on through the whole mass and burns for several days, producing a very high heat, often sufficient to reduce and fuse some of the metal, which, however, is not desirable.

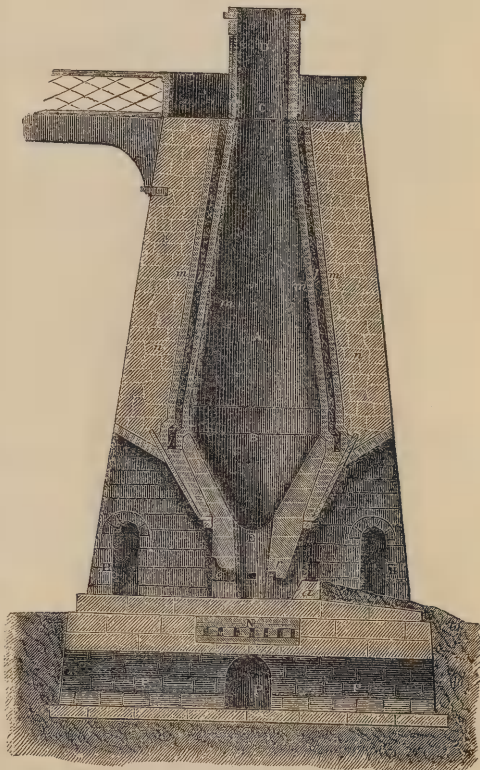
The black-band iron ore, of the average of thirty-three per cent. of iron, will contain, after calcination, an average of seventy per cent. of iron. The clay-band of thirty per cent. of metal in the ore, will, when properly calcined, contain about fifty-four per cent., so that by this means a great saving is effected in the amount of fuel required for the subsequent operation of smelting.

Instead of roasting the ore in open heaps, the same operation is sometimes performed in kilns, similar to those used for burning lime. In some districts, this method is found more convenient than large open heaps, covering often several hundred square yards.

SMELTING THE ORES.—The next operation is the smelting or reduction of the calcined ore, and the first subject which falls to be considered under this head is the form and *matériel* of the furnace.

The structure of the blast furnace varies considerably in different localities, according to the views of the smelter and the character of the ore and fuel, but in their general features there is much sameness. Drawings will be given of a few of the forms adopted at different times and in different places; but to enable the reader to understand the references to particular parts, it may be well to introduce, in the first place, an external and sectional view of a blast furnace of modern construction. The former is shown in Fig. 279, including the sand-bed in which the metal flows, to form the pigs of cast-iron as they are taken to market. Fig. 280 is a section of a similar furnace, consisting of two courses of fire-brick, *m m m m*; between these is a

Fig. 280.



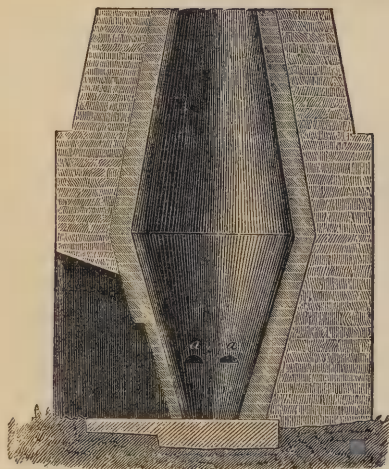
casing, *ll*, of pieces of brick, scoria, and sand. Over the whole is the external coating of thick masonry, *nn*, formed either of ordinary bricks or of stone, as is most convenient. The inside lining of fire-bricks is technically termed the shirt of the furnace; the part extending from the cross line at *B*, and running down into the crucible portion at *E*, is composed of fire-stone; occasionally fire-bricks of the most refractory sort are used for this part also. The small part at *E* is termed the hearth; the bottom is formed of a large fire-stone, supported by a mass of mason-work, having air-channels, as seen at *N*, while open arches or galleries, *p p p*,

are made below, one intersecting another at right angles, to keep the whole erection dry. D is the chimney surrounded by a gangway, with openings to admit the barrow, by which the furnaceman introduces the ore, flux, and fuel. c is the *throat* or *trunnel* hole of the furnace; A is called the cone or body; ■ the boshes; HH are arches leading through from one tuyere-hole to another, for convenience in attending upon the furnace. One of the stones composing the hearth, as shown at r, does not reach the base, but is supported by a strong bearer of iron built into the masonry, on which rests a block of sandstone called the *tymp*. Below, and a little in advance, is placed what is termed the damstone, a. The sides of the hearth are perforated a little above the level of the tymp with holes, cc, for the admission of the discharging orifices of the blowing apparatus, termed *tuyeres*; the arrangements of which will be shown in a future figure.

The preceding details will enable the reader to appreciate the points of resemblance and of difference in the following furnaces.

Fig. 281 represents a furnace which at one time was very common in Europe, and some specimens of which

Fig. 281.

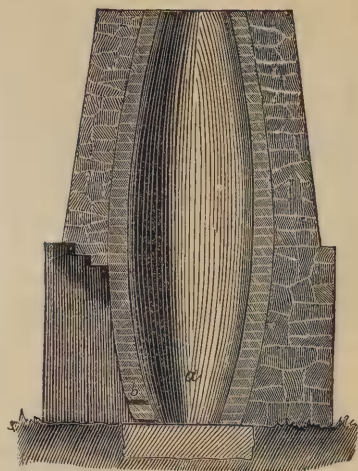


still exist in Spain and Hungary. It is exactly in the form of two crucibles, the one inverted over the other. This furnace measures from ten to sixteen feet in height, two feet wide at bottom and top, and five feet in the centre; two tuyeres are seen at aa, which admit the nozzles of two pair of bellows; in the front is an opening about two feet square, which, while in work, is built up with brick. After the furnace is heated sufficiently to permit the descent of the partially-fused metal, it is charged with the ore and charcoal fuel, and this is continued till, from the quantity of ore put in, the reduced metal would be up to near the tuyeres. The blast is then stopped, the front part, or breast wall, built up with brick, is removed, and the iron, which exists in a solid mass, is loosened and removed by crow-bars, and then carried to the forge hammers and wrought up into bar-iron. The front is again built up, and the smelting operations renewed. From the state in which

the iron is obtained, this furnace has been named the *salamander* furnace.

Fig. 282 represents what is termed the *blue oven*. This kind of furnace is in common use in Germany,

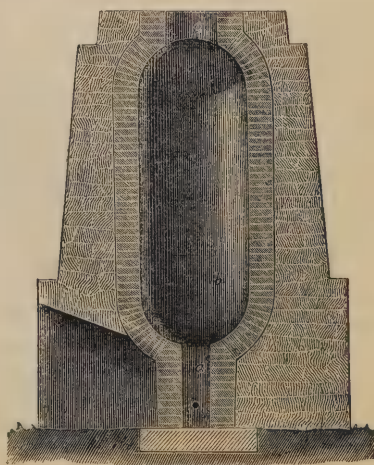
Fig. 282.



and approaches near to our ordinary blast-furnace in the internal shape; its height is from twenty to twenty-five feet; a indicates the tuyere holes; it is also furnished with a breast, which can be removed; at the bottom, however, is a small hole, to let out the fluid metal; and a little above this, another to enable the scoria to be taken out. The bottom of the furnace is made to slope to the tap-hole. The fuel used is charcoal. This is considered an excellent furnace for spar-iron ore, and yields a good steel-iron.

The form of furnace used in the Hartz mountains is shown in Figs. 283 and 284. It is constructed of very

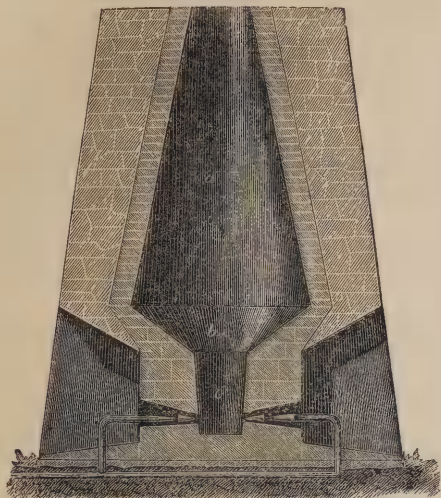
Fig. 283.



heavy masonry. The crucible portion, c, is very high and narrow, while the boshes, b, are exceedingly flat, to allow of a very large body of coal and ore; the ores in that locality being very refractory, composed mostly of red

and brown hematites and carbonates. The metal is let out from time to time in a fluid state, and is celebrated for its superior quality over most other irons.

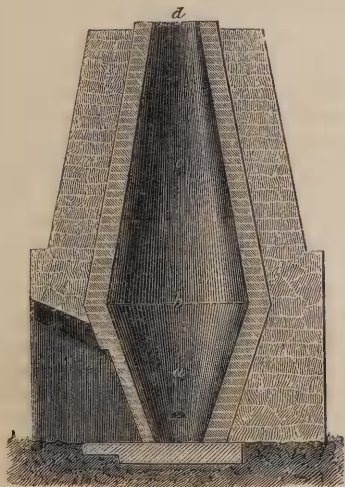
Fig. 284.



This form of furnace is used in Prussia and other localities for smelting bog-iron ores. It differs materially from all the other blast furnaces in its internal shape; the hearth or crucible part, however, resembles that of the one last described. The height of the furnace is about thirty feet; the crucible portion at the bottom is slightly tapered, its length being about six feet, and one and a half feet wide. Iron of very good quality is made from the bog-ore in this furnace, the fuel being charcoal.

Fig. 285 exhibits the structure of a furnace used in Styria for the smelting of sparry iron ore. The total

Fig. 285.



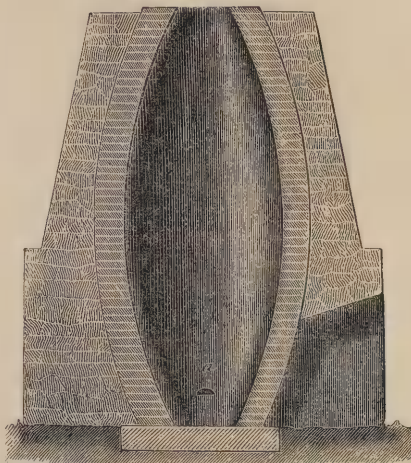
height is about thirty-four feet; the boshes, *b*, are about nine feet, and the top and bottom about two feet six inches diameter. The blast is produced by square wooden bellows, driven by water wheels. The

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iron is tapped out at intervals in quantities of from two to three hundred pounds weight. Charcoal is used as the fuel, and the best quality of metal is produced in these furnaces.

Fig. 286 represents the old blast furnaces of Sweden, which were known to have produced good iron, but in

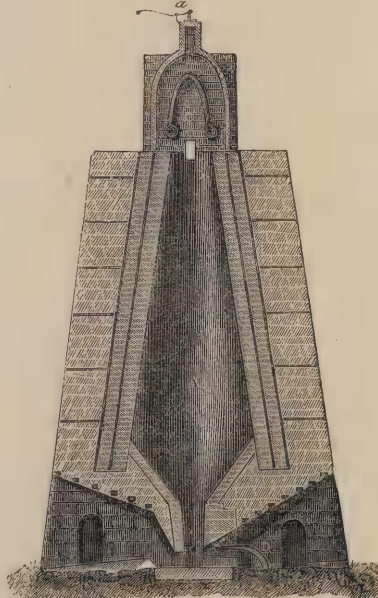
Fig. 286.



small quantity, not exceeding three tons per week. At the present time the furnaces of Sweden are similar to those used in England.

Fig. 287 shows the interior of a furnace used in

Fig. 287.



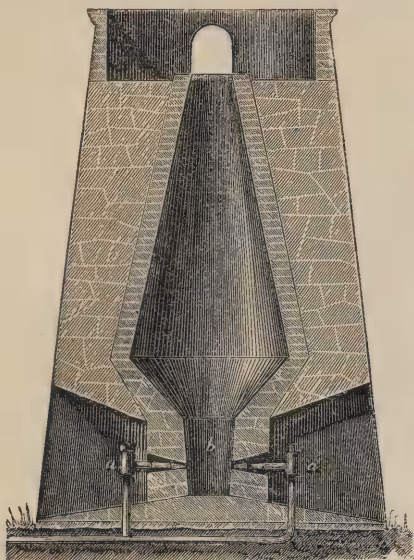
different parts of Germany, which is a very close approximation to the most improved furnaces of this country.

Fig. 288 is a blast furnace in Silesia. It is twenty-seven feet high, and is blown with hot-blast heated at the top of the furnace. The crucible portion re-

3 G

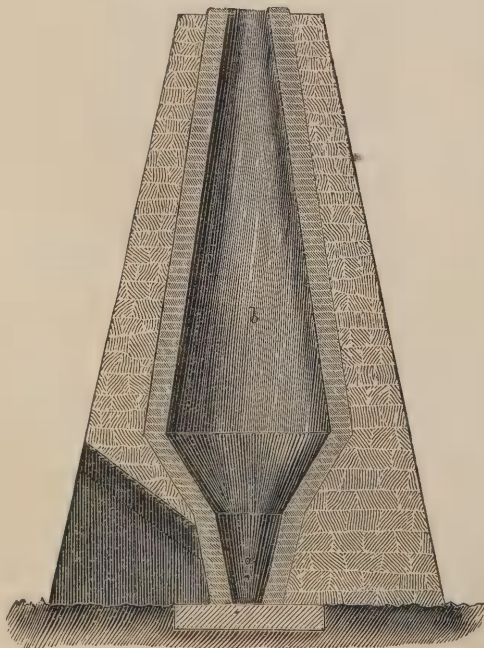
sembles some of those already given; it is seventeen inches wide at bottom, and twenty-eight inches at top; the boshes are nine feet in diameter, the mouth or top

Fig. 288.



three feet. The tuyeres are fifteen inches above the bottom stone. The ore used is the hydrated oxide of iron, and the fuel pinewood charcoal. This furnace is remarkable for the small amount of fuel required, and

Fig. 289.

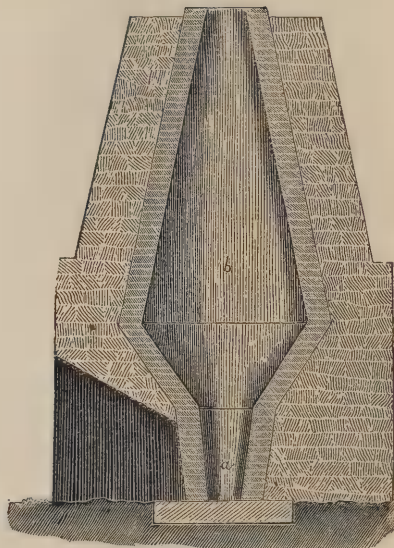


the production of a very fluid metal, excellent for fine castings, and much used for the manufacture of the celebrated Berlin castings.

Fig. 289 is a charcoal blast furnace at New York; it is forty feet in height, and nine feet in width at the boshes; its hearth is six feet six inches high, and one foot nine inches wide. The ores wrought are mostly the magnetic oxide and brown hematite, with a small quantity of bog-iron ore. It produces a good quality of grey iron, very fusible. Two tons seven hundred-weights of ore, and one hundred and twenty bushels of charcoal, are required to produce one ton of cast-iron.

Fig. 290 is another charcoal furnace, representing those in use at Pennsylvania in America. The height of this furnace, says OVERMANN, is thirty-two feet, width

Fig. 290.



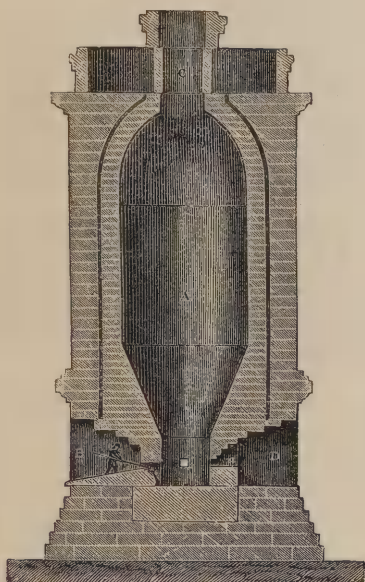
of boshes nine feet six inches, hearth five feet high, two feet in width at the bottom, and two and a quarter feet at top. The rich hydrates, pipe ores, fossil ores, *et cetera*, are generally used. Two tons and a half of ore produce, on an average, one ton of metal; for each ton one hundred and eighty bushels of charcoal are required. The furnaces in operation at the oldest establishments West of the Alleghany mountains, such, for instance, as the Dover furnaces at the Cumberland river, Tennessee, are almost a true copy of those in use in Eastern Pennsylvania; both require the same amount of fuel, and both yield similar results. Going further West, there is a greater amount of coal used to produce a given amount of iron. For instance, at the Alleghany and Ohio furnaces, as far down as Hanging Rock and Portsmouth, one hundred and seventy to one hundred and eighty bushels of charcoal are considered sufficient to make a ton of iron, while in Kentucky and Tennessee from two hundred to two hundred and fifty bushels of charcoal are required to produce the same amount.

Such are a few of the different sorts of furnaces, fitted up as circumstances and locality have suggested, —all of them possessing certain qualities suitable to the conditions in which the work is conducted, and

showing, what has been already stated, that the kind of fuel and ore often necessitates modifications in the furnace.

The furnaces at present in use in this country vary a little in their structure, according to the fancy of the builder, their early or recent construction, and whether originally intended for the cold or hot blast. A view of the general structure of the modern furnace has been already given—page 415. Mr. J. J. GRIFFIN, in a series of interesting models of manufacturing apparatus for lectures, exhibits one of a blast furnace, similar to those employed in the neighborhood of Glasgow, where the hot blast is used. This is represented in Fig. 291, and will be seen to differ a little from any

Fig. 291.



of the preceding, in having the body of the furnace more of a cylindrical shape.

The interior dimensions and measurement of two

well-going furnaces, of the average size and structure used in this country, are thus tabulated by Dr. URE:—

	No. 1. Feet.	No. 2. Feet.
Height from the hearth to the throat or mouth,.....	45.0	49.0
Height of the crucible or hearth,.....	6.5	6.0
Height of the boshes,.....	8.0	7.0
Height of the cone,.....	30.5	36.0
Height of the chimney or mouth,.....	8.0	12.5
Width of the bottom of the hearth,....	2.5	2.0
Width at its upper end,.....	3.0	2.5
Width of the boshes,.....	12.5	13.5
Width at one-third of the belly,.....	12.0	11.5
Width at two-thirds of the belly,....	8.5	9.5
Width at mouth,.....	4.5	3.5
Inclination of the boshes,.....	59°	52°

Materiel of the Furnace.—The bottom or hearth, which may be considered the crucible portion, or the part where the fused matters collect, is generally composed of a silicious stone found in the coal measures, termed millstone-grit, or fire stone, from its refractory character. The upper portion of the chamber is lined with fire brick.

The fire clay for making the bricks which line the furnace, and which is generally found in the same mine with the ironstone, varies very considerably in composition in different localities, having properties more or less suitable for the purpose, according to the absence of oxides, and the quantity of silica and alumina. TAYLOR, in his analysis of the rocks of the coal-measures at the Hartley pit, gives the following:—

	Fire clay.	Muscle bind.	Blue Shale.	Bituminous Schist.
Silica,.....	62.14	63.89	58.99	56.51
Alumina,.....	31.07	33.49	26.19	31.89
Oxide of iron,.....	2.24	—	10.25	7.04
Lime,.....	0.74	2.01	0.67	1.69
Magnesia,.....	0.83	0.61	1.54	0.85
Potassa,.....	2.45	—	2.34	1.38
Soda,.....	—	—	—	0.61
Loss,.....	0.53	—	0.02	0.03
	110.00	100.00	100.00	100.00

Dr. RICHARDSON gives the subjoined analysis of the principal fire clays in the neighborhood of Newcastle:—

Silica,.....	51.10	47.55	48.55	51.11	71.28	83.29	69.25
Alumina,.....	31.35	29.50	30.25	30.40	17.75	8.10	17.90
Oxide of iron,.....	4.63	9.13	4.06	4.91	2.43	1.88	2.97
Lime,.....	1.46	1.34	1.66	1.76	2.30	2.99	1.30
Magnesia,.....	1.54	0.71	1.91	trace	2.30	2.99	1.30
Potassa,.....	2.45	—	—	—	—	—	—
Soda,.....	—	—	—	—	—	—	—
Water, and organic matter,...	10.47	12.01	10.67	12.29	6.94	3.64	7.58
	100.55	100.24	97.10	100.47	100.70	99.90	98.90

Stourbridge has been long celebrated for its fire clay, which is admirably fitted for making crucibles and lining furnaces. The composition of various qua-

lities of this clay as given by different analysts, along with fire clays from several other localities, is shown in the following table:—

	Stourbridge.			Monmouth.	Pembroke.	Govan.	
	Bertlender.	Salvett.	Cowper.	Cowper.		Penny.	Penny.
Silica,.....	63.7	45.25	63.3	75.3	88.43	60.2	59.7
Alumina,.....	20.7	28.77	25.3	16.8	6.90	37.7	37.5
Oxide of iron,.....	4.0	7.72	1.8	1.0	1.50	1.0	2.3
Lime,.....	—	0.47	1.5	0.9	3.40	1.0	1.0
Magnesia,.....	—	—	trace	—	trace	—	—
Water,.....	10.3	17.34	10.3	6.0	dried	dry	dry

For the sake of comparison, analyses of a few fire clays from different localities on the Continent are here added:—

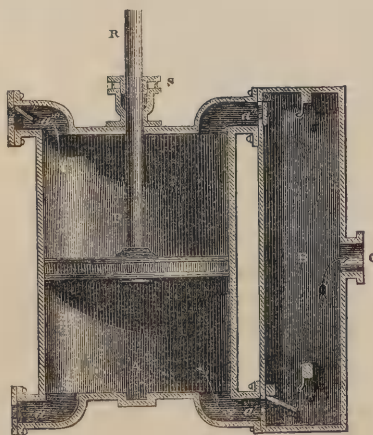
	Gross. Berthier.	Almerode. Salvetal.	Beaufoy's dep. des Ardennes. Berthier.	Schierdorf near Passau. Salvetal.
Silica,.....	46.5 ..	47.50 ..	52.0 ..	45.79
Alumina,.....	34.9 ..	34.37 ..	27.0 ..	28.10
Oxide of iron,...	3.0 ..	1.24 ..	2.0 ..	6.55
Lime,.....	— ..	0.50 ..	— ..	2.00
Magnesia,.....	— ..	1.00 ..	— ..	—
Water,.....	15.2 ..	14.43 ..	19.0 ..	17.00

In making the bricks from these clays, they lose the water and become anhydrous; so that the character of the compound is thus considerably altered. Fire clay is also used as mortar for the inside lining of the furnace, which is subject to high heat. The outside work of the furnace is constructed either of common brick or stone, according as the one or the other is most easily procured in the locality.

THE BLAST.—Having described the various forms of furnaces, it will now be necessary to refer briefly to the mode of producing the blast. It has been stated that in olden times the pit furnaces, or *bloomeries*, as they were termed, were often made on the face of a declivity, having a frontage to the sea-breeze, with a proper construction for admitting the air; but that, by-and-by, bellows were used of various forms, according to the state of the arts; and that in the last century an improvement was effected, which completely revolutionized the smelting operations by the introduction of what is termed the cylinder blast, or *blowing machine*. This is made somewhat similar to the cylinder of a steam-engine, as shown in the annexed drawing—Fig. 292.

The cylinder is made of cast-iron, accurately turned inside, and fitted with a piston, made air-tight either by packing with hemp or gutta-percha, or by a metallic spring. It is closed at both ends; but the cover is provided with an aperture for the piston-rod, stuffed

Fig. 292.

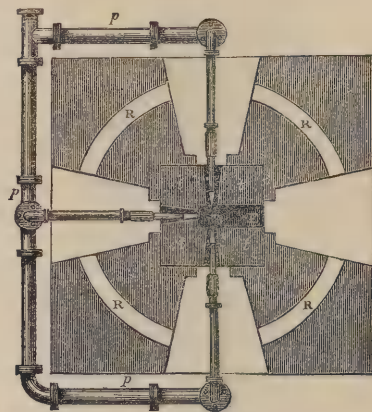


with leather or other suitable material to prevent the air from passing through. In the figure the piston is being forced down; the valve at *a'''* is open to admit

the air from the external atmosphere; while the valve, *a*, is shut to prevent it being pressed out; and the valve, *a'*, is open to allow the pressed air to pass into the chamber, B; while the valve, *a''*, is shut to prevent the pressed air returning to the upper portion of the cylinder. When the piston returns upwards, the conditions are reversed; the valves, *a'''* and *a'*, are shut, and *a* and *a''* are open; from the chamber, B, is a pipe, O, which conveys the blast to the tuyeres opening into the furnace.

To prevent the fusion of the nozzles of the pipes conveying the blast, the tuyeres are made of a hollow

Fig. 293.



mass of cast-iron of a conical shape, through which flows a current of cold water. The nozzle of the pipe is connected with the main pipe by leather bands or rings.

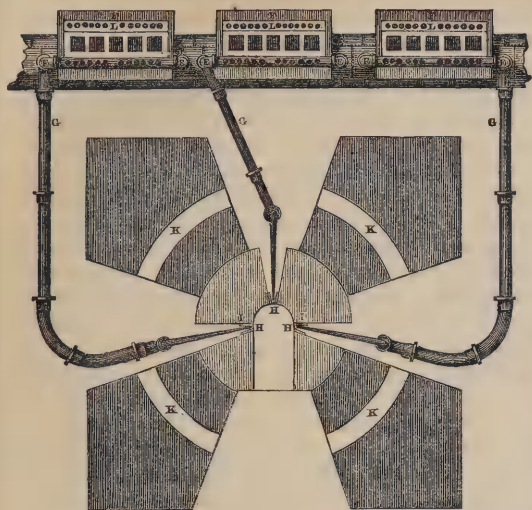
The tuyeres are generally three in number, entering the blast furnaces in three different parts. Care is taken, however, that although at the same level, they are not placed in such a position that the different currents should come into contact with each other in the furnace. The drawing—Fig. 293—will illustrate their position.

When cold-blast is applied, the air passes directly to the blast furnace; but when hot-blast is used, the air is made to circulate through pipes fitted into a large chamber furnace, by which the air is heated to several hundred degrees, and then admitted to the blast furnace. Fig. 294 will give an idea of the mode of heating the air in its passage from the blowing machine to the blast furnace.

The chamber in which the air is condensed by the blowing cylinder is large, and a considerable quantity of air is pressed into it, so that the blast entering the tuyeres is continuous. The pressure at which the air is thrown into the furnace varies, and smelters work with different pressures, according to the nature of the fuel employed and the season of the year. In summer a larger quantity is injected than in winter, owing to the air containing less oxygen in a given bulk in warm than in cold weather. The moisture of the air also affects the action of the blast—all which circumstances, even where the greatest care is taken,

are found to cause considerable variation in the working of the furnace. The special effects produced by

Fig. 294.



the nature and quality of the blast will be considered afterwards.

Having given a brief outline of the different forms of blast furnace and the blowing machine, it may be necessary further to mention in reference to the furnace, that when newly built, great care is required in bringing it to a heat. If the heat be raised too rapidly, the furnace is apt to crack and become damaged. A small fire is, therefore, kindled in the first place, and gradually increased till the whole building is quite dry, by which time the fire in the furnace will be at the height of the boshes, requiring for this several days; then small quantities of ore are mixed with the fuel, and this is continued until the first portions of the ore have sunk to near the tuyeres, when the furnace may be said to begin its work.

THE FUEL.—The fuel employed in the blast furnace is either charcoal, coke, or coal. It has been shown that the first was almost exclusively used until the second half of the last century, when the introduction of the cylinder blowing machine, along with the steam-engine, permitted pit-coal to be most advantageous. It is true that, when this change was introduced, considerable difficulties were experienced in working the rich oxide ores; they fused too easily, and passed down into the mass of melted iron before the whole of the oxide was reduced to the metallic state. Experience, therefore, taught the smelter to use these rich ores in small quantities only, mixing with them the earthy and carbonated ores; and a more judicious apportioning of the flux has latterly enabled him more completely to overcome the difficulty.

The nature and qualities of different kinds of fuel have been fully discussed in a separate article devoted to that subject, to which the reader is referred for some important information in connection with its application to the smelting of iron ores. It is of the utmost importance that the

metallurgist should have a thorough understanding of the nature and value of his fuel, otherwise he will be always liable to variations in the production of his furnace. There is first to be considered the intensity of the heat to be obtained from a given bulk of fuel. This will be modified to a certain extent by the nature of the blast and the shape of the furnace; but coals that have much volatile matter in them lose this at a low heat, before the caloric which it would supply can act upon the lime employed as flux. Such coals are considered weak for smelting. Fuel containing much ash is also proportionally weak. The quality of the ash must likewise be considered with a view to the question, whether it contains ingredients deleterious to the iron; and also, whether the coal or coke contains any impurity, such as sulphur, which, though not remaining in the ash, may yet combine injuriously with the iron.

When charcoal is the fuel, the only care of the smelter is economy, as far as consistent with the production of slags free from iron; for the ash or incombustible portion of charcoal is so small, and generally of such a character, as to be easily fused and taken up by the earths of the ore, so that there is little risk of any deterioration of the iron from this cause. Indeed the ash of charcoal is generally composed of such matters as form the best class of flux for the silica. In slags from the iron smelted with charcoal, there is generally nothing present but the pure silicate of lime, with a little potassa or other alkali, which may have been present in the ash of the charcoal. With coal and coke, however, the results are different. It will be seen from the analysis of coal, given under FUEL, that much of it contains small quantities of sulphur in the form of iron pyrites. Whether the coal be used raw or coked, the sulphur and the iron remain united, the sulphur being often amongst the last matters expelled by combustion, and only when the heat of the combustion is lower than will fuse the sulphide of iron; but, if higher, these will fuse together, and flow by their weight through the burning fuel, and, in the blast furnace, would mix with the iron; consequently, the presence of sulphur in the fuel is highly injurious, and ought to be carefully avoided. The ash of some coals being also considerable in quantity, constitutes a great proportion of the materials entering into combination in the furnace, either as scoria or with the metal. When fuel contains sulphur, or, as is often the case, the ore contains small portions of sulphur, a large excess of lime has to be added, which, when sulphide of iron is present and brought into contact, decomposes it, forming a sulphide of calcium, which is found in the slags or scoria. Yet, notwithstanding these reactions, the iron produced from coke and coal is seldom free from a small portion of sulphur, and is inferior to that made by charcoal.

Many processes have been tried to free the coke used for smelting purposes from sulphur. Mr. CALVERT recently proposed to apply small portions of chloride of sodium to the coke in the process of manufacture, by which means the fuel was made more suitable for the iron being freed from its sulphur, and in several experiments the iron made from this prepared coke was found much superior to the ordinary quality; but the process has not yet been very

extensively adopted. Small portions of chloride of sodium have also been applied directly to the blast furnace, being injected by the blast, with results less or more favorable in different localities where tried. Carbonates of potassa and soda in small quantity, mixed with slaked lime, have also been injected into the furnace for the same object; but nothing as yet of any real practical value has been adopted to free the iron from the sulphur which may have combined with it from either the fuel or ore. It is true that its deteriorating influence is generally considered by the smelter to be greater than that of any other impurity; but this effect is probably exaggerated, as there are other impurities common to cast-iron, which are as injurious to the quality, and are present in greater proportion than the sulphur; some of these will be considered in a subsequent part of this article.

In a paper which was read by Mr. Fairbairn before the Society of Civil Engineers, the chemical action of the chloride of sodium added to the coke was thus described:—When coal was first subjected to heat in a coke oven, the bisulphide of iron contained in the coal was decomposed into sulphur, which latter was distilled or burned, and also into protosulphide of iron, which remained in the mass, and was acted upon by the chloride of sodium, as it was volatilized at a red heat; thus chloride of iron and protosulphide of sodium were produced. Then a second chemical reaction ensued: the protochloride of iron was decomposed into a subchloride of iron, and the chlorine gas, thus liberated, reacted on the sulphide of sodium, giving rise to chloride of sodium and to chloride of sulphur, which latter was disengaged—so that the prepared coke contained less sulphur than the ordinary coke; but admitting even that a small portion remained, it would be in the state of sulphide of sodium, which would not yield any of its sulphur during combustion, but passed into the cinders of the blast furnace or of the cupola, and the sulphur, thus fixed, did not enter into combination with the iron, preventing crystallization during the process of smelting, and giving greater tenacity and closeness of texture both to the cast and to the malleable iron.

THE FLUX.—It will be seen, by referring to the different qualities of the ores of iron, that mostly all of them contain small quantities of other matters; and that when these are silica and alumina, which are the most common, either separately or together, they are infusible in the blast furnace; but at a temperature below that of melting iron, they will combine with the oxides of other metals, and form with them combinations that are fusible. The oxides of iron combine readily with silica, and form a silicate of iron which is very easily fused. If, then, a mixture of iron ore and coal be put into the blast furnace, the reactions may be represented as somewhat like the following. Suppose a mixture is taken of clay and black band, composed as under:—

Oxide of iron,	80
Alumina,	13
Silica,	7

When these materials reach a temperature in the furnace sufficiently high to fuse a compound silicate of

alumina and oxide of iron, the silica and alumina present will take up the required proportion of oxide of iron, and only the remainder of the iron will be reduced as metal, the silicates forming scoria; and thus a great quantity of the iron will be lost, varying according to the quantity of silica present in the ore. By a mixture of the iron ores above-mentioned, nearly one-third of the whole iron would be lost.

The object of the smelter is to obtain all the iron that exists in the ore. In order to effect this, it is necessary to put into the furnace, along with the ore, some matter that will combine with the silica in preference to the oxide of iron, and leave the latter to be reduced by the carbon. This must be some ingredient which can be procured in abundance at little expense, that it may not materially enhance the cost of producing the iron. The substance which best fulfils these conditions is limestone. Accordingly, in the smelting of iron on the large scale, lime is the only flux used; and fortunately it is generally found in abundance along with the ore, as the lowest bed of the coal formation in this country usually rests upon limestone. Thus, not only the ore, but the flux, and even the fuel itself, the blocks of refractory stone necessary for constructing the furnace, and the clay of which the fire bricks are composed, are often all found together—a provision calculated to excite the admiration of even the most unreflecting.

When lime and silica are subjected to a high temperature they combine easily, and form a fusible compound. The proportions in which lime and silica unite are various; but the heat required for their fusion differs according to the amount of lime present. If there is but a small quantity of lime compared with the silica, it requires a much higher temperature to fuse than if the former was in greater quantity than the latter. Taking the equivalent of silica at 46, then the weights which will be required to form a protosilicate with the following bases, are—

Slaked lime,	45
Limestone,	58
Fluor spar,	39
Carbonate of magnesia,	34
Carbonate of potassa,	69
Carbonate of soda,	53
Protoxide of iron,	36
Sesquioxide of iron,	40

When alumina is combined with the silica, forming a natural clay, a much more compact and fusible compound is formed with the lime than when the silica is alone. Indeed, it has been observed as a general principle, that the point of fusion is materially affected by the relation and number of bases the whole materials contain: thus, a more liquid scoria is obtained by the addition of a limestone containing magnesia than with a pure limestone. But experience is against the use of a magnesian limestone, because it deteriorates the iron produced, while the purity of the metal is the primary consideration. That which contains much silica should also be used sparingly, as silica combines with the iron and injures its quality.

The purest limestones are the most suitable for flux. Common marble is nearly a pure carbonate of lime; but is too rare and expensive to be used as a flux.

Chalk is another very pure carbonate, and forms a most excellent flux, but is seldom used in large operations.

Oolite limestone, which derives its name from its being composed of small round grains like the roe of a fish, is another excellent and pure carbonate of lime.

Compact limestone, grey limestone, mountain limestone, *et cetera*, are very abundant, and are found of a great variety of colors, but never so white as the preceding, as they often contain carbon and oxide of iron, which are not detrimental as a flux.

There is another family of limestones termed the swinestone, and bituminous limestone; or sometimes *stinkstone* or fetid limestone, from its giving out an offensive smell when rubbed against any hard substance. This mineral is dark in the color, owing to the carbonaceous matters combined with it, and very hard; but when burned it is white, and forms an excellent pure lime and a good flux.

The following analyses of different limestones used as flux, selected from various sources, will give the reader the best idea of their variety:—

CONTINENTAL LIMESTONES.

	Calcareous spar from Andreasberg.	Coarse-grained limestone from Paris.	White granular limestone from Drehbach.	Chalk from Bougival.	Yellowish-grey limestone from near Lyon.	Shell-limestone, Muschelkalk, from Hollenhagen.
Carbonate of lime,	99.54	98.5	96.30	95.50	94.0	83.83
Carbonate of magnesia,	—	—	2.42	0.80	1.6	1.76
Protoxide of iron,	—	—	0.72	0.80	—	—
Protoxide of manganese,	—	—	0.40	—	—	—
Silica,	—	—	—	—	—	10.66
Alumina,	—	—	—	—	—	0.03
Oxide of iron,	0.36	1.5	trace.	1.70	3.9	1.73
Oxide of manganese,	—	—	—	—	—	0.06
Water,	0.10	—	1.20	1.20	—	1.93
	100.00	100.0	101.04	100.00	99.5	100.00

SUTHERLANDSHIRE.

	Assynt.
Carbonate of lime,	49.92
Carbonate of magnesia,	36.23
Oxide of iron and alumina,	4.70
Silicious matter,	7.92
Alkaline salts, .....	.20
Sulphate of lime, .....	.27
Loss, .....	.76
	100.00

STIRLINGSHIRE.

Carbonate of lime,	93.32	97.80
Carbonate of magnesia,	—	—
Sesquioxide of iron,	2.79	0.63
Carbonaceous matter,	0.28	0.64
Silica and alumina,	1.36	1.92
Loss,	2.25	—
	100.00	100.99

ARGYLSHIRE.

	Ardour.		Contyre.	Ban.
Carbonate of lime,	90.14	89.15	98.05	90.96
Carbonate of magnesia,	0.31	2.56	0.44	0.62
Alumina and oxide of iron,	0.51	0.51	0.29	1.81
Silicious matter,	9.08	7.48	1.27	6.40
Loss,	—	0.30	—	0.21
	100.04	100.00	100.05	100.00

INVERNESS-SHIRE.

	Beaulay.	
Carbonate of lime,	93.82	94.10
Carbonate of magnesia,	1.64	1.00
Alumina and oxide of iron,	0.99	2.16
Silicious matter,	3.55	2.74
	100.00	100.00

NORFOLKSHIRE.

Carbonate of lime,	62.95	81.55	69.90	47.90	88.40
Carbonate of magnesia,	—	trace.	5.85	—	—
Oxide of iron and alumina,	7.40	4.65	6.45	trace.	4.55
Clay,	29.35	14.15	17.45	8.22	5.25
Loss, .....	.30	—	.35	3.88	1.80
	100.00	100.35	100.00	100.00	100.00

NORTHUMBERLANDSHIRE.

	Hastington.	Kirkheaton.	Belsay.	Allerwash.	Dryburn.	Oxford.
Carbonate of lime,	97.5	93.1	95.6	98.39	99.	96.2
Carbonate of magnesia, .....	.6	4.4	1.4	—	—	—
Silica,	1.3	2.2	3.0	2.40	1.	3.6
Loss, .....	.6	.3	—	—	—	.2
	100.0	100.0	100.0	100.79	100.	100.0

CUMBERLANDSHIRE.

	Cockermouth.	Brampton.	Kelhead.
Carbonate of lime,	94.86	94.56	95.95
Carbonate of magnesia,	1.26	2.32	0.54
Sulphate of lime,	0.23	0.32	0.24
Phosphate of lime,	—	0.33	—
Alumina and oxide of iron,	0.73	1.18	1.21
Silica,	2.92	1.29	2.06
	100.00	100.00	100.00

Many of the preceding analyses indicate small quantities of magnesia, which, when only a small percentage is present, may be used freely; but where it exceeds six per cent., it is better not to employ such limestones if others can be obtained; for although fluxing more easily than pure lime, they are considered to deteriorate the iron. The following are a few analyses of what are termed the magnesian limestone

which, for reasons already stated, ought to be avoided as a flux:—

	English.	Scotch.	Foreign.
Carbonate of lime,	54.50	53.09	55.36
Carbonate of magnesia, ..	44.93	43.49	41.30
Oxide of iron,	0.33	0.96	2.00
Silica,	0.24	2.46	0.50
Loss,	—	—	0.84
	100.00	100.00	100.00

Limestone also often contains much more silica than is shown in any of the above analyses; this is likewise a deleterious matter, as it combines with the iron and makes it very weak; consequently, limestone should all be tested previous to using it as a flux, which may be done easily. Good limestone should effervesce with great violence when put into dilute hydrochloric acid; magnesian limestone produces less effervescence. The best method of testing is to take twenty-five grains of the limestone ground and dried, and digest in a small glass flask with dilute hydrochloric acid till all effervescence ceases; the solution is then filtered, and that which remains upon the filter may be regarded as silica; this is to be dried and weighed. To the filtered solution add ammonia to neutralize the acid; this will precipitate the iron and any alumina in solution, but when these are in minute quantity the solution need not be filtered, as the presence of iron is as useful as lime. In this case, add, immediately after the ammonia, oxalate of ammonia, so long as a precipitate is formed; warm the solution, and after about thirty minutes, filter and wash; this when dried and burned at a red heat, gives the quantity of carbonate of lime. To the filtrate add a solution of phosphate of soda, which precipitates the magnesia, if any be present, as phosphate. This, after being filtered, dried, and burned, contains in every one hundred parts, 36.5 magnesia, equal to 76.7 of carbonate of magnesia—the condition in which it exists in the mineral. Thus the quality of the lime for fluxing can be easily ascertained; of course, as only twenty-five grains are used in this test, the results must be multiplied by four to get the per-centage.

Proportions of the Charge.—It has been stated that, in the assaying process, the iron is reduced from its ore by putting the mixed materials into a crucible, which is placed in the centre of the fire, so that the heat is applied to it externally. A blast furnace differs from a crucible, in so far as not only the ore and flux, but likewise the whole of the fuel, is thrown into it. For this purpose, men are constantly employed in wheeling the materials to the furnace in barrows made of sheet-iron, which are raised up by machinery to the platform round the mouth of the furnace, and their contents discharged into it, care being taken to keep the furnace full. Where the ore is a mixture of clay and black-band with coal as fuel, the charge is generally about the following proportions:—

	Hundredweights.
Calced black-band,	4.5
Calced clay-band,	4.5
Limestone,	1.5 to 2.0
Coal,	10.0

These are all mixed roughly and put into the barrows. Sometimes the very large pieces of coal are broken

into smaller ones; some smelters also break the limestone into small pieces of the size used for macadamizing roads; others think this unnecessary, from the fact that the limestone, when put into the furnace, very soon flies to pieces by the heat, and thus saves the labor of breaking by hand. Dr. URE gives the following as the practice in Staffordshire:—As soon as the furnace gets into a regular heat, the working consists simply in charging it at the opening in the throat whenever there is a sufficient empty space, the only rule being to keep the furnace sufficiently full. The coke is measured in a basket, thirteen of which go to the ton. In twenty-four hours there are thrown into a furnace, such as Fig. 280, fourteen and a half tons of coke, sixteen tons of roasted ore, and six and three-quarter tons of limestone, from which about seven tons of pig-iron are produced. But the exact proportions of the materials put into the blast furnace differ in every locality, and with every change of ore or coal.

Reactions in the Furnace.—The changes produced in the materials put into the furnace in their descent from the mouth to the hearth, where they are separated as iron and scoria, must be, to a certain extent, matter of speculation. It has been shown that the ores contain oxide of iron and silica, mixed with clay. A portion of these substances is often in a state of combination produced by the roasting operation. The lime is put in as a carbonate, which will not combine with the silica until the carbonic acid in union with the lime be driven off, and this does not take place till the limestone has descended to a considerable depth to experience the requisite heat. When lime and silica and oxide of iron are together, their combination depends upon the temperature to which they are exposed. The probability is, that the silicate of iron is the first compound formed, as it melts at a comparatively low degree of heat, and then in a melted state it trickles down, until it comes to a temperature sufficiently high to allow a simultaneous reaction of all the materials. From the results of analyses of cast-iron, it appears that a considerable portion of silicate of iron passes through the furnace without being decomposed, and mixes with the iron, rendering the metal impure. The scoria floats upon the surface of the metal, and as it accumulates, the furnace-man allows it to flow out by a hole in the side of the furnace, into large beds, where it is broken up for removal; or it is cast into large blocks and employed for building walls or any rough purpose. Every twelve hours the furnace is *tapped*; that is, the metal is let out into sand moulds of various shapes, but generally of a long semi-circular form, known technically as pigs.—See Fig. 279.

The whole process of the action of the furnace is given by TRURAN as follows:—

The changes which occur in the descending ore commence with the uncalcined ores in the throat of the furnace; they lose their moisture and volatile gases before they reach the level of the boshes, absorbing from the fuel the necessary caloric for calcination. Below this the ore is gradually converted from a sesquioxide to a magnetic oxide, or, as sometimes occurs, into metallic iron; having combined with a portion of the carbon from the fuel, to form the fusible carbide of

iron. From the bottom of the boshes to the level of the tuyeres, the reduction of the ore and flux into a liquid mass is completed. The fusion of the ore and flux occurs at a height of eight or ten inches above the tuyere, from whence it descends into the hearth. Here the metal, from its greater specific gravity, falls to the bottom, freed more or less from the fluid cinder which floats on the surface, and protects it from the oxidising influence of the blast.

Gases Evolved.—The gases passing through and escaping from the blast furnace have been the subject of several investigations by the most eminent chemists. They were obtained by inserting into the furnace the end of a wrought-iron pipe through which the gases escaped, and were conducted by a leaden tube attached to the external extremity of the iron pipe into a pneumatic apparatus, where they were subjected to analysis.

The following are the results obtained by BUNSEN of Heidelberg, the fuel used being charcoal; the proportion of the gases is given in volume:—

Height above tuyeres, Feet.	Nitrogen.	Carbonic acid.	Carbonic oxide.	Light carbide of hydrogen.	Hydrogen.
17 $\frac{1}{2}$	62.34	8.77	24.20	3.36	1.33
16 $\frac{1}{2}$	62.25	11.14	22.24	3.10	1.27
14 $\frac{1}{2}$	66.29	3.22	25.77	4.04	1.58
13 $\frac{1}{2}$	62.47	3.44	30.08	2.24	1.77
11 $\frac{1}{2}$	63.89	3.60	29.27	1.07	2.17
8 $\frac{1}{2}$	61.45	7.57	26.99	3.84	0.15
5 $\frac{1}{2}$	64.58	5.97	26.51	1.88	1.06

Subjoined are the results of a similar experiment at Alfreton by Messrs. PLAYFAIR and BUNSEN. In this table the measurement is taken from the mouth or top of the furnace downward, extending to a depth of between one and two feet above the tuyeres:—

Feet from top	Nitrogen.	Carbonic acid.	Carbonic oxide.	Carbide of hydrogen.	Hydrogen.	Olefiant gas.	Cyanogen.
5	53.35	7.77	25.97	3.75	6.73	0.43	—
8	54.77	9.42	20.24	8.23	6.49	0.85	—
11	52.57	9.41	23.16	4.57	9.33	0.95	—
14	50.95	9.10	19.32	6.64	12.42	1.57	—
17	55.49	12.43	18.77	4.31	7.62	1.38	trace.
20	60.46	10.83	19.43	4.40	4.83	—	—
23	58.28	8.19	29.97	1.64	4.92	—	trace.
24	56.75	10.08	25.19	2.33	5.65	—	trace.
34	58.05	0.00	37.43	—	3.18	—	1.34

The annexed table exhibits the relative proportion of oxygen and nitrogen at the different depths stated:

Feet.	Oxygen.	Nitrogen.
5	24.9	79.2
8	23.6	79.2
11	24.6	79.2
14	19.5	79.2
17	25.7	79.2
20	23.7	79.2
23	28.2	79.2
24	27.7	79.2
34	27.8	79.2

OVERMANN tabulates as follows the per centage of the different gases given off from a coke furnace:—

Above the tuyeres.	Nitrogen.	Carbonic acid.	Carbonic oxide.	Hydrogen.	Total.
2 ..	61.07	0.68	36.84	1.41	100.00
17 $\frac{1}{2}$..	64.66	0.57	33.39	1.38	100.00
28 ..	63.59	2.77	31.83	1.81	100.00
31 ..	60.70	11.58	25.24	2.48	100.00

The subjoined results are those obtained by Dr. SCHAFFHAUTL from the Ystalyfera anthracite furnaces:—

	Taken off one foot below the coal and ore in the furnace.	Taken off sixteen feet below the surface of the coal and ore in furnace.
Carbonic acid.....	9.546	00.136
Carbonic oxide.....	12.012	18.974
Hydrogen.....	21.278	27.834
Light carbide of hydrogen,...	2.548	3.212
Sulphurous acid, with traces of arsenide and phosphide of hydrogen,.....	0.111	trace.
Nitrogen.....	54.505	49.844
	100.000	100.000

In BUNSEN's and PLAYFAIR's elaborate report to the British Association for 1845, upon the theory
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of the blast furnace deduced from the examination of the gases, they conclude that the evolution of carbonic acid is owing to the reduction of the ore; and that the process of reduction takes place only in the boshes. The average proportion of the mixed gases must be somewhere between the following numbers:—

Nitrogen,.....	60.907	57.878
Carbonic acid,.....	8.370	9.823
Carbonic oxide,.....	26.846	24.042
Light carbide of hydrogen,....	2.536	2.743
Hydrogen,.....	1.126	4.972
Olefiant gas,.....	0.112	0.392
Sulphide of hydrogen,.....	0.045	0.035
Ammonia,.....	0.058	0.115
	100.000	100.000

This mixture of gases contains:—

First. The products of distillation of the coal.

Second. The products of its combustion.

Third. The carbonic acid generated during the reduction of the ore, and expelled from the limestone.

WASTE PRODUCTS.—*Cyanogen.*—Another object of inquiry into the gaseous products of the blast furnace, besides the chemical reactions going on within, was to find if there could be any application of the products, and of the great quantity of heat given out at the mouth of the furnace. It will be observed in the analyses of the gases from the Alfreton furnace by Messrs. BUNSEN and PLAYFAIR, that cyanogen was detected at the lower portion of the furnace. They found in their experiments that when they withdrew the iron tube from this part of the furnace, it was incrustated with melted cyanide of potassium, which speedily deliquesced in the air. This led to inquiry as to the source of the potassium; and by very careful analyses of the ore and coal, these were found

to contain small portions of alkali. The calcined ore gave—

Sesquioxide of iron,.....	60.242
Silica,.....	25.775
Alumina,.....	6.583
Lime,.....	3.510
Magnesia,.....	3.188
Potassa,.....	.743
Manganese,.....	traces.
	100.000

And the coal—

Carbon,.....	74.98
Hydrogen,.....	4.73
Oxygen,.....	10.01
Nitrogen,.....	0.18
Water,.....	7.49
Silicates,.....	2.61
Potassa,.....	0.07
	100.00

The presence of potassa is likewise shown in the table of the analyses of the North and North Midland ores given at page 410.

The formation of cyanogen gas by the direct combination of the nitrogen of the air with carbon at a high heat had been, previously to these experiments, pointed out by Dr. FOWNES and Mr. JAMES YOUNG. The production of cyanide of potassium in the blast furnace, and the value of it as a product, were then calculated. The mixed gases, as already seen, possessed the following composition:—

Nitrogen,.....	58.05
Carbonic oxide,.....	37.43
Hydrogen,.....	3.18
Cyanogen,.....	1.34
	100.00

Every 219.33 cubic inches of gas must contain 1192.97 grains of carbon, corresponding to 1774.79 grains of coal. Hence, out of 100 parts of coal, at least 0.778 of cyanide of potassium is generated; and as 31,200 pounds of coal are consumed every twenty-four hours in the furnace, it is obvious that at least 224.7 pounds of cyanide of potassium are generated daily in the Alfreton furnace, and hitherto have been altogether lost.

Ammonia.—Another product obtained from the furnaces is ammonia. This substance, which is present in the gases of blast furnaces fed with coal, but never found in those furnaces fed with charcoal, is often in such abundance as to be sensible to the smell in the gases collected from the deeper parts of the furnace. BUNSEN and PLAYFAIR remark that the ammonia may be obtained in the form of chloride of ammonium, if the gas, previous to its application as fuel, be conducted through a chamber containing hydrochloric acid. The advantage of its collection is, that without any further consumption of fuel, or any considerable expenditure of labor, a valuable commercial ingredient would be economized. The furnace coal of Alfreton was subjected to trials to ascertain the quantity of ammonia which might be produced by distillation, and the mean results gave 0.769 per cent.; and hence, the conclusions drawn were, that as two hundred and eighty hundredweight of coal were consumed in the

furnace every twenty-four hours, not less than two hundredweight of sal-ammoniac might be obtained as a subsidiary product, without increasing the cost of manufacture, or in the slightest degree disturbing the process of smelting.

Application of the Waste Heat.—The great value of the investigation into the gases evolved from blast furnaces, was the economizing of the fuel, and the experiments proved the combustibility of the entire column of gas, from a depth of twenty-four feet to the mouth of the furnace; hence the gas collected at any point to this depth is capable of being applied as fuel. It was found that at the Alfreton furnaces there was at least 81.54 per cent. of valuable fuel lost; and, as about fourteen tons of coal were used every twenty-four hours, it followed that 11.4 tons of coal were lost, by escaping at the mouth of the furnace in the form of gas capable of being used as excellent fuel. It was also proved, that by the combustion of these gases, a temperature could be obtained equal to what would melt iron.

After the application of the hot-blast to the furnace, several manufacturers tried to heat the air or blast by the waste heat of the furnace; adopting several methods of causing the air of the blast to pass through pipes ranged around the trunnel head, or coiled round the interior of the furnace so as to be heated by the ignited materials themselves, or built into the masonry so as to receive heat by transmission: these plans were, after various trials, abandoned. Other expedients were adopted, such as covering the top of the blast furnace, except during charging, and carrying the gases to a reservoir or gasometer, from which they were pumped into a gas furnace for heating the blast; but from several practical difficulties these plans also were abandoned.

In 1848 Mr. PALMER BUDD adopted a more successful mode of applying the waste heat of the blast furnace; part of his success lay in not making his apparatus a portion of the furnace, nor burning the gases; hence the operations did not interfere in any way with those of the blast furnace. Three or four horizontal flues, of about twelve inches diameter, are constructed about three feet below the top of the furnace, and lead into an adjoining chamber or stove provided with a stalk, which creates the draught. Into this stove he draws as much of the gaseous escape as he requires, the supply being regulated by means of a damper. The quantity required to heat the blast for a furnace, he considers to be only about one-sixth of that which passes off from the trunnel head. He does not burn the gases, but allows them to pass hot through the stove or furnace for heating the blast; they enter at a temperature of about 1800° Fahr., and leave it at a temperature of about 800°, the heat required for the blast being about 600°; and thus the mere passage of these heated gases through the stove serves his purpose.

Mr. BUDD says that his plan has several great advantages; it requires no coal or labor, the blast is better and more regularly heated, and the apparatus more durable. Besides the heating of the blast, the same ingenious manufacturer applied these heated gases to his steam-boilers, and states that the saving effected by

the application to one boiler was equal to three hundred and fifty pounds sterling per year, and the total saving in his works by doing away with the use of coal in all the boilers, fire-bars, *et cetera*, would at full worth exceed two thousand pounds sterling *per annum*.

Notwithstanding these practical results, the improvements recommended have not been generally adopted. TRURAN, while acknowledging that the gases escaping from certain blast furnaces, may, with proper management, be made to yield eighty-two per cent. of the caloric evolved during the imperfect combustion of the fuel, dissents from the generally-received opinion, that a sufficiently intense heat can be maintained by their combustion for the purposes of the forge, or for the rapid generation of steam. Although the actual heat evolved be ample for generating steam and for heating the blast, still, owing to its dissemination through such a large volume of gas, the quantity of heat in contact with the plate-iron is small, and the evaporating power is much slower than with coal fires.

At three several experiments made at the Dowlais Works, the temperature obtained rarely went above a dull red heat, and the evaporating power of the boiler, as compared with a coal fire, was reduced nearly two-thirds. At the Ebbu Vale, Aberychan, Sirhowy, Aberdare, Ystalyfera, and other establishments using the gas, the number of boilers now in use is nearly twice as many as formerly sufficed with coal fires only.

After a careful examination of the various modes of collecting the gases adopted in this country and on the Continent, and having witnessed the alterations produced on the operations of the blast furnace by each, TRURAN gives it as his opinion that it is neither expedient nor profitable to control the escape of the gases; and that where the consumption of coal is proportioned to the requirements of the case, not one particle of gas, or one unit of heat, can be withdrawn from a furnace, without disturbing the equilibrium of the smelting. This opinion is at variance with the statements of Continental chemists, but it must be remembered that their estimates of the commercial value of the products of combustion have invariably been drawn from theoretical calculations, and are based on the assumption that they may be withdrawn in quantity without affecting the smelting. But the fact of their withdrawal occasioning an alteration in the economy of the furnace, has been established in practice; and, on the whole, the brilliant anticipations formed of the value of these gases for heating purposes have not been realized. The obtaining of the iron being the primary object in all the operations of the blast furnace, whatever improvements or alterations are made must in no way interfere with either the quality or quantity of the metal produced, and every alteration affecting this must be adopted with great caution. At the same time, the practical observations above-mentioned are of the highest importance, and should stimulate to further inquiry.

STATE OF THE BLAST.—In connection with the gases evolved in the working of the blast furnace, this may be the proper place to consider the state of the blast as it is allowed to enter into the furnace. It has been seen from the analyses of the gases passing through

the furnace, that, however great the quantity of air admitted, it was all consumed, no oxygen passing through uncombined; but it has likewise been shown that it is not all profitably consumed, which is a desideratum. There is a general opinion amongst practical men, that the furnace works best and produces the largest casts, and frequently the best iron, in dry frosty weather, and the opposite when the weather is warm and moist. The irregularity of the working of the furnace from these supposed causes, led Mr. JOHN HART, a few years ago, to institute a series of experiments upon this subject. He ascribes some of the irregularities to differences in the atmospheric pressure; thus the range of the barometer in this country being about three inches, or rather more than one-tenth of the mean pressure, this change of density would produce a difference of one-tenth in the bulk of the air; and, therefore, between a severe frost with the thermometer at 20°, and sultry weather with the thermometer at 70°, the difference would be 50°; and as atmospheric air dilates or contracts one four hundred and eighty-fifth part for every degree, this difference in temperature would produce a variation of rather more than one-tenth in the mass or bulk of the air; so that, if during severe frost the barometer stood at thirty-one inches, while during sultry weather it stood at twenty-eight inches, the combined effects of the difference in temperature and pressure would amount to a total variation of one-fifth in the bulk of the blast, which would be nearly equivalent to a careless furnaceman putting into his furnace ninety pounds of coal instead of one hundred, during a whole casting. Indeed, the difference from temperature and pressure amounts to something like an irregular charging of the furnace with ninety pounds up to one hundred and twelve pounds indiscriminately, instead of one hundred pounds regularly.

There is still another source of irregularity, occasioned also by the barometric changes in the density of the air, when the power employed is the double-stroke condensing steam-engine having neither fly-wheel nor governor to regulate its speed, and whose motion is only contracted by the resistance of the blast. As the fireman keeps up his steam to the regular pressure indicated by the steam gauge, without any reference to the pressure of the air, whether it can support twenty-eight or thirty-one inches of mercury; and as the steam must always displace the atmosphere, to make room for itself: therefore the difference of pressure upon the steam-loaded piston descending into a vacuum, will be one-tenth greater when the mercury is at thirty-one than at twenty-eight inches; hence, if a blowing engine works to forty horse-power, when the barometer is at twenty-eight inches, it will work equal to a forty-four horse-power when the mercury is at thirty-one inches, and of course it will perform an additional number of strokes. However, these atmospheric changes being comparatively slow, will affect the quantity more than the quality of the iron.—*Hart*.

These observations of Mr. HART are certainly worthy of attention; the impression of the effect of moisture in the air is still as firmly held as ever. Taking the average of five years, selected at intervals

of the same period, for twenty-two years' working, the following quantities of coal were consumed for every ton of crude iron produced :—

	Winter. Cwt.	Spring. Cwt.	Summer. Cwt.	Autumn. Cwt.
Foundry iron furnace,....	49·7	52·2	53·1	55·4
Forge iron furnace,.....	43·6	44·2	44·6	45·8
Blast iron furnace,	43·2	44·1	50·1	49·5

In the first or foundry furnace, the excess of autumn over winter months is eleven per cent.; in the forge furnace equal to five per cent., and in the blast fifteen per cent.

How useful would a series of meteorological observations have been in connection with these results !

Advantages of the Hot-Blast.—The great practical discovery in connection with the blast furnace, and one which has formed an era in the iron trade, is the introduction of the *hot-blast*, which is now all but universally used by the iron smelters in this and other countries. The advantages of hot-blast are, an increased make of iron, and great economy in the consumpt of fuel. These advantages, however, are not equal in all localities, nor with all classes of ore and coals; in general, greater benefit has been experienced in Scotch than in English furnaces, either owing to the former having been working less economically than the latter, previous to the introduction of the hot-blast—thus making the saving appear greater; or else the fuel used in Scotch furnaces being in general weaker than the English, the hot-blast has consequently effected much greater comparative advantages. So early as July, 1833, a comparison of the product of the blast furnaces in the neighborhood of Glasgow, before and after the introduction of the hot-blast, gave the following results :—

By cold-blast—

	Tons.	Cwt.	Lbs.
Consumed for each ton of iron, three tons coke, equal to,	6	13	0
For the blowing engine,	1	0	7
	7	13	7

using ten and a half hundredweight of limestone.

By hot-blast—

	Tons.	Cwt.	Lbs.
Consumed for each ton of iron, raw coal,	2	0	0
For heating the air,	0	8	0
For blowing engine,	0	11	2
	2	19	2

using seven hundredweight of limestone.

The economy in fuel is proportional to the temperature of the air admitted into the furnace. This saving of fuel was accompanied by an increased make of iron of upwards of one-third, which adds materially to the advantage of using hot air.

How these effects are produced, is a question which

has not yet been answered to the general satisfaction of scientific men. The opinion of the chemist may be stated thus :—Wherever a forced stream of air is employed for combustion, the resulting temperature must evidently be impaired by the coldness of the air injected upon the fuel. There is nearly equal temperature over the whole extent of a fire-place; so that if the air and coal be very cold, the portions of heat absorbed by them might be very considerable, and sufficient to prevent the resulting temperature from rising to a proper pitch; but if they were very hot, they would absorb less caloric, and would leave more to elevate the general temperature. This excess of temperature may produce in metallurgical operations, a *play of affinities dormant at lower degrees of heat*; often a few degrees is all that is required to modify the state of a fusible body.

THE SLAGS.—Having entered at considerable length upon the gaseous products, the state of the blast, and the theory of the action, both mechanical and chemical, that takes place within the furnace, it will now be necessary to advert to the fluid or solid products; namely, the slag or scoria, and the metal. The intrinsic value of the former is nothing to the ironmaster; the great end of all the operations is the iron; but the appearance and quality of the slag is an index to the working condition of the furnace, and the quality of the iron. The furnace-manager must therefore keep a watchful eye on the state of his slags, when withdrawn from time to time. If the furnace is yielding an iron proper for casting into moulds, the slags have a uniform vitrification, and are slightly translucent. If the quantity of ore be too much in proportion to the other matters—an excess which is sometimes intentionally introduced, in order to produce a grey pig-iron fit for fabrication into bars—the slag is opaque, dull, and of a greenish-yellow tint, with blue enamelled zones. When the furnace is producing a white metal, which is an inferior quality, the slags are black, glassy, full of bubbles, and emit an odor of sulphide of hydrogen. Such are the three leading characteristics of the quality of the slags; but practice can detect the slightest tendency towards any of these conditions, so that much depends upon a careful furnace-manager.

The quality of the slag becomes, therefore, an important consideration to the smelter, as anything that will affect the obtaining of a good slag, any want of material in its composition, will affect the quality and quantity of the iron; nevertheless, the principle of good slags does not appear to depend so much on any particular composition, as on the obtaining of a slag that is perfectly fusible, and capable of taking up from the ore all the earthy matters. The appended analyses will show this :—

	I.	II.	III.	IV.	V.
Silica,	43·75	38·12	40·4	36·6	55·48
Alumina,	12·50	16·97	11·2	37·5	19·32
Lime,	31·22	32·77	38·4	20·7	14·57
Magnesia,	17·15	6·22	5·2	1·5	2·54
Protoxide of manganese and iron,	4·88	5·92	3·8	1·0	4·36
Sulphur,	—	—	—	2·7	2·43
Loss,	·50	—	1·0	—	1·30
	100·00	100·00	100·00	100·00	100·00

The first three are good slag, giving good iron; the fourth was not considered so by the workman, and led to a change in the proportion of materials, producing a white iron; the fifth is a bad slag, both in color and structure, yielding an inferior quality of iron of

the following composition:—Iron, 88·9; carbon, 3·0 silicious matters, 7·4; sulphur, ·7. The subjoined table of analyses of slags from the blast furnace, is from the report made upon that subject to the British Association by Drs. PERCY and HENRY:—

Silica,	38·05	38·76	37·63	37·91	39·52	28·32	45·59	52·31
Alumina,	14·11	14·48	12·78	13·01	15·11	24·24	11·88	5·12
Lime,	35·70	35·68	33·46	31·43	32·52	40·12	38·20	30·71
Magnesia,	7·61	6·84	6·64	7·24	3·49	2·79	—	9·50
Manganese,	·40	0·23	2·64	2·79	2·89	0·07	0·91	1·41
Protoxide of iron,	1·27	1·18	3·91	0·93	2·02	0·27	1·11	0·95
Potassa,	1·85	1·11	1·92	2·60	1·06	0·64	—	—
Sulphide of calcium, ..	·82	·98	·68	3·65	2·15	3·64	1·76	—
Loss, <i>et cetera</i> ,	·19	·74	·34	·44	1·24	0·09	0·55	—
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

Phosphorus, which is a common ingredient in iron ores, and is considered to be very prejudicial to the metal produced, has been carefully sought for in the slags, and various means have been tried of causing it to combine with these in preference to the metal. Ores containing phosphorus, which may be distinguished as Nos. 1 and 2, were smelted with hot and cold blast, and the iron and slag tested for phosphorus gave the following results:—

By hot-blast the iron, No. 1, contained 0·74; No. 2, only 0·68 per cent. phosphorus, and the slag only a trace. By cold-blast the iron, No. 1, contained 0·81; No. 2, only 0·62 phosphorus, and the slag only a trace. The conclusions derived from a series of experiments were, that ordinary iron, such as the bands and hematites, whether smelted by hot or cold blast, will give the phosphorus in the iron with grey pig-iron; but if white iron is produced, and the slag contain protoxide of iron, some of the phosphorus may go away in the slag. For example, samples of slag from white iron made from pisolitic ores, gave—

Silica,	41·11	37·84
Alumina,	13·45	13·20
Lime,	29·82	20·68
Protoxide of iron,	6·44	20·83
Magnesia,	4·75	2·93
Protoxide of manganese, ..	0·66	0·80
Alkalis,	1·84	1·08
Phosphoric acid,	0·15	1·77
Sulphide of calcium,	1·34	0·87
Loss,	0·44	0·05
	100·00	100·00

This slag was considered bad by the workmen.

Various patents have been taken for the application of slags to useful purposes, especially to building. The difficulty in the annealing and in producing a com-

pound from these slags not capable of being affected by the air, combined with the cheapness of the articles for which it is to be used as a substitute, will operate greatly against the profitable and general application of such substances; still, the Editor would not wish to discourage the prosecution of any scheme for utilizing waste products of manufacture, as he considers this subject too much overlooked by manufacturers generally.

THE METAL.—The next and most important product of the blast furnace is the iron. It has been seen that this, unlike other metals, which must be pure before they can be available for useful purposes, is practically valuable in various states of impurity, or, perhaps it may be better to say, in various states of combination. Pure iron is tough, malleable, and ductile; is softened into a sort of clayey or pasty consistence by intense heat, but is not melted. In combination with carbon, it assumes various degrees of hardness, tenacity, *et cetera*, according to the quantity of that element in combination with it; but besides the carbon, there are also other impurities affecting the quality of the iron, as silica, phosphorus, manganese, and other matters found in the ore, fuel, and flux. According to the appearance it presents in fracture, it is divided into different qualities, as under:—

- No. 1.—Grey or black and soft—best quality of cast-iron.
- No. 2.—Mottled—a mixture of No. 1 with No. 3.
- No. 3.—White—an inferior iron for certain purposes.
- No. 4.—Silver iron—a still inferior quality.

From the mere analysis of cast-iron, it is very difficult, if not impossible, to discriminate the line where grey ceases and white begins, *et cetera*. The subjoined are a few of the results obtained by analyses, showing the effect of different kinds of fuel:—

IRON SMELTED WITH CHARCOAL.

Iron,	96·77	96·2	96·8	96·0	95·3	95·9	96·0
Carbon,	2·95	3·5	3·1	3·6	4·2	3·6	3·5
Silica,	0·28	0·3	0·1	0·4	0·5	0·5	0·5
	100·00	100·0	100·0	100·0	100·0	100·00	100·0

IRON SMELTED WITH COKE.

Iron,	92·5	92·2	94·2	95·3	97·8	98·8
Carbon,	3·0	4·3	2·3	2·2	1·7	1·0
Silica,	4·5	3·5	3·5	2·5	·5	·2
	100·0	100·0	100·0	100·0	100·0	100·0

The preceding analyses were mostly made on the Continent in different localities.

GREY PIG-IRON SMELTED IN WALES WITH COKE.

Iron,.....	95.15	95.81	94.84
Carbon,.....	2.45	2.55	1.67
Silica,.....	1.62	1.20	3.00
Phosphorus,.....	.78	.44	.49
Manganese,.....	trace.	trace.	trace.
	100.00	100.00	100.00

IRON SMELTED WITH COAL—SCOTLAND.

Iron,.....	93.6	93.4	92.3	89.7	91.6	94.2
Carbon free,.....	1.4	.5	1.8	2.5	1.5	1.6
Carbon combined,..	1.2	1.9	.4	.7	.3	.5
Silica,.....	1.5	1.2	2.8	2.2	1.8	1.1
Sulphur,.....	.4	1.4	1.4	—	.6	—
Phosphorus,.....	.4	1.2	1.3	—	.9	—
Manganese,.....	.5	.4	—	2.8	2.6	1.5
Slag,.....	1.0	—	—	2.1	.6	1.1
Loss,.....	—	—	—	—	.1	—
	100.0	100.0	100.0	100.0	100.0	100.0

The introduction and extension of the hot-blast led to a good deal of valuable investigation, both as to the chemical and mechanical qualities of the iron so produced; and the subject is yet far from being exhausted. The chemical question has been, whether that produced by the hot or by the cold blast is the purest, and what impurity prevails? The following analyses of the two products—cold and hot blast—will give a general view of the result with certain kinds of ore. The experiments were made at the Hartz:—

	Cold-blast.		Hot-blast.	
	Specific gravity, 7.43.	Specific gravity, 7.08.	Specific gravity, 7.100.	Specific gravity, 7.077.
Iron,.....	93.29	93.66	91.42	91.98
Carbon combined,..	2.78	0.48	1.44	0.95
Carbon free,.....	1.99	3.85	2.71	3.48
Phosphorus,.....	1.23	1.22	1.22	1.68
Sulphur,.....	trace	trace	trace	trace
Lime,.....	trace	—	—	—
Silica,.....	0.71	0.79	3.21	1.99
Manganese,.....	trace	trace	trace	trace
	100.00	100.00	100.00	100.00

From these analyses it appears that the hot-blast iron has more silica than the cold-blast.

The annexed analyses, however, made by Dr. THOMSON and Mr. J. TENNANT, prove that the question must be further studied in relation to many circumstances not yet taken into consideration:—

	Cold-blast. Specific gravity 6.70.	Hot-blast. Specific gravity 7.06.
Iron,.....	91.95	95.58
Manganese,.....	2.03	.83
Carbon,.....	3.85	2.09
Silica,.....	1.17	1.08
Alumina,.....	1.65	.42
Loss,.....	.15	—
	100.00	100.00

The mechanical constitution of the two products does not come so directly under the consideration of the chemist. The Editor will, therefore, merely give the results of some experiments which were laid before the British Association a few years ago. In the following table, the second column shows the force in pounds necessary to crush a cylinder, the transverse section of which is a square inch; the third column gives the force in pounds, which is required to tear asunder the same cylinder; and the ratios of these forces are shown in the fourth column:—

Description of metal.		Compressive force per square inch in pounds.	Tensile force per square inch in pounds.	Ratio
Devon iron,	No. 3—hot-blast,.....	145,435	21,907	6.638 to 1
Buffery iron,	No. 1—hot-blast,.....	86,397	13,434	6.431 to 1
“	No. 1—cold-blast,.....	93,385	17,466	5.346 to 1
Coed Talon iron,	No. 2—hot-blast,.....	82,734	16,676	4.961 to 1
“	No. 2—cold-blast,.....	81,770	18,955	4.337 to 1
Carron iron,	No. 2—hot-blast,.....	108,510	13,505	8.037 to 1
“	No. 2—cold-blast,.....	108,375	16,684	6.376 to 1
“	No. 3—hot-blast,.....	133,440	17,755	7.515 to 1
“	No. 3—cold blast,.....	115,442	14,200	8.129 to 1

From this table it appears that the resistance of cast-iron to rupture by extension varies from six to nine tons upon the square inch; while its resistance to compression varies from thirty-six to sixty-five tons. It further appears that the absolute strength of some kinds of iron, both as regards their tenacity and their power of resisting compression, is considerably increased by the hot-blast.

Owing to the very infusibility of pure iron, it would be impossible to obtain it in large quantities, were it not for what may be termed its impurities, especially

its combination with carbon. In this form it is easily fused, and, by processes afterwards to be described, the pure or malleable iron may be separated from the carbon which has served the purpose of extracting it from the ore and oxygen.

FOUNDING.—A great quantity of the iron produced by the blast furnaces is used in the state of cast-iron for a variety of purposes in the arts and manufactures. The qualities employed for this purpose are termed foundry-iron, and include the grey and mottled pig-iron, these kinds being more easily fused than the

white, which is known as forge-iron. The founder divides cast-iron into five classes:—

No. 1 is the best grey; it possesses the greatest quantity of carbon, and melts at a lower degree of heat than any of the others; it sets with a smooth surface, is soft, and has little sound when struck by the hammer.

No. 2 is lighter in the color than number one; not so soft nor so fluid when melted, nor so smooth on the surface when solidified; it is closer in the texture, and is preferable for strong parts of machinery.

No. 3 has less carbon than the other two, and is still less fluid when melted; has smaller grains, and is smoother in the fracture. This is used for very strong machinery where it is subjected to sudden and great strains, such as heavy shafts, wheels, *et cetera*.

No. 4 is not so much employed for foundry work; it is lighter in color, harder, and is sometimes employed for foundry work; it requires some experience to distinguish it from number three, and this can only be done comparatively.

No. 5, or what is termed white-iron—sometimes silver-iron—is very seldom used in the foundry; it is very brittle, and does not run into the moulds, being difficult to keep in fusion.

The distinguishing of these qualities is more dependent upon practical experience than any theoretical description of quality. The following practical directions are given by GRIER:—

When cast-iron is fractured, it exhibits a grey color, sometimes approaching to dull-white, and, in other cases, to dark-grey, with spots nearly black. The lustre is sometimes metallic, resembling freshly-cut particles of lead lying on the surface; and, in other cases, there seems to be crystals in the iron disposed in rays.

When the color is a uniform dark-grey, the iron is tough, provided there be also metallic lustre; but if there be no metallic lustre, the iron, though soft, will be more easily crumbled than in the former case. The weakest sort of soft cast-iron is where the fracture is of a dark hue, mottled, and does not shine.

The iron may be accounted hard, tenacious, and stiff, when the color of the fracture is lightish-grey with a high metallic lustre.

When the tint is light-grey, without metallic lustre, the iron is hard and brittle.

If the hue is dull-white, the iron is more hard and brittle than in the last case.

When the fracture is greyish-white, interspersed with small radiating crystals, the iron is of the extreme degree of hardness and brittleness.

The best way to try the quality of cast-iron is to strike its edge with a hammer. Should the blow make a slight impression, the iron must be in some degree malleable, and, if the specimen be uniform, it may be regarded as good for machinery; if, on the contrary, the hammer make no impression, and fragments fly off, the iron is brittle, and, consequently, bad. The soft cast-iron yields readily to the file after the outer crust has been removed, and is, in a cold state, slightly malleable.

The quality is also easily judged when in the melted state from the nature of the agitated aspect of its sur-

face. The mass of fluid seems to undergo rapid circulation within itself, inducing a constant tremor on the surface, having the appearance of ever-varying net-work; when this net-work is minutely subdivided it indicates soft iron. If, on the contrary, the iron be thrown up in large convolutions, the quality of the metal must be hard.

In founding, it is necessary to select the class of iron most suitable for the kind of articles to be cast. The furnaces used in this operation are termed cupola furnaces. These are also of various construction, and are generally urged by a blast similar to that employed for the smelting furnace, or, what is more common in foundries, by a fan-blast. Fig. 295 is a front elevation of an ordinary cupola of a large size; Fig. 296 is a vertical section in a plane at right angles to that of Fig. 295; *a* is the charging door, about two feet square, by which the pig-iron and coke are introduced

Fig. 295.



Fig. 296.

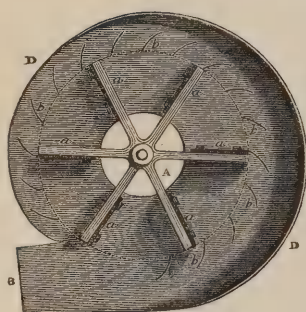


into the furnace; *b* is the tapping-hole, fifteen inches square, at which the melted metal is occasionally drawn from the furnace; *c*, *e*, not seen in Fig. 295, are the tuyere holes or orifices by which the blast enters, to afford a supply of air capable of maintaining a sufficiently intense heat in the furnace by combination with the fuel. These apertures are of considerable extent upwards, so as to admit of the tuyeres being set to any height required, which is regulated by the quantity of metal that may be collected in the furnace; for, of course, the tuyeres must always deliver their air clear of the surface of the metal. The tuyeres are knee-pipes for delivering the blast into the cupola, into which one end is directed, while the other extremity slides in an upright pipe through which the blast is con-

veyed, in the manner of a telescope-tube, so that the tuyere may be set to any height required. The under part, *d f*, of the structure below the charging door, is the most essential division, and is indeed that which gives its character to the furnace. The upper portion, *f g*, is the chimney, intended to convey away the volatile noxious products of the whole operation of fusion, being sufficiently long to pass out through the roof of the foundry. The furnace is built entirely of fire-brick, and it will be observed that the trunk is incased in cast-iron plates bolted together. The casing is in some instances cast in one or two entire cylindrical pieces, and in other instances it is made of boiler plates rivetted together. The latter is undoubtedly the more durable material, as it stands the alternate expansion and contraction with much less injury to itself. The chimney is simply bound with wrought-iron belts fastened round it at regular intervals. The whole structure stands upon a square base-plate, of which the centre is cut out into a circular aperture; this plate is bedded upon a brick or stone foundation, represented in the figures. As the bottom must be protected from the action of the melted metal which collects there, it is laid over with a bed of sand, mixed with wet loam to give it consistency. This is shown in section at *d*, Fig. 296. It is continued over the bottom and sides of the spout, *b*.

Fig. 297 represents the most approved form of fan for producing the blast. It consists of a central spindle, upon which are hung six arms, *a a*, meeting on an eye at the centre, through which the axle is passed, and by which they are fixed to the axle.

Upon each of these arms a square blade, generally of sheet-iron, is firmly fixed by rivets or bolts, and these blades constitute the propelling agents. To render them effectual, they are incased in a round box, *DD*, having a central opening, *A*, on each side



for the admission of air, and an opening, *B*, in the circumference, with a short prolongation, for the expulsion of the air. By the rapid revolution of the blades, a strong current of air sets in at the centre, and to prevent it from impinging against the cover, *D*, by which its progress would be retarded, a series of cutters, *b b*, are fixed between the cheeks around the dotted circle, which indicates the line described by the outer edges of the revolving blades. These cutters are curved, and are so placed that they may receive the air on their interior edges in the tangents to their curvatures, by which precaution the air should glide uninterruptedly upon their interior surfaces, and ought to be deflected in the direction of its motion, so as to join smoothly in with the general current which is propelled through *B*, to the tuyeres leading into the cupola.

According to experience, the iron melted in a cupola urged by a fan-blast improves more in the operation of melting than when a cylinder-blast is used, although the latter has certain advantages which the practical man considers important.

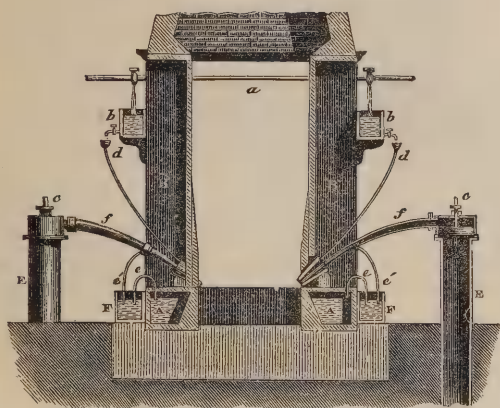
The fires in the cupola furnaces are generally kindled by putting in a quantity of wood, which is then ignited; the usual fuel, either coal or coke, is afterwards introduced, and the blast applied. When a sufficient heat is raised, and the cupola is well filled with fuel, quantities of pig-iron are thrown in, which melts in its passage down, and finds its way to the bottom or hearth in the same way as in the blast furnace. If the fuel be of good quality, having little earthy matter in it and no sulphur, the iron during this melting is considerably purified; a portion of the iron and silica in the pigs is oxidised, forming silicate of iron, which, from its less specific gravity, floats upon the surface of the metal, and is separated as scoria or slag; the remaining charge of iron is consequently much purer, and makes a stronger metal. When the fuel contains earthy matter, this combines with a portion of the iron, also forming silicate and scoria, by which means much of the metal may be lost without in any way tending to purify what remains. It is, therefore, a common custom to put into the furnace a small portion of lime, which acts as a flux upon the silica of the coal by which the iron is partially saved. Coke, which is seldom free from sulphur, is very generally used as fuel.—See analysis of coke, article FUEL.—The sulphur has a strong tendency to combine with the iron, and often to an extent sufficient to deteriorate greatly the quality of the metal in the cast, as the sulphide diffuses itself through the body of the iron. From analyses made of pig-iron before and after being fused in the cupola by certain qualities of coke, it was found to give in the former case only 0.4 per cent. of sulphur; and in the latter so much as 1.0 per cent., showing an increase of six-tenths of a per cent. derived from the fuel. The quality of the fuel for cupola furnaces should, therefore, be a primary consideration with the iron-founder. Wood charcoal, being free from sulphur, is employed with advantage where it can be had in abundance.

MANUFACTURE OF MALLEABLE IRON.—When pig-iron is to be converted into malleable or bar-iron, it has to undergo certain processes of purification, to separate the metal from the foreign matters which more or less affect its natural properties of malleability and ductility. Although these foreign matters were essential to give it the necessary fusibility for the obtaining of the cast-iron from the ore, and are, for the same reason, equally essential for the production of cast articles so valuable in machinery and other works of art, they must be got rid of in that iron which is to be used for purposes requiring the greater tenacity and strength of the pure material. The operations of refining consist in remelting and blowing upon the iron, to burn out a portion of its impurities, and then subjecting it to a process of heating and hammering, termed *puddling*, by which means, partly chemical and partly mechanical, the foreign matters are eliminated from the metal.

Refining.—The first operation, or that more generally

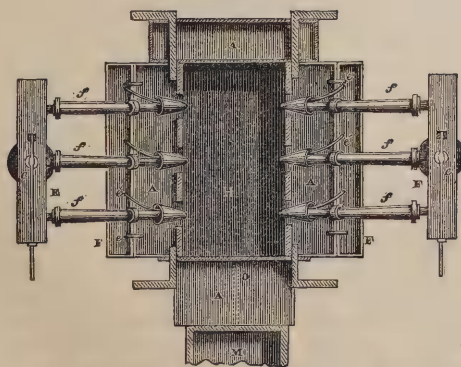
termed *refining*, is performed in peculiarly-constructed furnaces, called *refineries* or *running-out fires*. These are composed of a body of brick-work, about nine feet square, rising but little above the ground, and are shown in Figs. 298 and 299, the former of which is a sectional elevation and the latter a plan. The hearth, H, is placed in the middle of this, and is of a rectangular shape, being about three feet by two, and about thirty inches deep; it is formed by the junction of four cast-iron troughs, A, through which a stream of cold water is made to circulate to prevent them from being fused

Fig. 298.



by the heat. Over the hearth, and supported by iron columns, B, about six feet high, is a chimney from ten to twelve feet high, making the total height about twenty feet. The tuyeres, *f*, are placed on the longest sides of the hearth at the lip or edge, and are inclined towards the bottom so as to blow upon the bath of melted metal. The noze-pipe is incased similarly to that of the blast furnace, and water is made to circulate in the hollow space by cylindrical tubes, to prevent the tuyeres from being burned. The supply of water for this purpose is brought by the pipe, *a*, into the reservoirs, *b*,

Fig. 299.



from which it flows through the pipes, *d*, to the nozzles of the tuyeres, and thence escapes by the tubes, *e*', into the tanks, F; from these it is conveyed by the siphon-tubes, *e*, into the troughs, A. The blast arrives at the tuyeres through the mains, E, which

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are furnished with screw-valves at *c* for the purpose of regulating the supply. The tapping-hole, O, is placed at one of the shorter sides of the hearth, and by it the melted metal and the slag flow out into the mould, M.

The operation begins by filling the hearth or crucible portion of the furnace with coke; upon this are laid six pigs of iron from the blast furnace, and more coke is heaped upon them. The fire is kindled at bottom; after a little the blast is let on, and, as the heat increases, the iron melts and flows to the bottom; more coke is added as it burns away, to preserve the metal in a state of fusion. The iron during this operation expands, heaves up, and evolves oxide of carbon. After about two hours the metal is tapped out into pits or beds, forming large plates, upon which quantities of water are thrown with the view of rendering it brittle. The metal thus treated is very white, and possesses in general a fibrous radiated texture, consequent on its rapid cooling; it is also full of cells from the escaping of gaseous matters. In this operation there is formed a heavy black scoria, principally composed of silicate of iron with other impurities. When the iron is very inferior in quality, a small portion of lime is added to the fire to take up the earthy matters; in this case the scoria will contain lime. As already remarked, in fusing iron in the cupola the earthy matter in the coke employed requires a little lime to combine with it; otherwise, if present in any considerable quantity, it will take away much of the iron. In some places the iron is run into these refining furnaces directly from the blast furnace, a method which saves the time and fuel required to remelt the pigs; but this saving is attended with certain disadvantages which have prevented its general adoption.

The change effected upon the iron in this operation is the oxidation and consequent separation of a great portion of the impurities. The following are analyses of the results:—

	Iron from blast before refining.	Same iron after being refined.
Iron,	95.26	98.33
Carbon,	2.63	.87
Silicium,	1.38	.53
Aluminium, .....	.73	.26
Phosphorus,	trace	trace
Sulphur,	trace	trace
	100.00	99.99

The slag or scoria from the refining of the above iron gave—

Protoxide of iron,	70.3
Silica,	21.5
Alumina,	7.8
	99.6

As a general rule, the longer the blowing and consequent exposure to the oxygen of the blast, the greater the deprivation of alloys and improvement in quality; but the process may be unnecessarily prolonged.—*Truran*.

A very good criterion of the effect produced upon the iron by this process, is the composition of the cinder or slag from the operation. BERTHIER gives the fol-

lowing analyses of this slag from two different works in different localities:—

	Dudley.	Dowlais.	
Protoxide of iron,....	61.2	61.0	52.0
Silica,	27.6	36.8	42.4
Alumina,.....	4.0	1.5	3.3
Phosphoric acid,....	7.2	—	—
	100.0	99.3	97.7

The presence of the phosphoric acid in the scoria is important, as showing the use of the operation; a portion of both the silica and alumina may have been in the ashes of the fuel, so that this should be strictly attended to in these investigations. The following is an analysis of refining cinder from a work near Birmingham:—

Protoxide of iron,	61.28
Silica,	22.76
Protoxide of manganese,	3.58
Alumina,	7.30
Lime,	3.41
Magnesia, .....	.76
Sulphur, .....	.46
Loss, .....	.45
	100.00

It is very probable that several of these matters have been from the fuel. If the fuel contains much silica, the loss in iron, from this cause alone, will be considerable. In the above analysis the silica and protoxide of iron appear as one to three. The combined weight of the iron and cinder is always more than the weight of the pig-iron put in. TRURAN gives, as the result of his own experience, the following:—

	Pounds,
Crude iron put in,	2498
Produce, { Refined metal,	2240
{ Cinder,	325
	2567
Showing an excess of weight,	69

The principal portion of the excess, says this authority, is due to the fixation of oxygen forming the protoxide of iron in the cinder, silica, and alumina. The remaining portion is composed of the silicious earths of the coke and stones composing the hearth. The increase of weight by the oxygen in the scoria is counterbalanced by the direct loss of carbon; so that the increase is wholly from the last-named sources, the ash of the fuel and stones of the hearth. The loss of iron in this process varies according to the quality of the crude iron. BERTHIER gave from his results twelve to seventeen per cent. of loss; in the preceding statement of TRURAN the loss is ten per cent.

Puddling.—The next process of refining is termed *puddling*, and is performed in a reverberatory furnace of the shape shown in sectional elevation and plan in Figs. 300 and 301. The sole or hearth, D, is made of brick or cast-iron; if of the former, it is arched below, the bottom of the furnace being the top of the arch; if of the latter, it is a large plate of cast-iron, supported by pillars, and is covered with a layer of slag, which is made to incline towards E, where there is a rapid fall to allow of the escape of the slags formed during the process; these are removed at the opening or *floss-hole*, b. The length of the hearth is about

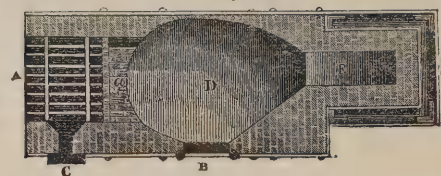
six feet; its breadth at the middle about four feet; at the chimney-end about two feet; and from two and a half to three feet at the fire-end. The fire, A, is

Fig. 300.



separated from the hearth by a wall of fire brick, a, about ten inches high, termed the bridge. The draught is produced by a chimney, F, forty or fifty feet high, and furnished at top with a damper, H, which can be raised or lowered by means of a chain and lever.

Fig. 301.



The opening, C, which communicates with the grate, is generally closed by heaping up the fuel. The opening, B, into the hearth or sole of the furnace, is that through which the workman introduces his iron bar, or *paddle*, during the process of puddling. Nearer the chimney is another aperture, G, which is used for cleaning out the furnace at the end of an operation.

From three and a half to four hundredweight of the fine metal obtained by the refining process is put into the puddling furnace, in pieces laid one upon another upon the sides of the hearth, leaving the centre or middle part free for the operations of the puddler. The furnace is then closed up, and the fire pushed to a high heat; in about twenty minutes the metal begins to melt, and falls off in drops upon the sole of the furnace. The furnaceman, by means of a paddle, removes the iron from the hottest parts to prevent its melting too rapidly. When the whole of the metal is reduced to a pasty state, the temperature of the furnace is lowered that it may not become more fluid. The furnaceman then works about the pasty metal with his paddle, during which it swells up with the discharge of gaseous matters. As this goes on, the metal becomes less fusible as it gets finer, the gases cease to escape, and by the constant puddling or kneading with the paddle, it becomes reduced to a sort of sandy consistence. During these operations, small quantities of water are thrown into the furnace. At this stage the heat is increased, and the particles of metal begin again to

agglutinate, and become, in the language of the workman, *heavy*. The furnaceman with his paddle gathers a lump of metal on the end of it, as a nucleus, and makes it roll about on the surface of the clotted mass; he thus collects a ball of about seventy pounds in weight, which is placed on the side of the hearth at the hottest part, where, with a rake or paddle, termed a *dolly*, it is squeezed as much as possible to force out any scoria. After the whole of the metal is thus formed into balls, the heat of the furnace is still augmented to facilitate the welding. The balls are then lifted out—by means of tongs, if roughing rollers are to be used, or with an iron rod, welded to the ball, if the hammer is to be employed.

The time taken to puddle a charge is from two to two and a half hours. The loss of iron in this process varies considerably, both according to its quality, and also the expertness of the workman. The loss is on an average about ten per cent. During this operation, a considerable quantity of scoria, which sweats out from the metal, is allowed to run off from the hearth, and is removed. The composition of this scoria differs little from that of the refining furnace,

except that a quantity of the iron is found in the state of sesquioxide. The following is the analysis of two samples of scoria, the one exposed in a flue of a puddling furnace for some time, and the other, called *tap cinder*, direct from the furnace:—

	Scoria found in flue.	Tap cinder.
Silica,.....	29·60	23·86
Protoxide of iron,.....	48·43	39·83
Sesquioxide of iron,.....	17·11	23·75
Protoxide of manganese,.....	1·13	6·17
Alumina,.....	1·28	·91
Lime,.....	0·47	·28
Magnesia,.....	·35	·24
Phosphoric acid,.....	1·34	6·42
Sulphide of iron,.....	1·61	·62
	101·92	180·02

These results show the impurities to be of the same kind as those of the scoria given out at the refining or running-out furnace.

The following are analyses of refined or malleable iron of different qualities, and from various localities, exhibiting the extent of the effects produced by refining, when compared with the composition of crude iron:—

	Iron.	Carbon.	Sulphur.	Phosphorus.	Silica.	Arsenic.	Copper.	Manganese.
Swedish from Danemora,.....	98·78	.. 0·84	—	.. —	.. 0·12	.. 0·02	.. 0·07	.. 0·05
Swedish common bar,.....	99·73	.. 0·24	—	.. trace.	.. 0·03	—	.. —	.. trace
German very strong rod,.....	99·13	.. 0·66	—	.. —	.. trace.	.. —	.. 0·05	.. 0·29
German strong, Hartz Mountains, ..	98·88	.. 0·40	.. trace.	.. —	.. 0·01	.. —	.. 0·32	.. 0·30
German weak, fibrous,.....	99·87	.. 0·09	.. trace.	.. —	.. 0·03	.. —	.. —	.. —
Welsh puddled iron,.....	98·90	.. 0·41	—	.. 0·40	.. 0·08	.. —	.. —	.. 0·04

In comparing these analyses with the qualities, it is difficult to say wherein lies the difference. That termed weak is the purest, and the strong Swedish iron appears the most impure.

CALVERT and JOHNSTON have recently carried out a series of researches, instituted for the purpose of ascertaining the progressive chemical changes effected in the operation of puddling.

The material operated upon was good cold-blast Staffordshire iron, No. 3, rather grey. The puddling was conducted in the usual manner; and at intervals portions of the iron were taken out from the mass, and subsequently analysed so as to ascertain the nature of the changes produced at the different stages of the operation.

The following table gives the quantity of the several portions, so far as regards the per centage amounts of carbon and silicium, which embrace what are considered the principal changes in this process:—

Pig-iron used.	Time.	Carbon.	Silicium
Iron as put in,	12 o'clock.	2·275	.. 2·720
Sample 1 ..	12·40	2·726	.. ·915
" 2 ..	1·0	2·905	.. ·197
" 3 ..	1·5	2·444	.. ·194
" 4 ..	1·20	2·305	.. ·182
" 5 ..	1·35	1·647	.. ·183
" 6 ..	1·40	1·206	.. ·163
" 7 ..	1·45	0·963	.. ·163
" 8 ..	1·50	0·772	.. ·168
Puddled bar,.....		0·296	.. ·120
Wire bar,.....		0·111	.. ·088

These interesting results show the value of such investigations; and it is to be hoped that similar experiments will be repeated again and again under various circumstances, and with a view to all the impurities.

One thing worthy of notice is the fact, that, after the furnace operations are complete, the hammering and rolling seem to eliminate a great quantity both of the carbon and silicium. The carbon in the wire-iron is only one-seventh of that in the iron at the end of the puddling operations, and the silicium is reduced nearly one-half.

With regard to the sulphur and phosphorus in the iron before and after the puddling, the final results only are given, namely:—

	Pig-iron.	Puddled bars.	Wire-iron.
Carbon,.....	2·275	.. 0·296	.. 0·111
Silicium,.....	2·720	.. 0·120	.. 0·088
Phosphorus,.....	0·645	.. 0·134	.. 0·117
Sulphur,.....	0·301	.. 0·139	.. 0·094

The following composition of the slag produced in these operations confirms the preceding results:—

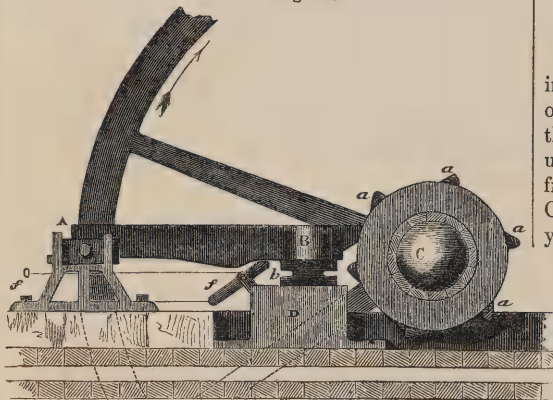
Silica,.....	16·53
Protoxide of iron,.....	66·23
Sulphide of iron,.....	6·80
Phosphoric acid,.....	3·80
Protoxide of manganese,.....	4·90
Alumina,.....	1·04
Lime,.....	0·70
	100·00

Hammering, Squeezing, and Rolling.—The process of refining and toughening the iron after passing through the puddling furnaces, is completed by mechanical means; either by subjecting it to the action of large hammers, or by pressing and drawing it between rollers, during which operations a great quantity of scoriaceous matter is squeezed out, and the iron assumes a fibrous structure, possessing the malleable and

ductile qualities of wrought-iron. In the first place, the puddled balls are *shingled* or fashioned into oblong slabs or *blooms* by the blows of a heavy forge hammer, termed the *helve*. The blooms are then passed through a series of grooved iron rollers, which reduce them to the form of long bars. These are cut up into short pieces, several of which are *fagoted* together and brought to a welding heat in the *balling* furnace, after which they are again passed several times between grooved rollers, and by this latter process are made into bars or plates, ready for the shears.

The helve or shingling hammer is a ponderous beam of cast-iron, A B—Fig. 302—about ten feet long, and weighing from three to four tons. At one extremity, A, it

Fig. 302.



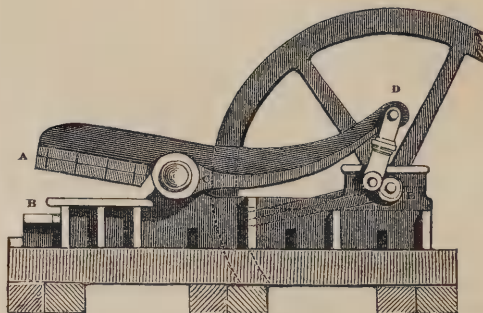
turns on an axis, which rests on heavy plummer blocks, and to the other is secured the *head*, B, which is of wrought-iron, faced with steel, and weighs from seven to eight hundredweight. The anvil, b, is supported on a massive block of iron, D. The head is raised by a number of cams, a a, fixed to a powerful shaft, C, which is turned by steam or water-power, assisted and regulated by a heavy fly-wheel. The ball or bloom is placed upon the anvil, and the head, being lifted from eighteen to twenty-four inches by each cam as it revolves, makes from seventy-five to one hundred blows per minute, by which the scoriæ and other impurities are separated.

Another instrument used for preparing the blooms to pass through the rollers, acts by compression like a pair of pliers, and is termed the *squeezer* or *alligator*. This machine is represented in Fig. 303. It acts by means of two powerful jaws, A B, united at C like a pair of shears, and having their faces grooved in order to hold fast the bloom, which is introduced between them. A current of water flows through a cavity in the lower jaw to keep it cool. The upper jaw alone moves, and is worked by a cam on the axis, E, of the fly-wheel, operating on the crank, D. This machine requires an attendant to keep the bloom rolling about between the jaws, A B.

The alligator is said to squeeze out the slag more thoroughly and expeditiously than the helve does; but

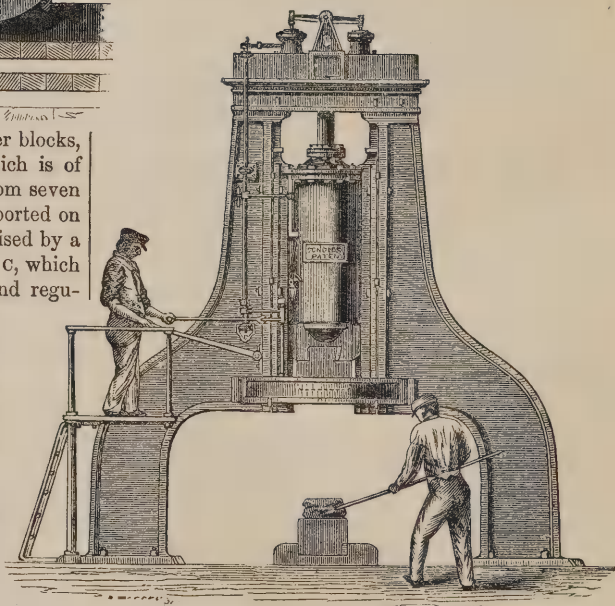
both are now being rapidly superseded by steam-hammers, one of the most celebrated of which is that of NASMYTH, patented in 1833. The hammering weight

Fig. 303.



in this machine is attached directly to the lower end of the steam piston-rod, and the percussive action of the blows is found to be objectionable in its effects upon the piston and rod, causing wear and serious fractures. To obviate this practical defect, Mr. JOHN CONDIE, of the Govan Iron-works, Glasgow, about the year 1846, gave the subject much consideration, and

Fig. 304.



the result of his deliberations was the hammer delineated in Fig. 304. The great difference between CONDIE's hammer and all earlier contrivances, consists in the fact that the steam cylinder is movable, and itself gives the blow, whilst the piston and its rod are fixed to the framing. The cylinder is, therefore, constructed of great strength, particularly at the lower end, which is formed with a dovetail socket, to receive the acting hammer face. This arrangement permits of the replacement of the striking portion when worn.

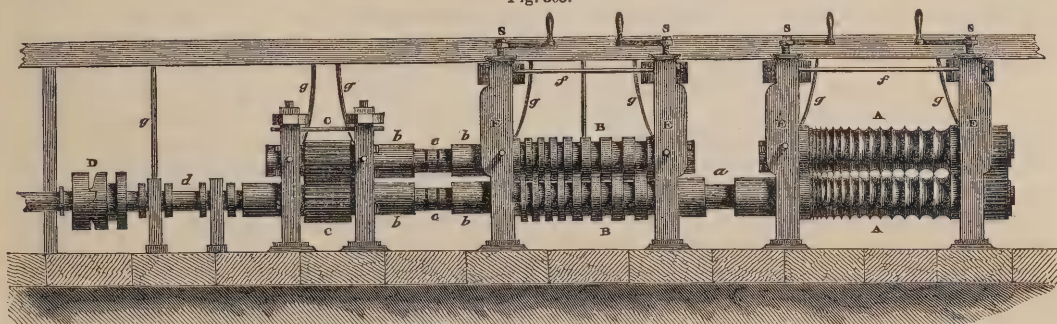
The first experimental Condie hammer was erected at the Govan Iron-works in 1848, and it has worked day and night since that time, doing all sorts of puddling and forging work in a most successful manner. The size of the instrument has gone on increasing in quick gradations until the climax of a six and a half tons dead hammering weight, with a fall of seven feet six inches, has been reached. All the unprecedentedly heavy shafts in the great steamer, the *Leviathan*, were forged under Mr. CONDIE's hammers at a time and under circumstances when such heavy masses could not have been shaped elsewhere. For puddling forges, hammers of forty and fifty hundredweight are now generally superseding the old-fashioned helves and squeezers.

Among the latter class of machines, however,

BROWN's patent squeezer is acknowledged to be very effective. It consists of a series of massive rollers, so arranged that the heated bloom of puddled iron, being placed on the top of the machine, is taken in between the two upper rollers, and is gradually compressed between these and others as it descends. At the bottom, it falls upon an endless revolving chain ladder, by which it is elevated and thrown on to a platform in front of the rolls for drawing it out into bars.

The drawing rolls are represented in Fig. 305, and consist of two sets, AA and BB. The former are called the *roughing* rolls, and serve to conclude the refining process by expressing the last portions of slag; the latter are termed the *finishing* rolls, and are differently grooved, according to the section intended to be

Fig. 305.



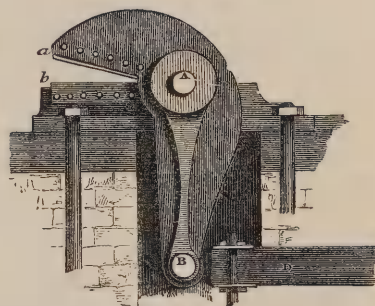
given to the bar. They are mounted in pairs, one above the other, on massive iron bearers, EE; the lower rolls are driven direct by a shaft, *d*, from the fly-wheel of the engine, and motion is communicated to the upper rolls by strong toothed wheels, CC; the distance between them is regulated by screws, *ss*, which work through the tops of the bearers. These are connected at the upper part by stout iron bars, *ff*, which serve to support the heavy tongs employed in lifting the blooms. Through the small pipes, *gg*, a stream of water is made to play upon each pair of rolls, to keep them cool, descending into a channel beneath the frame, in which the scale that falls from the surface of the heated iron, as it passes between the rolls, is carried away by the water. The roughing rolls vary from four to five feet long, and are about eighteen inches in diameter.

The bloom on arriving at the platform in front of the roughing rolls, is still at a bright heat, and is now of an oblong form. The workman immediately seizes it with a pair of tongs, and forces it into the largest groove in the rolls, the first three or four grooves being roughened with teeth, by which it is caught, and carried through without slipping. It is then passed in succession through the other grooves of the same series, until it attains the required form for railway bars or other purposes to which it is intended to be applied.

For good bar-iron, however, an additional process is required. When the blooms have been reduced by the roughing rollers to the form of long bars, they are cut into short lengths, which are welded together in piles, and again drawn out into bars in the rolling mill. A great variety of shears is used for cutting iron, some driven by cams or eccentrics, and some by con-

necting rods and a crank on the revolving shaft. In large iron-works it is necessary to have two or three kinds, some for cutting up scrap iron and bars for piling, and others for boiler-plates. The shears employed in cutting the bars for piling consist of two jaws, Fig. 306, to which are firmly bolted cutting edges, *ab*, of hardened steel. The lower blade, as in the squeezer,

Fig. 306.



is fixed, but the upper one moves on the pin, A, by the action of the bar, D, on the lever, B A. Bars of considerable thickness are easily divided by the jaws, and a number of the short lengths thus produced are placed together in *piles* or *fagots*, which are raised to a welding heat in a reverberatory furnace, taking care not to expose them to the oxidising influence of the air. The experience of the workman enables him to judge, from the appearance of the furnace, when the piles are at a welding heat, so that, when afterwards compressed in the rolls, the particles will unite. When he ascertains that this point has been attained, the piles are taken

out, one at a time, and thrown to the workmen at the finishing rolls, who pass them through the grooves as rapidly as possible, so as to elongate each pile into a bar of the required size, before the iron has cooled down below the proper temperature for drawing. The short lengths which compose the pile or fagot tend to produce a fibre in the bar, which in good iron is always perceptible, however perfect the weld, and seems to be necessary to give it strength and toughness.

Sheet-iron is made by passing the metal between smooth rollers, without grooves, the rollers being gradually screwed nearer together as the desired thickness is being approached.

The speed of the different kinds of rolling mills varies according to the work they have to perform. Those for merchant-bars make from sixty to seventy revolutions a minute, whilst those of large size for boiler-plates are reduced to twenty-eight or thirty. Others, such as the finishing and guide rollers, run at from one hundred and twenty to four hundred revolutions a minute.

BESSEMER'S PROCESS.—The nature of the changes taking place in the iron during the preceding refining operations is obvious, the whole being simply a process of oxidation of the impurities, which are subsequently squeezed out by the pressing and rolling. Since the invention of puddling by Mr. CORT, many improvements or alterations, both of a chemical and mechanical nature, have been introduced, some of which have done much to facilitate the operations; but all have been merely modifications of the same principle: the process was still essentially CORT'S. But during the year 1856, a method was patented which sets all previous plans and modifications aside, and, as with the wand of the magician, effects the refining of the iron from the crude pig to malleable bar without either fuel or hammer. Unfortunately, from various experiments tried, the practical utility of this beautiful process is still doubtful. Mr. BESSEMER, the inventor, describes it in nearly the following terms, in a paper which was read before the British Association in the year above-mentioned:—

The assumptions with which he set out were, that crude iron contains about five per cent. of carbon; that carbon cannot exist at a white heat in the presence of oxygen, without uniting therewith, and producing combustion; that such combustion would proceed with a rapidity dependent on the amount of surface of carbon exposed; and, lastly, that the temperature which the metal would acquire would be also dependent on the rapidity with which the oxygen and carbon were made to combine, and consequently that it was only necessary to bring the oxygen and carbon together in such a manner that a vast surface should be exposed to their mutual action, in order to produce a temperature hitherto unattainable in our largest furnaces. With a view of testing practically this theory, he constructed a cylindrical vessel of three feet in diameter, and five feet in height, somewhat like an ordinary cupola furnace, the interior of which was lined with fire-bricks; and at about two inches from the bottom of it, he inserted five tuyere pipes, the nozzles of which were formed of well-burnt fire-clay, the orifice of each tuyere being about three-eighths of an inch in diameter. At one side of the ves-

sel, about half-way up from the bottom, there was a hole made for running in the crude metal, and in the opposite side there was a tap-hole stopped with loam, by means of which the iron could be run out at the end of the process. In practice this converting vessel might be made of any convenient size, but he preferred that it should not hold less than one, or more than five tons of fluid iron at each charge. The vessel was placed so near to the discharge-hole of the blast-furnace as to allow the metal to flow along a gutter into it; a small blast-cylinder was employed, capable of compressing air to about eight or ten pounds to the square inch. A communication having been made between it and the tuyeres before named, the converting vessel was in a condition to commence work.

It has been stated that the tuyeres were situated nearly close to the bottom of the vessel; the molten mass would, therefore, rise some eighteen inches or two feet above them. It was, consequently, necessary, in order to prevent the metal from entering the tuyere holes, to turn on the blast before allowing the fluid crude iron to run into the vessel from the blast-furnace. This having been done, and the liquid run in, a rapid boiling up of the metal was heard going on within the vessel; the metal being tossed violently about and dashed from side to side, shaking the vessel by the force with which it moved. Flame then issued from the throat of the converting vessel, accompanied by a few bright sparks. This state of things continued for about fifteen or twenty minutes, during which time the oxygen in the atmospheric air combined with the carbon contained in the iron, producing carbonic acid gas, and at the same time evolving a powerful heat. Now, as this heat was generated in the interior of, and was diffused in innumerable fiery bubbles through, the whole fluid mass, the vessel absorbed the greater part of it; its temperature became immensely increased; and by the expiry of the fifteen or twenty minutes before named, that part of the carbon which appeared mechanically mixed and diffused through the crude iron was entirely consumed. The temperature, however, was so high, that the chemically-combined carbon now began to separate from the metal, as was at once indicated by an immense increase in the volume of flame rushing out of the throat of the vessel. The metal in the vessel now rose several inches above its natural level, and a light frothy slag made its appearance, and was thrown out in large foam-like masses. This violent eruption of cinder was generally found to last about five or six minutes, when all further appearance of it ceased, a steady and powerful flame replacing the shower of sparks and cinders which always accompanied the boil. The rapid union of carbon and oxygen which thus took place, added still further to the temperature of the metal, while the diminished quantity of carbon present allowed a part of the oxygen to combine with the iron, which underwent a combustion and was converted into an oxide. At the excessive heat which the metal had now acquired, the oxide as soon as formed underwent fusion, and formed a powerful solvent of those earthy bases which were associated with the iron. The violent ebullition which was going on mixed most intimately the scoria and metal, every part of which was thus brought in contact with the fluid

oxide, which thus washed and cleansed the metal most thoroughly from the silica and other earthy bases combined with the crude iron; while the sulphur and other volatile matters which cling so tenaciously to iron at ordinary temperatures were driven off, the sulphur combining with the oxygen and forming sulphurous acid. The loss in weight of crude iron during its conversion into an ingot of malleable iron, was found on a mean of four experiments to be twelve and a half per cent., to which would have to be added the loss of metal in the finishing rolls. This would make the entire deficiency probably not less than eighteen per cent., instead of about twenty-eight per cent., which is the loss on the present system. A large portion of this metal was, however, recoverable, by treating with carbonaceous gases the rich oxides thrown out of the furnace during the boil. These slags were found to contain innumerable small grains of metallic iron, which were mechanically held in suspension in the slags, and might be easily recovered.

It has been stated, that after the boil had taken place, a steady and powerful flame succeeded, which continued without any change for about ten minutes, when it rapidly fell off. As soon as this diminution of flame is apparent, the workman will know that the process is completed, and that the crude iron has been converted into pure malleable iron, which he will form into ingots of any suitable size and shape by simply opening the tap-hole of the converting vessel and allowing the fluid malleable iron to flow into the iron ingot moulds placed there to receive it. The masses of iron thus formed, are found to be perfectly free from any admixture of cinder, oxide, or other extraneous matters, and are far more pure, and in a forwarder state of manufacture, than a pile formed of ordinary puddle bars. And thus it will be seen, says Mr. BESSEMER, that by a single process, requiring no manipulation or particular skill, and with only one workman, from three to five tons of crude iron pass into the condition of several piles of malleable iron in from thirty to thirty-five minutes, with the expenditure of about one-third part the blast now used in a finery furnace with an equal charge of iron, and with the consumption of no other fuel than is contained in the crude iron.

To those who are best acquainted with the nature of fluid iron, it may be a matter of surprise that a blast of cold air forced into melted crude iron is capable of raising its temperature to such a degree as to retain it in a perfect state of fluidity after it has lost all its carbon, and is in the condition of malleable iron, which, in the highest heat of our forges, only becomes a pasty mass. But such was the excessive temperature which Mr. BESSEMER was enabled to arrive at with a properly-shaped converting vessel and a judicious distribution of the blast, that the fluidity of the metal was not only retained, but so much surplus heat created, as to remelt the crop ends, ingot runners, and other scrap that was made throughout the process, and thus to bring them without labor or fuel into ingots of a quality equal to the rest of the charge of new metal.

The ingots of malleable metal so formed, were found to have no hard or steely parts, such as exist in puddling iron, requiring a great amount of rolling to blend

them with the general mass; nor do such ingots require an excess of rolling to expel cinder from the interior of the mass, since none can exist in the ingot, which is pure and perfectly homogeneous throughout, and hence requires only as much rolling as is necessary for the development of fibre.

One of the most important facts connected with Mr. BESSEMER'S system was stated to be, that all the iron so produced was of that quality known as charcoal iron: not that any charcoal is used in its manufacture, but because the whole of the processes following the smelting of it are conducted entirely without contact with or the use of any mineral fuel; the iron resulting therefrom being, in consequence, perfectly free from those injurious properties which that description of fuel never fails to impart to iron that is brought under its influence. At the same time, this system of manufacturing malleable iron was considered as offering extraordinary facility for making large shafts, cranks, and other heavy masses; since any weight of metal that can be founded in ordinary cast-iron by the means at present in common use, could thus be founded in molten malleable iron, and be wrought into the forms and shapes required, by simply increasing the size and power of the machinery to the extent necessary to deal with such large masses of metal.

So far as the principle of Mr. BESSEMER'S process is concerned, it is certainly a beautiful application of chemical knowledge to practical purposes; but in its present probationary state it would be premature to venture more than a congratulation to the inventor upon the correctness of his inductions, although many of the most ingenious theories have been found inapplicable, from some cause involved in the very nature of the operation. What could have been more beautiful than DAVY'S application of zinc protectors to the copper sheathing of ships, or what more completely successful in accomplishing the object intended; and yet its perfect success was the cause of its being unsuitable. One evident defect in the practical result of the process, is its failure to free the iron from phosphorus and sulphur, which is certainly a serious drawback, as shown by the following analysis of iron refined by this method:—

Iron,.....	98.90
Carbon,.....	0.05
Sulphur,.....	0.16
Phosphorus,.....	1.08
	<hr/> 100.19

From the analyses of wrought-iron which have been given, it will be seen that its comparative weakness or strength has no apparent relation to its chemical purity; a circumstance suggesting the probability that there may also be mechanical requirements in preparing malleable iron, which the puddling process supplies. Mostly all metals, when melted and left to solidify undisturbed, do so in a crystalline form. The stirring and working in the puddling operations may prevent this crystallization in the metal, and hence the tenacious and fibrous character of wrought-iron. Time and experience are required to prove the practicability of the best inventions, and these often enable the experimenter to modify the pro-

cesses, so as to overcome the collateral difficulties that arise in the first applications. Should such difficulties exist in the present case, Mr. BESSEMER will have the sympathy of all men of science, and their best wishes for the success of a process at once beautiful, ingenious, and simple. It may be remarked here that perfectly pure iron seems not to be desirable; it is very malleable and ductile, and might do for wire, but its softness would be a considerable objection for many requirements. The iron wanted must be hard as well as tough, and this is the object to be aimed at.

LOSS IN REFINING.—On looking back upon the refining operation, the quality of the crude iron from the blast furnace, and the state of the malleable iron produced, there is one circumstance which must strike every reader with surprise; namely, the great loss of metal which takes place in the refining. Something is evidently wanting in the process to reduce this deficiency. Mr. BESSEMER gives the loss in the common process at twenty-eight per cent.; of course this will vary according to the quality of the cast-iron used, but in many localities the loss has been found to average nearer thirty-three than twenty-eight per cent. The proportion of loss will be more apparent when stated thus:—If pig-iron having six per cent. of silica be refined with coke containing three or four per cent. of the same substance, and if, as shown by the analysis of the cinder, every part of silica represents three of protoxide of iron, consequently the gross loss cannot be much less than one-third of the pig-iron, especially when one takes into consideration the other sources of silica with which the iron may be brought into contact in the process of refining both in the running-out and puddling furnaces. Even in the mere operation of remelting to produce cast-iron articles for machinery, the loss from the formation of cinder is very considerable.

The cinder, however, although lost to the manufacturer of malleable iron, is not entirely thrown away; in many places it is collected and re-smelted with lime flux, by which an inferior iron is obtained. It is also often mixed in small quantities with the ordinary ores in the blast furnace; but their presence generally affects the quality of the iron produced. A patent was recently taken by Mr. CALVERT to recover the iron from rich cinders; but no good and effective method has yet been applied.

SWEDISH IRON.—Notwithstanding the facilities enjoyed in this country, and the great improvements in the manufacture of iron, still the qualities produced on different parts of the Continent are preferred—particularly those of Sweden, Norway, and Russia—and command a higher price in the English market than the British best iron; but the ores from which the iron of these countries is made are much richer, the quantity of iron produced is less, and the fuel is of a superior kind, namely, charcoal.

At the smelting works of Sweden and Norway, the principal ores from which the iron is manufactured are the magnetic oxide, the composition of which has been already given. According to M. JARS, the smelting furnaces of Sweden and Norway are about thirty feet high from the tuyere-hole to the base

of the chimney. The time required by the ore to descend from the top of the furnace to the tuyere is very considerable, during which time it is mixed up with charcoal under the effects of a constant and regularly increasing heat; and the ore, having little or no earthy matters in it, the iron is gradually reduced to the metallic state by loss of its oxygen, and then by an increased heat it combines with from three to six per cent. of carbon, in which state it is more easily kept in a fused condition. This fused metal runs down into the hearth, and is from time to time let out, as in the process of smelting in this country. It is then introduced into a refining furnace, which consists of a low quadrangular stack of masonry, with a sloping ledge inside, just opposite the tuyere-hole, and on this the crude-iron is placed and covered with charcoal, to prevent the iron from burning away by the action of the blast, which is directed so as to strike upon the under surface of the pig, and the latter is pushed forward from time to time in proportion as the lower part is melted away by the blast. When all is fused, a man with an iron bar keeps stirring and intermixing, while the blast is continued. In a short time jets of flame arise from the surface of the metal, and soon after it becomes of a thicker consistence; it is then gradually solidified, and is removed from the furnace to the hammer. How close is this in principle to BESSEMER's new process?

The scoriæ stirred into the melted metal, says BERZELIUS, consist of oxide of iron vitrified with silica and other earthy substances, all of which contain oxygen, and this, reacting on the carbon of the cast-iron, separates it in the state of inflammable gas—carbonic oxide. The best quality of Swedish bar-iron was found by the above-mentioned illustrious chemist to contain half a per cent. of carbon and one-tenth of a per cent. of silicium.

As already stated, much of the superior quality of the iron produced in these countries depends more upon the purity of the ore and the fuel, than on any difference in the mode of manufacture. When coke or mineral coal is used by the same method, and for the same ores, the iron produced is very inferior; and when the ordinary ore of this country is treated by the same process, even with charcoal, the iron produced is not equal to that made from the best ore and charcoal, showing how much depends upon the character and quality of the fuel.

The most celebrated iron mine of Sweden is that of Dannemora, about thirty miles to the North of Upsala. It is imported into England, chiefly at Hull, and is known as *Oregrund* iron, from the name of the port at

Fig. 307.



which it is shipped. Foreign iron is generally imported in bars, on which certain marks are stamped by the manufacturers. The marks which distinguish the Swedish iron are shown in Fig. 307. The different qualities of the *Oregrund* are known as the *hoop L*—so called from being marked with the letter L enclosed

in a circle or hoop—the *G L*, and the *double bullet*. Inferior Swedish iron is known by the marks *C* and *crown*, *D* and *crown*, the *steinbuck*, and the *W* and *crowns*.

STEEL.—Steel is a compound of iron and carbon, nearly in the proportion of five equivalents of carbon and seventy-three equivalents of iron, giving the formula $\text{Fe}_{73} \text{C}_5$, and is manufactured from the purest malleable or bar iron, such as the charcoal iron of Sweden and Russia. It is generally divided into four qualities—namely, Damascus steel, German steel, blister steel, and cast-steel.

Damascus steel derives its name from the city of Damascus in Asia, which, from the earliest time, has been famed for producing a steel of remarkably superior quality, and eminently fitted for swords or scimitars—hence Damascus *blades* have long been proverbial. The surface of these blades presents a variegated appearance of *watering* in white and black lines. A similar effect has been given to other steel; but the quality of the metal has never been surpassed in this country. It is of the nature of cast-steel, and is a little more highly charged with carbon than European steel, but the characteristic quality of metal is obtained by some peculiar mode of cooling and conducting the operations.

M. BREANT, who devoted much time to the production of this kind of steel, made some excellent blades by mixing one hundred parts of soft iron with two parts of lamp-black, and fusing. This was considered an easy method of making cast-steel without the previous cementation of the iron. A good Damascus steel was also obtained by mixing one hundred parts of the best grey cast-iron with an equal amount of the same iron reduced to filings and oxidised, and then fusing the two together. This gave a metal remarkable for its elasticity. In making this steel, care should be taken to stir the materials during their fusion, before they are allowed to set. The iron filings should be as fully oxidised as possible before being used; for when the carbon is in excess, the steel produced is difficult to forge, except within a very narrow range of heat, and the proper temperature has to be carefully watched.

Indian steel is found very difficult to work in this country, in consequence of our workmen not studying the particular temperature at which alone the steel will forge easily. Experience, says URE, has taught that the orbicular veins which are seen upon the finest Eastern scimitars are the result of the manner of forging them, as well as the method of twisting the Damascus bars. If these be drawn in length, the veins will be longitudinal; if they be spread equal in all directions, the stuff will have a cylindrical aspect; if they be made wavy in the two directions, undulated veins will be produced like those in the Oriental Damascus.

The mode of manufacturing steel in the East, at the present day, is probably the same as was practised in the earliest age in which there is any reference in history to the use of that article. The iron is made from the magnetic oxide by the means which were formerly adopted in the old bloomeries. When about to be converted it is made into small pieces, and packed in

crucibles formed of clay. From one to two pounds of iron is put into each crucible with about one-tenth of its weight of chopped wood, and is then covered with clay to exclude the air. When the crucibles and covers are dry and well tempered, about twenty-four of these are built in the form of an arch within a small furnace; the whole are then covered over with charcoal, the mass is ignited, and the fire is kept up by a blast during from two to three hours, when it is allowed to go down, and the crucibles are removed. When cold, they are broken, and the steel is obtained in the form of a cake at the bottom. This product is known as Indian steel, or wootz, and is said to be superior to the best English steel for the purposes of fine cutlery.

BLISTERED STEEL, OR STEEL OF CEMENTATION, is largely manufactured in Great Britain, particularly in Sheffield. The furnace in which the operation is conducted is represented in Fig. 308. *c* is the grate and hearth; *AA* are chests or troughs made of the best

Fig. 308.



fire-clay; *aa* are flues leading to the chimney to assist the draught; and at the back is a door by which the men enter for the purpose of filling and emptying the troughs. The whole is built under a large cone or chimney, from forty to fifty feet high, resembling the dome of a glass-house.

The troughs are of various dimensions, according to the size of the furnace and the taste of the manufacturer, varying from eight to sixteen feet in length, and from two to three feet in width, and the depth generally corresponding to the width. Small troughs are considered to produce the most uniform quality of steel. They are so set in the furnace, that a space is left under and round the sides, to allow the flame of the fire to play all round them. The troughs are charged by laying first in the bottom a layer of about two inches of fine charcoal-powder, mixed up with one-tenth of ashes and common salt, which is technically called the *cement*. Upon this are placed the bars of iron, separated from each other about half an inch; and upon these is laid, to the thickness of one inch, more of the charcoal-powder, and then another layer of bars; and so on in successive strata, till the trough is filled to within a few inches of the mouth; the remaining space is filled up with old cement-powder, and there is then put upon the whole as a covering a layer of damp sand, or fire tiles.

The furnace is now fired, and heated carefully till the

temperature of the trough reaches about 100° Wedgwood, which should take from three to four days. This temperature must be steadily maintained until pieces of the metal, taken out by *proof-holes* at the ends of the troughs, show the process of conversion into steel to be complete, which requires, according to circumstances, from four to eight days. A few of the bars are allowed to project for this purpose. When the furnace is cooled, the troughs are opened and the steel-bars removed; they are found to be covered with blisters, and hence the term *blistered steel*. This steel is irregular in its texture, and has more or less of a crystalline appearance in proportion to the carbon absorbed. It is then subjected to the operation of tilting under powerful hammers, by which it is made more uniform, and fit for any useful process in tool-making. Good blistered steel should be of a greyish color, and possess a bright lustre, and should exhibit a coarse grain of a lamellar structure. That which is of a white color and fine-grained is inferior.

In the process of conversion much depends upon the degree of heat, and the regularity at which the heat is maintained, for producing a good article. No small experience is required for properly conducting these operations; and even with the most careful workmen, the charge occasionally proves bad. When the iron is good, it augments in weight during its conversion into steel; but bad iron increases very little. The best iron for making blistered steel is that from Sweden, although some English charcoal iron has occasionally produced very good steel.

SHEAR-STEEL.—Shear-steel is made from blistered steel; and is so called from the circumstance of the shears used for dressing woollen cloth being made from it, although it forms also the material of many other important manufacturing tools. It is prepared by binding together with a slender steel rod several short lengths of blistered steel, one of which is left longer than the rest, or a pole of iron is used for a handle, as shown in Fig. 309. The *fagot* is then put into the hearth of the forge, and brought to a welding

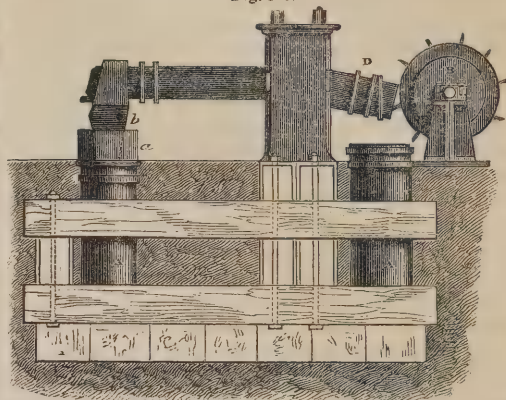
Fig. 309.



heat, a little sand being sprinkled over the bars, to produce a skin of scoria or glass over the surface, so as to protect them as much as possible from the air. The *fagot*, when removed from the furnace, is placed under a forge-hammer, which unites all the fragments, and closes up the internal fissures and cavities that always exist in blistered steel. A solid mass or bar is thus produced, which is again heated, the binding rings are knocked off, and the tilt-hammer, Fig. 310, comes into operation. This machine is similar in principle to the shingling hammer already described; but in shingling, where only a slow motion is required, the hammer is lifted up by means of levers attached to a cam revolving under the nose of the helve, whereas in the tilt-hammer the cogs of a wheel, *b*, are made to act upon the tail, *d*, of the helve, pressing it down, and thus causing an elevation of the head of the hammer

with a greater rapidity of motion, on account of the comparatively small arc described by the tail. The helve of the tilt-hammer is made of timber secured by

Fig. 310.



wrought-iron rings, and the head, which is also of iron, falls from two to four hundred times per minute upon the mass of steel, *b*, which is placed on the solid anvil, *a*. The workman is seated on a board suspended by iron rods from the ceiling of the mill-house, whereby he is enabled, with a slight motion of his foot, to advance or recede, and holding in his hand the pole, *o*, Fig. 309, to cause every part of the welded pile to receive the blows of the hammer in quick succession. By this operation, the steel is formed into bars of about an inch and a half broad, and three-eighths of an inch thick; all the seams and fissures of the blistered steel are closed, and it is now capable of being forged with the hammer into shears, edge-tools, and cutting instruments, or drawn out by rollers according to the use for which the metal is to be applied.

During these operations, even when great care is taken, the steel loses a portion of its carbon; and much attention is required to prevent its being reconverted into common iron. Shear-steel is more compact, malleable, and ductile than blistered steel, and much more easily wrought into shape.

CAST-STEEL is much harder, and much less malleable and ductile than shear or blistered steel, but may be wrought at a certain temperature; and, consequently, great care is required to notice the particular degree of heat required for the working of it. It is made by taking the most highly carbonised blistered steel, breaking it into convenient pieces, packing them into a crucible along with a little slag or broken glass to protect from oxidation, and fusing in a wind furnace. The crucibles for this purpose are made of very refractory clay, mixed with a small quantity of coke dust, and kneaded with the naked feet during five or six hours. This is put into a cylindrical mould of cast-iron, *a*, Fig. 311, which is open at both ends, and is inserted into a sole, *b*, also of cast-iron. In the centre of the sole, corresponding with the axis of the cylinder, is a hole to receive the supporting-rod of the inner mould, *c*, which consists of a block of hard wood. Through the centre of this block passes a strong iron axis, the upper part of which is rounded into a knob, *d*. The

surface of *c*, and the inner surface of *a*, having been smeared with oil, a quantity of clay is put into *a*, and the block, *c*, is then forced down by blows of a hammer, until the lower end of the axis, *d*, enters the hole in the sole, *b*. The black portion around *c*, shows a section of the crucible thus formed. To disengage it from the mould, the interior block or core is pulled out by means of the handle, *d*, and the hole made in the bottom of the clay by the lower end of the axis is filled up. The mould, *a*, is then separated from the sole, *b*,

Fig. 311.

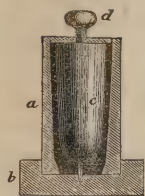


Fig. 312.



Fig. 313.



and the disc of wood which is seen on the tip of the iron rod, *t*, Fig. 312, is placed for a support under the exposed bottom of the crucible, to which it exactly fits. The exterior mould is then allowed to descend slowly, by which means the clay pot is left upon the top of the block of wood, as shown in the same figure. It is finished by hand, the top being pressed slightly inwards, and made to assume the form represented in Fig. 313. The crucibles are about two feet in height,

and weigh about twenty-five pounds. They are placed in short cylinders of clay, *e*, and the covers are thick discs, *f*, of the same material, slightly raised in the centre. Each crucible is removed as soon as it is finished into a heated vault, where it gradually becomes dry, and some hours before being used the crucibles are brought to a red heat, for the purpose of annealing them.

The furnace employed for melting the steel is simply a square prismatic cavity, of about fourteen inches on each side, and a depth of two feet. Iron bars are placed to support the fire. In most establishments several of these furnaces are so arranged along the walls, that the mouth is but a little above the floor of the foundry, for the convenience of the men lifting out and putting in the crucibles. The furnaces are also all connected to a chimney, so as to have a strong draught, and obtain a high temperature. The crucible, with its charge of steel, is inserted into the cavity or fireplace, then packed all round and over with coke, and a cover put on the mouth; and in a short time a powerful heat is raised, by which the steel, in the course of from three to four hours, is melted. The crucible is then removed from the fire, the cover taken off, and the steel poured into cast-iron moulds.

Cast-steel is much used for cutting and other edge-tools, being very hard. If a piece of polished iron be placed in the mould when the steel is cast, the iron and steel adhere, and may be rolled together. By this means many edge-tools are made, such as plane-irons, in which the part forming the edge alone is steel; so that not only a much cheaper article is produced, but one having the toughness of ordinary iron, while the cutting part has the hardness of the steel.

Another method of making steel, is by the conversion of cast-iron into what is termed *natural steel*. Much of this quality is prepared in Germany, where the best cast-iron is produced. As the presence of silica and earths in steel is very hurtful, it will be evident that only the purest cast-iron can be employed. The best for this purpose is that made from spathose iron ores, containing a small portion of manganese. The iron to be converted is cast into plates; a charcoal fire is kindled in a hearth, similar to that used for the refining of iron, and the iron plates are melted before the blast; to the fused mass is added a quantity of iron scale and rich scoria, which are considered to assist in the oxidising of the carbon in the iron.

The workman carefully watches the progress of the operation. After a small portion of the iron is melted, it is allowed to stand until, by the oxidising of its carbon, it becomes solidified into a pasty consistence; a little more cast-iron is melted into this, which renders the mass again fluid; after a time, the whole assumes once more its former state, and this operation is repeated, and continues until from three hundred to four hundred pounds of metal are added; care being taken to allow the melting iron to drop into the hearth in the centre of the charge, by which the mass acquires the appearance of a series of rings, the centre portion being fluid, and the rings becoming more and more pasty or spongy towards the circumference. After the scoria is let off, the whole mass of iron is removed from the hearth and cut into pieces in lines radiating from the centre to the circumference; these pieces are drawn into bars, but from the nature of the whole operation, different qualities of steel will exist in the same bar. To remedy this defect, the bars are made red-hot, and plunged into cold water, after which the refiner raises each bar by one end, and brings it down with a slight force upon an anvil placed upon the floor, by which means the most brittle parts of the steel break off, and are collected; after which the remaining portion of the bar is again brought down with a much harder stroke, which detaches other portions of the bar, and thus the different qualities are separated.

The parts broken off are examined, and, according to certain appearances of the fracture, are subjected to other manipulations, to give them density, which is done by welding together pieces of different qualities; the mass is afterwards tested in the same way by the refiner first heating it and plunging it into cold water, and then proceeding as before, repeating these operations till a perfect uniformity is obtained. The whole process must be watched carefully, as the metal gradually loses carbon, and would soon be reduced to common iron; to prevent this, the metal is covered during heating with a mixture of clay and oxide of iron, which forms a slag on its surface protecting it from the blast. These operations produce steel of very excellent quality, but it is at a considerable cost, both of time and material.

In those countries where German steel is made, a remarkable article is manufactured which deserves notice; it is harder than the best steel, and so brittle that it cannot bear any bending when cold. This article is cast-iron. It is derived from the remelted

steel-metal. From two hundred to two hundred and fifty pounds of this metal are melted down in the bottom of the forge hearth; a small portion of it is let off; it should be tapped as low at the bottom as possible. This mass, which flows like cast-iron or cast-steel, is broken into small pieces, and pounded into a flat piece of wrought-iron, which has a brim drawn up around it. This piece serves as a crucible. It is covered with loam, and exposed to a heat which will melt the cast-iron, and unite it firmly with the wrought-iron. The former then forms a thin coating of steel over the one side of the iron, of immense hardness. This does not become soft even though a long time is consumed in tempering it. Wrought-iron plates furnished with such a coating of steel, are used as draw-plates for wire. The holes for the wire are punched when it is warm, for, when cold, its hardness is so extreme that no drill-bit can make any impression on it.—*Overman.*

New Processes for Making Steel.—As may be supposed, a manufacture of such importance as steel could not fail to be the subject of many experimental trials and improvements, both in the processes of cementation and casting; and several patents have been taken out for new processes and modifications of the old. Some of these have been successful, and are included in the operations already described; while others have not been sufficiently economical or advantageous to warrant a change from existing plans. A curious and interesting process, considered in its chemical reactions, was suggested several years ago by Mr. MACINTOSH. His apparatus consisted of a furnace constructed in the form of a double cylinder, one surrounding the other, and containing the fire between them; the iron bars, to be converted into steel, were suspended in the internal cylinder; and, when they were at a red heat, there was passed through the interior cylinder a current of common coal-gas which the iron decomposed, combining with the carbon and becoming steel.

So great is the affinity between iron and carbon at a high heat, that at first sight the chemist is surprised to find the process not much more perfect than it really is; for experience teaches that there are many defects in the present modes of manufacture, from causes that have not yet been fully investigated, but which produce great irregularities in the quality and economy of the article. It may be that this same strong affinity between the constituents of steel, and the consequent ease with which the carbon will combine with the iron in different proportions, so as to produce different qualities of compound, may be the origin of the evils felt; and that to produce good steel the carbon and iron must be combined in a certain proportion. To take cast-iron having five per cent. of carbon in it, and at great expense and labor convert this, first into malleable iron by taking away the carbon, and then into steel by giving it back the carbon with equal labor and cost, seems a circuitous operation. If the difference between cast-iron and steel merely consist in the circumstance that the former contains more carbon than the latter, it would appear more consistent to deprive the cast-iron of just so much carbon as would

leave exactly the required proportion for making steel. Hence some such process as BESSEMER'S would seem the true course.

Upon this principle is based a patent of F. UCHARTINS, the specification of which sets forth the object of the invention to be, to reduce the cost of manufacturing cast steel by economizing the labor of the process. To this end, the inventor takes pig-iron of the purest quality, and melts it in a suitable furnace, and while in a molten state he runs the metal into cold water, and thereby reduces it into granulated iron. It is now in a suitable condition to undergo the process which will convert it into cast-steel. This mode is founded on the well-known fact, that cast-iron enwrapped or surrounded by any oxygenized materials, and subjected to a cementing heat for a given time, will yield up a portion of its carbon, which will combine with the oxygen driven off from the surrounding materials, and form carbonic oxide or carbonic acid gas. If this process is interrupted before completion, a partially decarbonized iron will result, the surface of which will have been converted into a pure iron, while the interior parts remain unchanged; or, in other words, the progress of the decarbonizing action will depend on the amount of metallic surface brought into contact with the oxygen-yielding material with which the iron is surrounded. In order, therefore, to expedite this operation, the pig-iron is reduced, as before mentioned, to a granulated state; and further to economize fuel and labor, the heat required for effecting the decarbonization of the iron is employed to reduce the metal, when sufficiently decarbonized, to a molten state; and thus by one and the same heating it is converted into cast-steel, which only needs to be forged to prepare it for the market. The granulated iron is mixed with about twenty per cent. of roasted pulverized sparry iron ore and four per cent. of fire-clay, and then placed in fire-clay crucibles, and subjected to heat in a cast-steel blast-furnace of an ordinary construction. By thus subjecting the granules of iron in presence of the sparry iron ore to a melting heat, the enwrapping oxides will first effect a partial decarbonization of the granulated iron, which decarbonization will be limited in amount according to the size of the granules operated upon; and by reason of the continued application of heat, the iron will melt and separate, with the assistance of the melting residues of sparry iron ore, from the impurities with which it was mixed, and also bring down with it a portion of the iron contained in the sparry iron ore, thereby increasing the yield of cast-steel by about six per cent.

The quality of the steel is capable of being by this process considerably modified. Thus the finer the pig-iron is granulated, the softer will be the steel made therefrom. The softer sorts of welding cast-steel may be obtained by an addition of good wrought-iron in small pieces, and the harder qualities by adding charcoal in various proportions to the before-mentioned mixture.

CASE-HARDENING.—Thin films of steel are formed upon the surface of iron articles, such as keys, gunlocks, tools, *et cetera*, by a process technically termed case-hardening. The article to be case-hardened is finished, or nearly so, in iron, and then heated to a bright red. When in this state, it is sprinkled or

rubbed over with powdered yellow prussiate of potassa—ferrocyanide of potassium. The salt is decomposed by the heat and iron, and the surface combines with the carbon of the salt, forming steel; or the operation may be performed by making a strong solution of ferrocyanide of potassium in water, then adding clay to make a thin paste. The iron article to be hardened is coated over with this paste, and dried slowly at a fire; it is then submitted to a white heat, and afterwards plunged into water when the heat has become reduced to a visible red.

TEMPERING.—One characteristic quality of steel is its being susceptible of having its hardness much increased by heating it strongly, and plunging it while hot into cold water. Different qualities of steel are affected in different degrees by this process of *tempering*. To know the degree of heat which is best fitted for any particular quality of steel, requires much experience. The practical test is to draw a bar into a tapered point, such as a chisel, and temper it; the thin tapered part will be variously affected in the process by the different rates of heat and cooling; by breaking off pieces from the point inwards the character of the grain will show the difference of temperature which has been applied; the finest and closest grain being considered the best. Such steel, then, is tempered with due relation to the test heat. The degree of hardness depends, in a great measure, upon the heat of the steel, and the coldness of the medium in which it is cooled. To give different effects different mediums are used, such as saline solutions instead of water. Mercury and oil are also employed. By this tempering process, steel may be made of any degree of hardness. The common method is to heat the steel and harden it in water, and then to anneal it, by reheating to a particular temperature, such, for instance, as that at which tallow or oil will burn when put on it; or the steel, being ground and polished, is then reheated, until it assumes a certain color, which indicates a certain degree of hardness. The gradations of the hues are a light straw, violet, blue, slate, and finally black. With this last color, the steel has become as soft as if it never had been hardened.

Several explanations have been offered of the changes in constitution through which the steel passes in the operations of tempering; but none of them are very satisfactory. It seems to be probable, says URE, that the ultimate molecules are thrown by the sudden cooling into a constrained state, so that their poles are not allowed to take the position of strongest attraction and greatest proximity, and hence the mass becomes hard, brittle, and somewhat less dense. The more sudden the cooling of ignited steel, the more unnatural and constrained will be the distribution of its particles, and also the more refractory, an effect produced by plunging it into cold mercury. This excess of hardness is removed in any required degree by judicious annealing or tempering. The state of the carbon present in the steel may also be modified by the rate of refrigeration, as, Mr. KARSTEN and M. BREANT conceive, happens with cast-iron and the damask metal. If the uniform distribution and combination of the carbon through the mass determine the peculiarity of white cast-iron, which

is a hard and brittle substance; and if its transition to the dark-grey and softer cast-metal be effected by a partial formation of plumbago during slow cooling,—why may not something similar be supposed to occur with steel, an analogous compound?

Alloys of Steel.—A few years ago, a series of experiments were made both in this country and on the Continent, to combine steel with other metals, for the production of an alloy or superior quality of steel. These experiments tended to show that steel, combined with very small quantities of platinum, silver, rhodium, or iridium, was much increased in hardness; but no extensive practical application ensued.

Composition of Different Kinds of Steel.—The whole operations in the manufacture of iron and steel, and their relation to each other, form a subject of great interest, and one which requires a thorough investigation—not confined to isolated experiments, but embracing both practical skill and chemical knowledge. One thing apparently essential to the production of good steel, is pure iron; but still, when the various qualities of steel have been analysed, there appears something which suggests further inquiry. The following are a few of these analyses:—

The first was a steel manufactured from iron produced from an ore of carbonate of that metal and manganese; it is termed Brescia steel, and is celebrated for hardness and elasticity. It is made in Styria, and is much used for cutlery; and gave—

	Centesimally.
Iron,.....	98.06
Carbon,.....	1.94
Sulphur,.....	trace
Silica,.....	trace
Copper,.....	trace
	100.00

The second was made from common Swedish iron, smelted from magnetic iron ore, which often contains silica, titanium, and copper; it was converted into steel in England, and is termed common English cast-steel. It was composed of—

Iron,.....	97.00
Carbon,.....	1.72
Silica,.....	0.22
Arsenic,.....	0.07
Copper,.....	0.07
Manganese,.....	0.02
	100.00

The third was made from Dannemora iron, smelted from magnetic iron ores. The steel was made in Sheffield, and is called best razor steel. It is uniform and hard, very fusible, and will not bear much heat. It gave—

Iron,.....	93.80
Carbon,.....	1.43
Sulphur,.....	1.00
Silica,.....	0.52
Arsenic,.....	0.93
Antimony,.....	0.12
Nitrogen,.....	0.18
Manganese,.....	1.92
Loss,.....	0.10
	100.00

The iron in the fourth was obtained from spathose iron ore, containing lime, copper, sulphur, silica, and

manganese. The steel was very tough, and known as Solingen or Siegen steel. It is admirably suited for swords. It gave—

Iron,.....	97.88
Carbon,.....	1.70
Sulphur,.....	trace
Silica,.....	0.04
Copper,.....	0.38
Tin,.....	trace
	100.00

The fifth and sixth were, like the first, made from Styrian iron which had been smelted from a carbonate of iron and manganese. Fifth is a very hard and brittle steel, and will not take a fine edge. The sixth is an inferior steel. They gave—

	5.	6.
Iron,.....	98.87	98.44
Carbon,.....	1.13	0.97
Sulphur,.....	trace	trace
Silica,.....	trace	0.50
Loss,.....	—	.09
	100.00	100.00

In comparing the composition of some of the malleable irons with No. 6, it would be difficult to say in what the difference consists, so far as the chemical composition is concerned. In wootz, or Indian steel, aluminium is found. As these different qualities of steel have each peculiar properties, rendering one more suitable for certain purposes than another, the question may be asked—Do these different properties depend upon the different impurities?

Mr. C. BINKS, in a series of interesting experiments upon the manufacture and true composition of steel, has advanced suggestions of very great importance. His experiments were conducted upon iron, submitted to different reagents, at a full red heat, as in case-hardening, or in the cementation-process. His results were as follow:—

1. That a small rod of iron packed in boxwood charcoal in a closed porcelain tube, and kept at a full red heat for twelve hours, did not, after being tempered, show a hard steel surface, nor did it exhibit, under high and different degrees of heat, the play of colors peculiar to real steel. It still remained malleable iron;

2. But when atmospheric air is admitted to such an arrangement, in such quantity only as still to keep the carbon in excess, then, in the first instance, the surface of the iron, and, finally, if the time of contact be long enough, the whole of the iron is converted into steel.

3. That the application to the iron of nitrogen gas does not produce steel.

4. That neither does the application of carbonic oxide give steel.

5. That the application to the iron of a hydrocarbon—as when olefiant gas is passed through the tube, or when the red-hot rod is dipped into oil containing no nitrogen—does not produce steel;

6. But that the application of olefiant mixed with ammoniacal gas, or the application of gaseous cyanogen, produces steel, as does also the dipping of the hot metal into a nitrogenised oil or fat.

7. That the application of ferrocyanide of potassium, as has been so long known, gives steel.

8. That equally with the ferrocyanide does the application of simple cyanide of potassium result in the production of steel; therefore, it is not to the iron contained in the ferrocyanide that the steel-making property of the latter salt is due.

9. That potassa applied to the hot iron, or the keeping the hot iron in the vapor of potassium, does not yield steel.

10. That with iron of the kind that has so far been referred to and used, *id est*, commercially pure wrought iron, containing no material proportion of carbon, the application to it of ammoniacal gas, or of nitrate of ammonia, fails to produce steel;

11. But that the application of ammoniacal gas or chloride of ammonium to iron containing a considerable proportion of carbon, ninety-five to five, results in its conversion into steel.

These results tabulated, and the composition of the reagents expressed in chemical formula, will better exhibit the inevitable deductions to which they lead:—

1. $\text{Fe} + \text{C}$ —in excess, every other element excluded,.....} leaves iron.
2. $\text{Fe} + \text{C}$ —in excess + atmospheric air,.....} gives steel.
3. $\text{Fe} + \text{N}$ —nitrogen,.....} leaves iron.
4. $\text{Fe} + \text{C O}$ —carbonic oxide,.....} leaves iron.
5. $\text{Fe} + \text{H}_4 \text{C}_4$ —olefiant gas,.....} leaves iron.
6. $\text{Fe} + \text{H}_4 \text{C}_4$ —in excess + NH_3 —ammoniacal gas,.....} gives steel.
7. $\text{Fe} + \text{N C}_2$ —cyanogen,.....} gives steel.
8. $\text{Fe} + \text{K}_2 \text{Fe Cy}_3$ —ferrocyanide of potassium,.....} gives steel.
9. $\text{Fe} + \text{K Cy}$ —cyanide of potassium,.....} gives steel.
10. $\text{Fe} + \text{KO}$ —potassa,.....} leaves iron.
11. $\text{Fe} + \text{K}$ —potassium,.....} leaves iron.
12. $\text{Fe} + \text{NH}_3$ —ammoniacal gas,.....} leaves iron.
13. $\text{Fe} + \text{N H}_4 \text{Cl}$ —chloride of ammonium,.....} leaves iron.
14. $\frac{\text{Fe} + \text{C}}{95 \quad 5} + \text{N H}_3$ —ammoniacal gas,.....} gives steel.
15. $\frac{\text{Fe} + \text{C}}{95 \quad 5} + \text{N H}_4 \text{Cl}$ —chloride of ammonium,.....} gives steel.

The conclusions drawn from these experiments are thus stated by the author:—

That the substances, by the application of which to pure iron it is converted into steel, all contain nitrogen and carbon, or nitrogen has access to the iron during the operation.

That carbon alone added or applied to pure iron does not convert it into steel.

That nitrogen alone so added or applied does not produce steel; but that it is essential that both nitrogen and carbon should be present, and that no case can be adduced of conversion in which both of these elements are not present and in contact with the iron.

That both nitrogen and carbon exist substantially in steel after its conversion; and the presence of both is the real cause of the distinctive physical properties of steel and of iron, in which latter these elements do not exist.

That presumptively, but not demonstratively, the form of combination is not that of cyanogen—though that compound plays so important a part in conversion—but is that of a triple alloy of iron, carbon, and nitrogen.

Lastly, that experimental research is yet required to determine the relative proportions of the elements when their union gives pure steel.

The reader will perceive that these investigations and their results are deeply interesting, and throw an entirely new light on the composition of steel. May not

the nitrogen take the place of that portion of carbon which is eliminated from the cast-iron during the process of its conversion?

Passive State of Iron.—The curious property which iron exhibits of passing into what has been termed the *passive state*, may not be entirely without its effects upon the different conditions and combinations of this metal. It shows, at all events, that its molecules are easily thrown into a peculiar condition in relation to other bodies; as, for instance, if a piece of iron is put into nitric acid of specific gravity 1·3 to 1·35, it dissolves freely with effervescence; but if a piece of platinum wire be placed in the acid, and then the iron be introduced in contact with the platinum, the acid will not now act upon the iron, even if the platinum is withdrawn. Another piece of iron put into the acid in contact with the previous piece, will become affected in the same way; and so on with a third or with more pieces, so that this simple contact effects some important change in the molecular state of the metal. A great many other methods are known of making iron passive—by oxidising one extremity in the flame of a lamp; by making it the positive pole of a battery; by a blow; by previous immersion in concentrated nitric acid, *et cetera*. This peculiar condition can be easily annulled by rubbing the piece of passive iron, or bringing it into contact with active iron. These phenomena are not yet satisfactorily explained, and ought not to be overlooked in any investigation into the properties of iron, even with reference to its chemical applications.

ALLOYS OF IRON.—Cast-iron and steel, which are compounds of iron and carbon, with perhaps nitrogen, do not properly fall under the designation of alloys, which are compounds of two or more metals.

Iron combines, however, with several other metals, and forms alloys, some of which are interesting to the chemical inquirer; but few of them have much practical value.

With potassium iron forms an alloy, which is white, malleable, and so soft as to take impressions from the nails of the hand, oxidising easily in the air.

With the metals of the earths iron combines, and produces hard, white, and brittle alloys of no known value; but it appears capable of taking up only a small quantity of these metals.

Iron combines with titanium, which is often found with it in the products of the blast furnace; but it seems incapable of taking up any great quantity of that metal; for, although the two metals are fused together, they readily separate, and only a small portion of the titanium remains with the iron.

Iron and molybdenum form an alloy of a bluish-grey color, hard, brittle, fine-grained, and magnetic. When formed of equal parts of the two metals, this alloy is fusible before the blowpipe; but if formed of two parts of molybdenum and one part of iron, it is not so. The following curious and interesting analyses of pig-iron, containing molybdenum in quantity along with other metals, are taken from GMELIN'S *Handbook of Chemistry*:—

	I.	II.	III.	IV.	V.	VI.	VII.
Calcium,	—	—	—	—	—	0·29	trace
Magnesia and alumina,	—	—	—	—	—	—	trace
Manganese,	—	—	0·01	0·02	0·12	0·14	—
Iron,	57·91	73·26	74·60	76·77	73·11	81·14	50 to 80
Cobalt,	0·67	0·77	3·07	3·25	4·16	2·40	trace
Nickel,	3·42	4·63	1·28	1·15	0·84	trace	1 to 6
Copper,	2·45	1·79	4·32	3·40	5·34	7·69	2 to 4
Silver,	—	—	—	—	trace	—	—
Molybdenum,	28·49	9·13	10·19	9·97	5·28	0·08	10 to 30
Silica,	—	—	0·39	0·35	1·83	1·94	—
Carbon,	0·87	1·42	0·48	0·38	1·20	0·69	trace
Arsenic,	—	—	2·47	1·40	2·70	1·82	—
Phosphorus,	3·52	6·05	2·27	1·25	1·38	0·81	2 to 5
Sulphur,	0·60	0·09	0·92	2·06	2·94	0·62	trace
Loss,	0·07	2·86	—	—	1·10	2·38	—
	100·00	100·00	100·00	100·00	100·00	100·00	

I. Pig-iron from the upper works at Eisleben, obtained in the fusion of bituminous marl-slate in smelting furnaces; fine-grained.

II. Ditto; coarse-grained.

III. The so-called Magdeburg meteoric iron, containing slag mixed with bronze, yellow copper cinder, probably the pig-iron from a copper furnace; fine-grained sample.

IV. Ditto; coarse-grained sample.

V. The same substance, analysed by WEHRLE.

VI. Pig of iron found in the neighborhood of the *Rothehütte* in the Hartz.

VII. Pig of iron found underground at Sauchstadt.

Iron and manganese combine together, forming an alloy whiter and more brittle than iron; and when the proportion of manganese is about twenty-two per cent., the alloy ceases to have magnetic properties.—*Mushet*.

Arsenic and iron combine and form alloys of a white color, hard and brittle. When fifty-four parts of iron filings and one hundred and eight parts of arsenic are ignited together in a close vessel, they combine into an alloy which does not fuse, but is easily pulverised,

and is composed of two equivalents of iron and one equivalent of arsenic.—*Gehlen*.

Iron and antimony, when heated together, fuse into a mass with combustion. When one equivalent of antimony and three of iron combine, they form a hard, brittle alloy, slightly magnetic, and having a density below the mean given by calculation. The alloy of one part of iron and two parts of antimony gives sparks when filed.

Iron and bismuth form a very brittle alloy. It is attracted by the magnet when the iron is only one-fourth of the bismuth.

Iron and zinc combine with difficulty, producing alloys that are very brittle.

Iron and lead do not readily combine. When slag containing lead and iron were reduced together, a brittle alloy was formed of a steel-grey color, and magnetic, composed in one hundred parts of—

Iron,.....	96.76
Lead,.....	13.24
	100.00

Iron and tin combine together in various proportions. Twenty-two parts tin and one part of iron give an alloy much harder than tin, and magnetic. Two parts iron and one part tin give a white, hard, and slightly malleable alloy, and difficult to fuse. In recovering the mercury used in silvering glass, an alloy of tin and iron is obtained, having the following properties:—Specific gravity, 8.733; brittle, and fuses at a white heat; when in powder, and put into the flame of a candle, it burns with emission of sparks and a white smoke; and does not rust when moistened with water and exposed to the air; it is composed of—

Iron,.....	57.86	57.9
Tin,.....	42.14	42.1
	100.00	100.00

being equivalent to $\text{Fe}_3 \text{Sn}$.

Nickel and iron combine and form a very hard alloy, which is that found in meteoric stones. Cobalt, copper, silver, gold, platinum, palladium, and other more rare metals, all combine in small proportions with iron, producing alloys of no known value in the arts.

STATISTICS.—The following table from a paper by Mr. KENYON BLACKWELL, on the Iron Industry of Great Britain, which was read before the Society of Arts a few years ago, gives the estimated production of crude iron in the principal countries of Europe at that period:—

	Tons.
Great Britain,.....	3,000,000
France,.....	750,000
United States,.....	750,000
Prussia,.....	300,000
Austria,.....	250,000
Belgium,.....	200,000
Russia,.....	200,000
Sweden,.....	150,000
Various German States,.....	100,000
Other countries,.....	300,000
	6,000,000

It will be seen, therefore, that Great Britain produces as much crude iron as all the other countries put together. The subjoined statement, extracted from the Mining Records, published under the direction of Mr. R. HUNT, in connection with the Museum of Practical Geology in London, gives the state of the manufacture in Great Britain in 1854:—

Counties.	Number of works	Number of furnaces erected.	Number of furnaces in blast.	Total produce in tons.
ENGLAND:—				
Northumberland, Durham, and Yorkshire,.....	37	106	80	348,444
Derbyshire,.....	13	33	25	127,500
Lancashire and Cumberland,.....	2	5	3	20,000
Staffordshire,.....	72	203	166	847,600
Shropshire,.....	13	34	28	124,800
Gloucestershire,.....	4	7	5	21,990
WALES:—				
Flintshire, Denbighshire,.....	7	11	9	32,900
Glamorganshire—anthracite district,.....	14	35	21	750,000
Glamorganshire and Monmouthshire—bituminous dis- trict,.....	34	134	100	
SCOTLAND:—				
Ayrshire,.....	9	41	30	249,600
Lanarkshire,.....	13	88	72	468,000
Other counties,.....	10	27	16	79,040
	228	724	555	3,069,874

The importance which Scotland has assumed in reference to the iron manufacture, as shown in the preceding table, is well worthy of notice. This appears still more strikingly in the following statement given by TRURAN for 1855:—

District.	Number of furnaces.	Mean weekly produce of each furnace.	Annual production of crude iron in tons.
South Wales,.....	169	118	1,042,776
Do., anthracite,.....	37	72	139,880
Dean Forest, North Wales, and Lancashire,.....	33	67	115,460
South Staffordshire,.....	169	108	948,520
North Staffordshire,.....	19	104	102,960
Derbyshire,.....	30	101	158,080
Shropshire,.....	34	86	151,720
Yorkshire,.....	31	72	116,480
Northumberland,.....	79	132	541,320
Scotland,.....	145	145	1,082,640
Total,.....	746	113	4,399,836

Sheffield and its neighborhood is the great seat of the steel manufacture. The annual quantity of steel produced during the last five years, says TOMLINSON, varies from sixteen thousand to seventeen thousand tons from foreign iron, and from one thousand five hundred to two thousand tons from iron of British manufacture. The number of converting furnaces is upwards of one hundred and twenty, each of which is capable of converting weekly six tons of iron; the coal consumed in the process is about equal to the weight of steel produced.

The cost of converting cast into malleable iron averages about three pounds per ton. Mr. TRURAN states that the conversion of Scotch pig-iron into bars is largely pushed in Wales; and that the bars so manufactured, after paying freight from and to Glasgow, undersell the produce of local manufactories of bar or malleable iron.

About three-tenths of the quantity of iron produced, says MACCULLOCH, is used in the state of pig or cast-iron, and is consumed principally in Great Britain and Ireland. The exports of pig-iron, however, amounted in 1850 to about one hundred and forty-two thousand tons, sent principally to the United States, Holland, Prussia, France, and British North America. The other seven-tenths are converted into wrought-iron, being formed into bars, bolts, rods, *et cetera*. The exports of bar-iron amounted in 1850 to nearly four hundred and forty-three thousand tons; and, during the same year, the exports of all sorts of iron reached the prodigious amount of seven hundred and eighty-three thousand four hundred and twenty-three tons, which, at seven pounds a ton, would be worth five million four hundred and eighty-three thousand nine hundred pounds sterling. And their declared value did in fact amount, in 1850, to five million three hundred and fifty thousand and fifty-six pounds sterling.

SALTS OF IRON.—It has been shown that iron is susceptible of two definite degrees of oxidation, forming a protoxide— Fe O —and a sesquioxide— $\text{Fe}_2 \text{O}_3$. Both these oxides are salifiable, giving rise to ferrous and ferric salts. The most important is the native *protocarbonate*, which constitutes the principal source of British iron, and has, therefore, been fully described in treating of the ores of this metal.

Protonitrate— Fe O, NO_3 —is formed when very dilute nitric acid is digested upon iron filings; but is a very unstable compound, and passes into *pernitrate* by exposure to the air. The latter is a deep-red liquid, occasionally used in dyeing.

Protochloride— Fe Cl —results from transmitting dry hydrochloric acid gas over iron at a red heat, when hydrogen gas is evolved, and the surface of the iron is covered with a white crystalline protochloride. Also, by acting with hydrochloric acid on iron, evaporating to dryness, and heating to redness in a tube without exposure to the air. It dissolves freely in water, yielding a pale-green solution, from which rhomboidal prisms of the same color are obtained by evaporation. The aqueous solution absorbs oxygen from the air, and becomes yellow from the formation of sesquichloride.

Sesquichloride— $\text{Fe}_2 \text{Cl}_3$ —is formed by the combustion of iron wire in dry chlorine gas, or by transmitting that gas over iron moderately heated, when it is obtained in small iridescent plates of a red color, which deliquesce readily, and dissolve in water, alcohol, and ether. The readiest mode of obtaining it in solution, is to dissolve sesquioxide of iron in hydrochloric acid.

But the only salts of iron of great commercial importance are the *protosulphate* or *green vitriol*, and the double haloid salt, the *ferrocyanide* of iron, better known as *prussian blue*. To these the Editor will, therefore, confine his attention in what follows; but, in connection with the latter, it will be necessary to describe the preparation of another important salt, in which iron occurs as an element, the *sesquiferrocyanide of potassium*, known commercially as *prussiate of potassa*.

PROTOSULPHATE OF IRON.—Syn. Green Vitriol, Copperas; *Couperose verte*, French; *Eisenvitriol*, VOL. II.

Schwefelsaures Eisenoxydul, German.—This salt, which has many important applications, is usually formed for medicinal and chemical purposes by dissolving iron filings or turnings in dilute sulphuric acid, filtering and evaporating the solution, and setting it aside to crystallize. The crystals are sea-green, transparent, rhomboidal prisms, and have a strong styptic inky taste. Exposed to dry air, they effloresce; in moist air, the salt gradually absorbs oxygen, and is partly converted into a sesquisulphate, becoming of a rusty or reddish color, whence the French term *couperose*, corrupted into the English name *copperas*. BONSDORFF has shown, that when perfectly pure it does not change vegetal blues, though generally stated to do so, the reddening effect being only produced when some of the iron of the protoxide passes into a higher state of oxidation. It is soluble in two parts of cold, and in three-fourths of its weight of boiling water. Crystallized protosulphate of iron contains seven equivalents of water, and is, therefore, represented by the following formula, $\text{FeO, SO}_3 + 7 \text{HO}$. When heated, it fuses in its water of crystallization, and at 238° loses five equivalents of water, but retains one equivalent till heated above 535° . At a red heat, it evolves anhydrous sulphuric acid, and by this process sulphuric acid used formerly to be prepared; hence it was termed *oil of vitriol*. The residue, consisting of *peroxide* of iron, which remained in the vessel, was known under the name of *Caput mortuum vitrioli*, or *colcothar*. The fuming sulphuric acid is still prepared from the protosulphate in this manner.

The copperas of commerce is usually prepared from the pyritous schists of the coal measures, in connection with the manufacture of alum. By referring to the article on that subject—Vol. I., pp. 155–7—it will be seen that iron pyrites, or the bisulphide of iron— Fe S_2 —is present in very large proportion in many aluminous schists, and that it is quite as indispensable to the production of alum as the alumina itself. When the schists are subjected to calcination in heaps, the sulphur of the bisulphide of iron absorbs oxygen from the air, by which it is converted into sulphuric acid, and this combines with the other ingredients, forming a sulphate of alumina and protosulphate of iron. These salts are extracted by lixiviation in the same waters; and therefore the next operation is to separate the iron salt from the aluminous, when both have been obtained in solution in the same vat. For this purpose the solution is evaporated in large cisterns, by carrying the flue of a furnace over its surface, and when sufficiently concentrated is run into coolers, where the sulphate of iron crystallizes, and the sulphate of alumina, being the much more soluble salt, remains in the mother-liquors. The process of separating the two salts by crystallization varies, however, in different manufactories, according to the quantity of sulphate of iron present; and the various methods adopted, with the nature of the changes that occur, will be found fully explained in the article already referred to.—See Vol. I., page 162.

The commercial article, prepared as above-described, is by no means pure; but generally contains a small proportion of alum, of the sesquisulphate, and other

ingredients, some of which increase its value for particular purposes. In dyeing black, for example, that copperas is preferred which contains sesquisulphate, and is known by its darker green color. The excess of acid in some kinds of copperas is objected to; and those in which the crystals are small do not fetch so high a price as when the crystals are large. The following table, from PAYEN, indicates the composition of specimens from different French manufactories:—

	Paris.	Honfleur.	Noyon.	Forges.
Water,	47.5	48.7	48.40	46.60
Acid in excess,	3.4	1.5	—	—
Sulphate of {	47.9	49.5	46.80	48.00
	0.8	0.2	1.11	1.90
	0.3	0.1	0.19	0.95
	—	—	0.99	0.35
	0.1	—	—	—
Alum,	—	—	2.51	2.20
	100.0	100.0	100.00	100.00

It will be observed from the preceding table that the copperas prepared at Paris and Honfleur is absolutely free from copper and alum, and is, therefore, of very great purity. This arises from the fact that in those localities it is prepared by the direct process, instead of obtaining it from the pyritous shales in connection with the manufacture of alum.

The original materials employed are iron turnings and shavings, obtained from establishments where such operations are conducted, and sulphuric acid of 18° or 23° Twaddell, which is also a residue obtained from the rectification of certain lamp-oils. The acid is poured into rectangular copper vessels, strengthened by iron plates, and heated by means of a fire below, the flames of which play under and around the sides of the vessels. The iron turnings, previously sifted, are then introduced, agitating from time to time with wooden stirrers, and adding more turnings in proportion as they dissolve in the liquid. The oxidised portion of the iron dissolves directly; the more abundant metallic portion becomes oxidised by seizing on the oxygen of the water, and causing the disengagement of its hydrogen, mixed with different volatile products arising from the rectification of the oils and other organic matters. These gases and vapors are given off with the steam, and the liquid is maintained for eighteen to twenty hours in a state of constant ebullition, by which it is gradually more and more concentrated. The strong and offensive odor exhaled during this operation would greatly inconvenience the neighborhood, were not the precaution taken to cover the boiler with a hood, from which the gases and vapors are conveyed through a wide tube into a tall chimney creating a powerful draught.

When the concentration has reached its proper limit, which is known by observing the crystallization when some drops of the solution are put upon a plate of porcelain or earthenware, the liquid is drawn out with a pump constructed of copper, and flows by a gutter into a cellar, where it is left for a period of eighteen to twenty-four hours, to deposit the matters in suspension. The clear solution is then transferred by means of a siphon into sluices, by which it is conducted into other vats, measuring about seven feet in diameter, by three or four in depth.

These are the crystallizing vats. Planks are laid

across them, pierced with holes, through which slips of wood are suspended vertically in the solution. The crystals which form on the sticks, and on the sides of the vat, are transparent, and exhibit the ordinary green color. At the end of eight or ten days, if the temperature of the air be not too high, the crystallization is finished; and the mother-water is made to flow out, to be conveyed back to the boiler along with the sulphuric acid and iron turnings. The sticks are taken out, and the crystals at the bottom, mixed with the deposited sediment of impurities, are taken to be redissolved. The crystals adhering to the sticks, and to the sides of the vat, are detached and rapidly dried, to avoid the formation of a rust-colored salt, which would tarnish the crystals. They are then put into barrels for the market.

Copperas is extensively used in dyeing black, especially for hats; in making ink and prussian blue; for reducing indigo in the blue vat; in calico-printing; and in many chemical and medicinal preparations. Its value as an ingredient in dyeing black, and in making ink, arises from the special reaction of the iron with the tannin contained in nut-galls, oak-bark, catechu, and different tinctorial substances. It promotes the solution of the indigo by a deoxidation of the coloring principle. On these applications, see the articles DYEING and INK. Copperas is used also for the decomposition of chloride of sodium in the fabrication of soda, and in making the *protoacetate of iron*, for which see Vol. I., page 41.

Sesquisulphate of Iron.—This salt— $\text{Fe}_2 \text{O}_3, 3 \text{SO}_3$ —is formed by mixing with a solution of the protosulphate exactly half as much sulphuric acid as that salt contains, and adding to the mixture in a boiling state successive portions of nitric acid until nitrous fumes cease to appear. The solution is then evaporated to dryness to expel the excess of nitric acid, and the sesquisulphate remains as a white salt. It is formed in the mother-waters of the protosulphate, and, according to DUMAS, the two salts are capable of crystallizing together and forming a kind of double salt. It is this combination which imparts to much of the protosulphate of commerce a dingy grass-green color, whereas the pure sulphate of the protoxide furnishes hydrated crystals which are of a bright bluish-green.

FERROCYANIDE OF IRON.—Syn. PRUSSIAN BLUE; *Bleu de Prusse*, French; *Berliner blau*, German.—This celebrated pigment was accidentally discovered by DIESBACH, a color-maker at Berlin, in 1710, from which it became generally known as Prussian or Berlin blue. The first description of the mode of preparing it was given by WOODWARD in the Philosophical Transactions for 1724. It is a compound of iron and cyanogen, and, therefore, its true composition was unknown till the latter body was discovered by GAY-LUSSAC in 1815.

At common temperatures and pressures, cyanogen is a colorless gas, and has a penetrating and peculiar smell, somewhat resembling that of bitter almonds. It was so named by its discoverer, from two Greek words—*kuanos*, blue, and *gemmao*, to produce—because it is essential to the formation of *prussian blue*.

It is composed of two equivalents of carbon and one of nitrogen; its formula is, therefore, C_2N ; its symbol is Cy, and its equivalent 26. It unites as a compound radical with oxygen, hydrogen, and most other non-metallic elements, and also with the metals. United to one equivalent of hydrogen, it forms *hydrocyanic* or *prussic acid*, which is, therefore, expressed by the formula $H\text{Cy}$, or NC_2H . In combination with iron, cyanogen forms a variety of double compounds, the composition of which is best explained by assuming the existence of a radical which contains one equivalent of iron in combination with carbon and nitrogen in the same proportion as they exist in cyanogen, but in such quantity as would form three equivalents of the latter, and which radical, by uniting with two equivalents of hydrogen, forms a bibasic acid. This hypothetical radical— $Fe + 3\text{Cy}$ —is termed *ferrocyanogen*, and its symbol is Cfy ; the acid— $Cfy + H_2$ —is termed hydroferrocyanic acid; and the compounds of the radical with the metals are distinguished by the same adjuncts to ferrocyanide as are used for the corresponding oxides.

Prussian blue is regarded as a compound of three equivalents of ferrocyanogen with two of iron, and its composition is therefore expressed by the formula $3\text{Cfy} + 2\text{Fe}$, or $Fe_2\text{Cy}_6$. It is formed whenever a salt of sesquioxide of iron is added to a soluble metallic ferrocyanide. The usual method is to precipitate a solution of sesquichloride or sesquinitrate of iron by ferrocyanide of potassium; and in point of fact a very important part of its manufacture consists in the preparation of this latter salt, which will now be described.

Ferrocyanide of Potassium, better known as *prussiate of potassa*, may be viewed as a double cyanide of iron and potassium, $Fe\text{Cy} + 2\text{K Cy}$. It is prepared on a large scale by fusing substances which are rich in nitrogen, as horn, hoof, and dried blood, with carbonate of potassa, in *iron* vessels. The result of the fusion, at a red heat, is a dark-grey mass, which, when lixiviated with boiling water, yields a solution which the Germans call *blutlauge*, or *blood-lic*, and when this has been sufficiently concentrated, it affords, on cooling, crystals of *yellow prussiate of potassa*, which are composed as follows:—

	Centesimally.
1 Eq. cyanide of potassium,.....	61.80
1 Eq. cyanide of iron,.....	25.47
3 Eqs. water,.....	12.73
	100.00

The crystals are transparent, of a lemon-yellow color, and are found in large quadrangular plates or short prisms, with truncated edges and angles, which belong to the square prismatic system. They dissolve in four parts of cold, and in two of boiling water. They are permanent in the air at common temperatures, but at 212° lose their water of crystallization, without changing their form, and acquire a whitish color.

Ferriidcyanide of Potassium or *Red prussiate of potassa*, is formed by passing a current of chlorine through a solution of the yellow prussiate, until a portion of the liquor, taken for trial, is found to give no precipitate with a salt of sesquioxide of iron. The solution is

then filtered and evaporated *in vacuo* by means of sulphuric acid, when small acicular crystals of a garnet-red hue are obtained; and on purifying by successive crystallizations, the *red prussiate* is obtained in large transparent crystals, combining with a ruby-red tinge an almost metallic lustre. These crystals are anhydrous, and are composed of—

	Centesimally.
3 Eqs. cyanide of potassium,.....	59.20
1 Eq. sesquicyanide of iron,.....	40.80
	100.00

This salt—the formula of which is $K_3\text{Cy}_6\text{Fe}_2$ —is formed by the abstraction of one equivalent of potassium from two equivalents of the yellow salt. The red salt is used in calico-printing, and both are employed in *de laine* printing, as well as in dyeing wool; the blue from the red prussiate being found more durable when fixed by binocide of tin.

In most metallic solutions the two prussiates occasion precipitates of a characteristic color, which renders them of great importance in analytical chemistry, especially in qualitative analyses. In these reactions, the metal in solution takes the place of the potassium, and the resulting products are a soluble salt of potassa, and a double cyanide of iron and of the metal in solution, which, being usually insoluble, is precipitated.

With *protoxide of iron*, the red prussiate gives a dark-blue precipitate; the yellow prussiate, a white precipitate, which almost immediately becomes blue when exposed to the air.

With *sesquioxide of iron*, the red prussiate gives no precipitate; the yellow prussiate, a dark-blue precipitate, which is *prussian blue*—

	Centesimally.
3 Eqs. cyanide of iron,.....	46.00
2 Eqs. sesquicyanide of iron,.....	54.00
	100.00

In the process which is usually followed for the fabrication of prussian blue, the product obtained has always a variable composition; because, instead of employing pure sesquioxide of iron, use is made of the sulphate of the protoxide or *green vitriol*, which is only partially converted into sesquisulphate, and still retains a greater or less proportion of protosulphate. This last gives, with the yellow prussiate, a white precipitate, which, as above stated, becomes blue by absorbing oxygen from the air, and forms a basic salt, which is distinguished from the true prussian blue by its solubility in pure water, giving it a fine blue color. This basic salt must not be confounded with another blue which is obtained by pouring slowly the sesquinitrate of iron into a solution of prussiate of potassa, keeping the latter constantly agitated. In this case the precipitate produced is partly soluble in pure water, which it colors a fine dark-blue. On evaporating the menstruum to dryness a brilliant residue is obtained, which has the appearance of a varnish, is almost completely soluble in water, and consists of a combination of neutral prussian blue with the yellow prussiate of potassa.

The insoluble prussian blue is found in lumps more

or less compact, with a dull fracture, of a dark-blue color presenting a reddish reflexion, but assuming, when rubbed, a fine metallic bronze lustre, and altogether much resembling indigo. It is completely soluble in water and alcohol, and is not affected by dilute acids. Concentrated sulphuric acid converts it, in the cold, into a whitish pasty mass, which, when diluted with water, becomes decomposed, and gives a precipitate of prussian blue. Heated with concentrated sulphuric or nitric acid, it is completely decomposed, and the subsequent addition of water no longer produces a blue precipitate. Potassa, soda, and their carbonates, baryta, strontia, and caustic lime, precipitate the iron of its cyanide in the form of sesquioxide, and there is formed an alkaline or earthy cyanide, which combines with the cyanide of iron to constitute a soluble double salt. If, for example, potassa be employed, the yellow prussiate will be reproduced; and in point of fact this is the best process for obtaining that salt in a state of purity. When prussian blue is digested with red oxide of mercury and water, the blue color disappears; there is formed cyanide of mercury, which dissolves, and a clear brown precipitate remains, formed of cyanide and sesquioxide of iron.

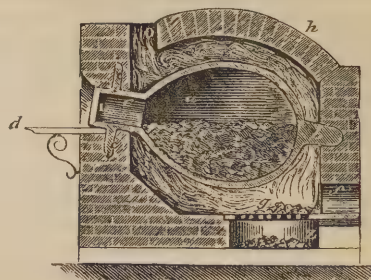
Manufacture of Ferrocyanide of Potassium.—This operation consists, as previously stated, in heating to redness nitrogenous organic matters, such as dried blood, horn, hair, skin refuse, and other offals, along with carbonate of potassa and iron. The animal matters may either be employed in the crude state, or after being subjected to a previous calcination. The latter method is generally adopted, because it permits of extracting, by a preliminary distillation of the nitrogenous substances, a considerable quantity of carbonate of ammonia, which may be converted either into chloride of ammonium, or directly into caustic ammonia—products of so much commercial value that prussian blue is generally a mere secondary product of the manufacture of ammoniacal salts.

All the residues of the calcination, or of the distillation of animal matters, are fitted for the fabrication of prussiate of potassa, with the exception of animal black, which, in consequence of the great quantity of phosphate of lime contained in it, would produce, by calcination with the carbonate of potassa, a corresponding quantity of phosphate of potassa instead of prussian blue.

The product of the preliminary calcination of the crude materials is ten to thirteen per cent. of animal charcoal, which is finely pulverized, and mixed very intimately with pearlash of good quality, as free as possible from sulphate, in the proportions of one and a half to two parts of charcoal to one part of potassa. The latter may be dissolved in the smallest possible quantity of water, which has the advantage of separating the foreign salts, and especially the sulphate—these being insoluble in a very strong solution of potassa; this concentrated menstruum is made into a paste with the charcoal powder, and the whole is then exsiccated. In this way the potassa is made to penetrate the pores of the charcoal, and the mixture is much more intimate than can be procured by any mechanical process.

The whole is then heated in a kind of retort, until brought to a state of pasty fusion, at which it is maintained. The retort employed is of cast-iron, very thick, somewhat varying in its shape, but which in all cases should have the mouth or neck rather narrow, to admit of being easily closed up. The form most generally adopted is represented in Fig. 314; the body of the retort, *a*, is ovoidal; it is supported at the back by a projection, *b*, which rests in the wall of the furnace; the neck, *c*, is cylindrical, and is kept firm in its place

Fig. 314.



by two lateral projections, *c c*. The mouth of the retort is closed by means of the lid, *i*, and in front of the opening is the working plate, *d*, which consists of an iron or stone slab, supported externally by a bracket; *g* is the grate on which the fuel is introduced through the charging-door, *f*; *z*, the ash-pit; *h*, the vault of the furnace; and *o* the flue which conducts the products of combustion into the chimney.

The retort is about half-filled with the mixture above-mentioned, and at first it is heated gradually by charging the grate with fuel. As soon as the retort arrives at a red heat, the mouth is closed by means of the lid, *i*, and the fire is then kept up just sufficiently to maintain the same temperature. Every quarter of an hour the plate, *i*, is removed for an instant, in order to agitate the pasty mass as quickly as possible with an iron rabble. During this operation combustible gases are disengaged, which inflame at the mouth of the retort every time it is opened. The quantity of these gases diminishes as the process proceeds, and this is considered to be completed when all flame disappears. The first operation lasts, on the whole, about twelve hours, including in that period the time necessary to heat the furnace and the retort; the subsequent operations, when the mixture is introduced into the retort already heated to redness, require only eight hours.

An inconvenience which has not hitherto been satisfactorily overcome, and which considerably increases the price of prussiate of potassa, is the circumstance that the iron which enters into its composition is supplied at the expense of the retort itself. The lower part of the vessel is thus worn away, and often very unequally, so that it breaks out into holes. Hence it is necessary to give it in the first instance a thickness of one or two inches, and this requires that, in order to produce in the interior of the retort a suitable temperature, the furnace be heated to a bright red, which rapidly consumes the outside of the retort. Attempts

have been made to add directly to the mixture of animal charcoal and potassa, iron very finely divided in the shape of filings or turnings, but not hitherto with that success which was anticipated. When a hole appears in the lower part of the retort, it is turned half round on its axis, the hole is stopped up with iron cement, and the retort is thus made to serve for a new series of operations.

When the fusing process is completed, the molten mass is scooped out with an iron shovel, having a long handle, and is thrown into an iron pan, in which it is shut up and left to cool. The soluble matters are then thoroughly drained out with boiling water, and filtered through woollen cloths. The animal charcoal which remains upon the filter, possesses the property of decoloring sirups, vinegars, *et cetera*. It may also serve, when mixed with fresh animal charcoal, for another calcining operation. The clear yellow solution which passes through the filter, may either be employed directly for the preparation of prussian blue, or concentrated to the proper degree in iron boilers, and then introduced into wooden crystallizing vessels. The yellow prussiate thus obtained has still to be februated by one or two subsequent crystallizations before being sent into the market. In consequence of the great solubility of prussiate of potassa, the mother-water, or the liquid that remains after crystallization, still retains a notable quantity of that salt, together with carbonate, phosphate, and sulphate of potassa, as also the chloride, sulphide, and sulphocyanide of potassium. It is therefore employed for the direct preparation of an inferior quality of prussian blue, or concentrated by evaporation to extract from it an impure prussiate of potassa.

Mr. MUSPRATT of Liverpool, the founder of the British *alkali* trade, was one of the earliest to manufacture the yellow prussiate, which he did in Dublin in the years 1819, 1820. He found it very difficult to obtain the salt in large crystals; but this object he surmounted by mixing with every dissolved metal of prussiate one pound of sulphate of iron. The result proved most satisfactory. He was the first to use the copperas for this purpose. It is now employed often, and is further dwelt on below.

The theory of this manufacture is as follows:—The animal charcoal consists essentially of carbon, and contains, besides, a small quantity of nitrogen; when it is heated *per se* it undergoes no alteration, but when mixed with potassa and heated to redness, the affinity of the alkali for cyanogen determines the formation of the latter by means of the nitrogen and a part of the carbon contained in the animal charcoal. When, in addition to potassa, iron enters into the mixture, there is formed cyanide of iron, which, having a great affinity for the cyanide of potassium, combines with it to form a double cyanide, which is the prussiate of potassa.

Almost always, especially when the operation is arrested a little too soon, there is not a sufficient quantity of cyanide of iron formed to saturate the cyanide of potassium, which is then present in excess, and passes into the solution. To transform this excess of cyanide into ferrocyanide, before crystallizing the solution, a quantity of dissolved protosulphate of iron is poured in until a white or bluish and persistent precipitate begins to be formed.

In this reaction, a part of the cyanide of potassium is decomposed; there is formed on the one hand sulphate of potassa, and on the other cyanide of iron, which combines with the undecomposed cyanide of potassium to form an additional quantity of the yellow salt.

Dr. URE remarks that, all things considered, the manufacture of prussiate of potassa is perhaps less understood, and therefore less perfect than that of any other chemical substance of equal importance. Whether the primary materials be calcined or not, a prodigious waste invariably occurs in the manufacture, and fully two-thirds of the nitrogen existing in the animal matters are driven off and lost. More frequently, indeed, the loss amounts to three-fourths, and even this is sometimes exceeded. Woollen rags or clippings, and good American potassa or pearlash, *with an admixture of scrap-iron*, are stated by Dr. URE to have given a larger produce than any other substances within the range of his experience, though, even in this instance, two-thirds of the whole nitrogen passed away as ammonia. In general one ton of dried blood or woollen rags, with about three hundredweight of good potassa, will produce from two to two and a half hundredweight of prussiate of potassa, and a proportionate amount of sulphate of potassa. The presence of scrap iron in a proper state of subdivision, is, however, necessary to insure the above result; for when no more is supplied than that which arises accidentally from the iron pot in which the operation is carried on, scarcely half these proportions will be obtained.—*Ure*.

In 1840 a patent for an improved method of conducting the manufacture of this important salt, was taken in the name of Mr. BERRY, with a special view to avoid the loss of nitrogen incurred in the common process. For this purpose the primary matters are treated differently, so as to collect the nitrogen which escapes during the distillation, and to cause it to enter into combination with carbon, iron, and potassium—the carbonate of ammonia being made to pass through a mixture of these substances placed in iron pipes which are maintained at a red heat. The following proportions of ingredients have been found to give good results:—

	Parts.
Potassa,.....	30
Nitre,.....	10
Acetate of iron,.....	15
Charcoal or coke,.....	45 to 55
Dried blood,.....	50

The blood or animal matter is put into an iron vessel resembling a gas retort, and the other materials, mixed and dried, are put into vertical pipes with which the retort communicates. The pipes containing the absorbing mixture must be raised to a red heat before the retort containing the animal matter is heated, in order that from the commencement of the operation the decomposition of the gases may take place. The charcoal in the mixture decomposes the carbonate of ammonia which passes over, and forms bicarbide of hydrogen; at the same time it gives up part of it to the nitrogen which proceeds from the decomposed ammonia, and thereby forms cyanogen, which, in its turn, combining with the reduced potassa, forms

ferrocyanide of potassium. To obtain the most complete reaction, the charcoal should be reduced into pieces of the size of a walnut, and soaked with a solution of carbonate of potassa in urine; the solution of nitrate or acetate of iron is then poured over the heap, and when the whole has been dried by a moderate heat, it is introduced into the pipes. The gas evolved by the decomposition is inflammable when issuing from the pipes, which are fitted with gas-burners, and the color of the flame indicates the progress of the operation. When it approaches to pink, it is known that the reaction is almost complete, and that very little if any ammonia has escaped decomposition. When the jet becomes smaller and clearer, and there is a good fire under the retorts, the operation is nearly terminated. The charge must then be removed; and being at a red heat, it should be at once thrown into water in order to extinguish it rapidly, the whole being well stirred and allowed to settle. The clear liquor is then drawn off, and the residuum is subjected to successive washings by filtration. The strong solutions are evaporated and crystallized, and the prussiate is extracted according to the old process. The weaker solutions, which will not crystallize, contain carbonate of potassa; and this is extracted to be em-

Fig. 315.

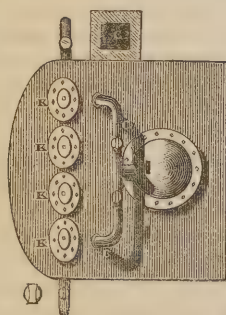
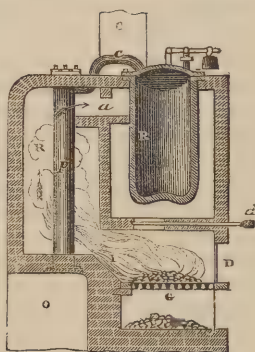


Fig. 316.



ployed in the next operation, along with the residuum of charcoal and iron mixed with fresh materials.

The apparatus in which these operations are conducted, is shown in different sectional views in Figs.

Fig. 317.

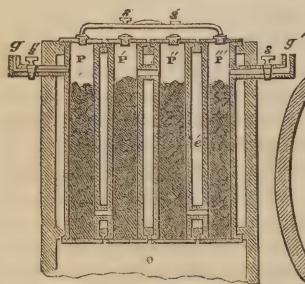
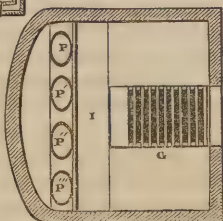


Fig. 318.



315, 316, 317, and 318, in all of which the same letters refer to the same parts. Fig. 315 is a top view of the apparatus. The general arrangement is exhibited in

Fig. 316, where D is the door and G the grate of the furnace, R the retort containing the animal matters, and P one of the pipes containing the absorbing mixture. The number, the elliptical form, and the vertical position of the pipes, are shown in the other figures. The form of the tube, C, by which they are connected with the retort, is represented in Fig. 315, and also in Fig. 317 with its stopcocks, S, S'. I is an incline over which the flame passes to heat the pipes before it is permitted to play upon the bottom of the retort by withdrawing the slide, d. The products of combustion escape by a lateral passage into the chimney, C. In Fig. 317 are shown the gas-burners, G, G', with their stopcocks, S, S'. K K, Fig. 315, are covers closing the pipes. Lastly, O, Fig. 316, is an open shed or roofed space under which the pipes are emptied at the end of each operation.

The most extraordinary event in the history of this manufacture, says GRAHAM, the writer of the Great Exhibition Jury Report on the prussiates of potassa, is the attempt made a few years ago to introduce the air-process, which is of much interest both in a scientific and practical point of view. As cyanogen is rapidly converted into ammonia, the artificial formation of the former from the nitrogen of air would likewise furnish an unlimited supply of ammonia, of which the importance to agriculture could not well be over-estimated. An account of the operations which were undertaken with this view, was communicated to Professor GRAHAM by Mr. F. R. HUGHES of Borrowstowness; who states that, in 1844, his firm commenced a series of experiments upon the large scale at Newcastle, in company with Messrs. BRAMWELL, to manufacture the ferroprussiate of potassa without animal matter, substituting the nitrogen of the atmosphere for it, and continued the experiments at very great expense till the latter end of 1847. In these operations a tube or retort of fire-clay was placed in a vertical position in a furnace capable of producing an intense heat. The tube was filled with wood-charcoal, saturated with a solution of the carbonate of potassa of commerce, and dried. The mixture in this state generally contained about twenty per cent. of potassa. By means of an air-pump, the atmospheric air was drawn through the tube of alkaliized charcoal in a continuous stream from the top, and discharged below in the state of nitrogen and carbonic oxide. The alkaliized charcoal was thus found to become pretty rich in cyanide of potassium; one half of the alkali of the cyanized charcoal frequently being found, upon testing, to be in combination with cyanogen; so that when all was working well, thirty-six to forty hundredweight of prussiate of potassa were produced in a week by means of seven to eight retorts, of ten to twelve feet long in the fire, and two feet internal diameter.

There were two great drawbacks to this process; one, the immense quantity of material to be lixiviated for a small return of prussiate; the other, and by far the more important, an extraordinary waste of potassa in the process, upwards of three parts by weight being consumed in producing one of prussiate. The whole of this waste could never be properly accounted for. About one part was, of course, recovered in a state of

prussiate. It was found that another was lost in the small refuse charcoal, which could not be lixiviated to pay, and the remainder appeared to be partly combined with the bricks of the retort, and partly dissipated up the chimney.

In 1847 the experiment was abandoned after a loss of many thousand pounds; but it proved the possibility of producing large quantities of cyanide of potassium, by drawing intensely-heated nitrogen and carbonic acid gases through a mixture of potassa and charcoal, with the difficulty of carrying this out as a manufacturing process, from the great waste of potassa.

Preparation of Prussian Blue.—The theory of the fabrication of prussian blue has been already stated; it only remains to enter into some practical details on this subject.

A distinction is made between the pure or *Paris blues*, and those that are mixed with alumina, or *Berlin blues*. The choice of the original raw materials naturally depends on the beauty and price of the article which is intended to be manufactured. For the finer kinds, one employs prussiate of potassa which has been purified by several successive crystallizations; for the common blues, the crude solution of prussiate of potassa is almost always taken; lastly, for inferior varieties, the mother-waters of the manufacture of the crystallized prussiate are used.

The salt of iron almost exclusively employed is the protosulphate. It should not contain copper, which would give rise to a reddish-brown precipitate very injurious to the color of the prussian blue. The presence of copper is easily detected by dissolving in water a little of the sulphate for trial, acidulating the liquor with sulphuric acid, and dipping into it a well-cleaned plate of iron; if copper is present, it will be reduced, and will form a red metallic coating on the surface of the iron plate. Cupriforous protosulphate may be purified, and all the copper precipitated, by dissolving it in water, and boiling it for some time with a little sulphuric acid and old scrap-iron or turnings; but this process entails considerable expense, and it is better in all cases to procure sulphate of iron which is sent into the market free from copper—a precaution attended with little difficulty. Before employing this sulphate, it is left exposed to the air till it acquires a reddish-brown color. Perhaps it would be still better to employ for the preparation of the finest blues sesquinitrate of iron, which furnishes a blue of such great beauty that the additional expense incurred in its manufacture would be more than compensated by the quality of the product obtained.

The crude solution of prussiate of potassa, and even the prussiate purified by a single crystallization, still contain, as has been stated, more or less carbonate of potassa, so that, besides the prussian blue, there is precipitated at the same time yellow oxide of iron, which deteriorates its tint. To obviate this inconvenience, the carbonate of potassa is neutralized by sulphuric acid, which may be added either to the solution of prussiate of potassa or to that of the protosulphate of iron. In the manufacture of the common Berlin blues, the carbonate of potassa is neutralized by alum; there results a precipitate of alumina, which mixes intimately with the prussian blue, and greatly augments

its weight without notably weakening the tint when the quantity is not very considerable. For this purpose, the requisite quantity of alum, previously determined by experiment, is dissolved in the solution of sulphate of iron; then the whole is poured little by little, and taking care to agitate continually, into the solution of prussiate of potassa, which gives a precipitate of a more or less dark blue that soon settles down. The supernatant liquid is then decanted, its place is supplied by pure water, it is again shaken, allowed to deposit, decanted, and is thus subjected to a series of successive washings, in order to abstract the soluble matters, and to deepen the color of the blue by the absorption of the oxygen contained in the water. The residue of the washing is then thrown on cloth filters, where it is left to drain; it is afterwards subjected to moderate pressure, and finally divided into small bricks or cakes, which are left to dry in the shade.

As prussian blue, when once dried, is difficult to reduce again to the state of extreme division which it possessed in the moist state, it is often sold and employed *in paste*—that is to say, *not dried*—especially for the manufacture of paper-hangings, *et cetera*.

A good article, says the late Dr. URE, is known by the following tests:—It feels light in the hand, adheres to the tongue, has a dark lively blue color, and gives a smooth deep trace; it should not effervesce with acids, as when sophisticated with chalk; nor become pasty with boiling water, as when adulterated with starch. The Paris blue, prepared without alum, with a sesquisalt of iron, displays, when rubbed, a copper-red lustre, like indigo. Prussian blue, degraded in its color by an admixture of free oxide of iron, may be improved by digestion in dilute sulphuric or hydrochloric acid, washing and drying. Its relative richness in the real ferrocyanide of iron may be estimated by the quantity of potassa or soda which a given quantity of it requires to destroy its blue color.

The precipitate formed by adding a solution of ferridcyanide of potassium—the red prussiate—to a protosalt of iron, constitutes the color known in commerce as *Turnbull's blue*. It is produced by the substitution of three atoms of iron for the three of potassium in the red salt. Its color is a little brighter than common prussian blue. It is prepared in the arts by adding to a solution of copperas a mixture of yellow prussiate of potassa and chloroxide of sodium.

Prussian blue is employed as a water color, but not in oil-painting. In 1837, Messrs. STEPHEN and NAX of London took out a patent for a process by which it can be obtained in solution, and employed not only in calico-printing, but also as a tinctorial agent, thereby greatly extending its application. The process consists in first digesting the prussian blue of commerce, for a period of twenty-four to forty-eight hours, with concentrated hydrochloric or sulphuric acid, and afterwards diluting the mixture with its own weight of water. It is then carefully washed, by decantation, with pure water, in order to remove all the acid; and, after being washed a second time on a filter, the residue is dried, and brayed in a mortar with oxalic acid. The resulting compound is found to be soluble in water.

The insufficiency of the description of this process which is given in the specification, and the absence of details with reference to the quantities of the materials to be employed, and the precautions necessary in the manipulation, induced M. KARMARSCH, a few years ago, to institute a series of experiments on this subject leading to the following results:—

1. The preliminary treatment of the prussian blue with hydrochloric or sulphuric acid, is attended with the advantages of requiring a much smaller quantity of oxalic acid to render the blue soluble; of causing the blue to keep longer without depositing any precipitate, which infallibly happens when it has not undergone the preliminary treatment; and, lastly, of rendering the blue soluble in a much smaller quantity of water, which permits of obtaining a more concentrated solution.

2. The quantity of oxalic acid necessary to determine the solution of the prussian blue is small; an excess of this acid, instead of increasing, diminishes its solubility in water.

3. The combination of prussian blue and oxalic acid is not soluble in water in all proportions; when the quantity of water is not sufficient, a portion of the color remains undissolved in the form of a dark-blue slime.

4. The most suitable proportions for obtaining a concentrated soluble blue, susceptible of being filtered without residue, and of keeping a long time without giving any deposit, are—eight parts of prussian blue treated with sulphuric acid, then well brayed with one part of oxalic acid, and dissolved in two hundred and fifty-six parts of water.

Physiological Effects.—Iron is probably inert, or only acts mechanically, so long as it retains its metallic form; but it readily oxidises in the alimentary canal, and thereby acquires medicinal power. As acids promote this chemical change, acid wines and fruits assist in rendering the metal active, while alkalies and their carbonates have an opposite effect. The oxidation of the iron is attended with the evolution of hydrogen gas, which gives rise to unpleasant eructations. If sulphur be taken along with iron, sulphide of hydrogen is developed. Like the ferruginous preparations generally, the internal employment of iron causes blackening of the stools, owing to the formation of the hydrated sulphide of iron. It is interesting to remark here, that iron is one of the few metals which by oxidisement *is not rendered more or less poisonous*.

The *local* effects of the sulphate, nitrate, and sesquichloride of iron, are those of caustics and irritants, and these preparations accordingly rank amongst poisons.

Most of the ferruginous preparations are astringent; that is, they constrict the parts with which they are in contact, and thereby diminish secretions and check sanguineous discharges. Thus, when swallowed, they repress the secretions and exhalation of the gastro-intestinal membrane, and thereby render the alvine evacuations more solid, and even occasion constipation. The sulphate, nitrate, and sesquichloride of iron, are the most powerful of the ferruginous astringents. Administered in large quantities, or when the alimentary canal is in an irritable condition, all the compounds

of iron are liable to excite heat, or weight and uneasiness at the præcordia, nausea, and even vomiting, and sometimes purging. The oxides and the carbonate of iron are very mild topical agents.

Before the chalybeates can produce constitutional effects, they must become absorbed. Under their use the blood frequently acquires a more scarlet hue, owing to an increase in the number of its coloring particles. TIEDEMAN and GMELIN have detected it in the serum of the blood of the portal and mesenteric veins of horses and dogs, to whom they administered either the sulphate or chloride. Occasionally, too, iron has been found in the urine.

The constitutional effects of iron are best observed in anæmia. If, in this condition of system, chalybeates be administered, the appetite increases, digestion is promoted, the pulse becomes fuller and stronger, the skin assumes its natural hue, the lips and cheeks become more florid, the temperature of the body is augmented, the oedema disappears, and the muscular strength is greatly increased. These results are mainly due to the alteration in the composition of the blood. This is shown by the healthy vermilion tint which the patient acquires, as well as by the chemical analysis of the blood.

Iron filings are employed as an antidote in poisoning by the soluble salts of copper and mercury. The iron reduces them to the metallic state. The following formula explains the action of iron on a solution of sulphate of copper:— $\text{Cu O, SO}_3 + \text{Fe} = \text{Cu} + \text{Fe O, SO}_3$.

Sesquioxide of iron is termed alterative, tonic, and emmenagogue. Its obvious effects on the body, however, are very slight.

Hydrated sesquioxide of iron has been employed as an antidote in poisoning by arsenious acid, a basic insoluble arseniate being formed. BUNSEN and BERTHOLD were the first to assert the antidotal powers of this preparation. Their statements were confirmed by the experiments of SOUBEIRAN and MIQUEL, of ORFILA and LESNEUR, *et cetera*.

Sulphide of iron in cutaneous maladies of a scrofulous character has proved a valuable alterative, and more serviceable than iodine. It appeared to be less irritating, and not so liable to excite suppuration in scrofulous swellings. BRIET gave it in obstinate lichen agrius.

Sulphate of Iron.—This salt acts locally as a powerful astringent, and when employed in a concentrated form, as an irritant. The latter effect depends on its chemical action on the organic constituents, albumen, *et cetera*, of the tissues. The remote effects of sulphate of iron are analogous to those of other ferruginous compounds, which have been already described.

Swallowed in *small doses*, it has an astringent operation on the gastro-intestinal mucous membrane, and thereby diminishes the quantity of fluids secreted or exhaled; hence its continued use causes constipation. It blackens the stools like other compounds of iron. It becomes absorbed, and operates on the system as a tonic, stimulant, emmenagogue, and astringent. In *excessive doses* it acts as an irritant poison. A girl took, as an emmenagogue an ounce of it in beer, and was seized in consequence with colic pains, constant

vomiting, and purging for seven hours. Mucilaginous and oily drinks soon cured her.

It is employed in lump, powder, or solution, as a styptic to check bleeding from numerous small vessels. The sesquinitrate, acetate, iodide, citrate, *et cetera*, are employed daily in medicine also. Their effects are similar to the other ferruginous salts.

The general indications for the use of the iron compounds are debility, feebleness, and inertia of the different organs of the body; atony, marked by a soft, lax, or flabby condition of the solids; and defect of the red corpuscles of the blood; as where there is a general deficiency of this fluid—*anæmia*; *oligæmia*, or a watery condition of it—*hydremia*, *serous crasis*; *leucophlegmatic temperament*.

The contra-indications are the reverse of these; great strength and activity of organs, excessive tonicity, characterized by a firm and tense condition of the solids, and redundancy of the red corpuscles of the blood,—as in general excess of the blood-plethora, in fever, in acute inflammation, in the sanguine temperament. To these may be added congestion, or a tendency thereto, of important organs—especially of the brain and lungs—and intestinal irritation.—*Pereira*.

Statistics.—At the Great Exhibition, the prussiates of potassa, which invariably accompany the manufacture of prussian blue, were exhibited of great purity and beauty, by several manufacturers, particularly Messrs. T. BRAMWELL and Company, of Newcastle; the Hurler and Campsie Alum Company, of Glasgow; the Bouxwiller Mining Company, of France; C. SCHLIPPE, of Russia; and ALEXANDER BRUSGHIN, also of Russia.

The prussiate made by Mr. MUSPRATT in 1820, in Ireland, and that manufactured in England, sold for five to six shillings the pound; but for some years previously a weak solution of the salt, or of the fluxed mass of animal matter and potassa, had been sold at one shilling per gallon. The process of manufacture, so far as regards the materials used and the furnaces employed, is still essentially the same as it was fifty years ago; but in consequence of agitating the fluxed mass by machinery in closed pits, introduced at Glasgow by the late CHARLES MACINTOSH in 1824, and other minor improvements in the manipulation, the production of prussiate from the same quantity of animal matter has been increased threefold. The rapid progress of this manufacture will appear from the following estimate of the annual production in the United Kingdom:—

ANNUAL PRODUCTION.

From 1825—1830 about	10 tons at 5s. 0d. per pound.
“ 1830—1835 “	40 “ 2s. 6d. “
“ 1835—1840 “	200 “ 1s. 4d. “
“ 1840—1845 “	700 “ 1s. 4d. “
“ 1845—1850 “	1040 “ 1s. 3d. “

There are eleven prussiate works in the United Kingdom, of which the aggregate produce is, when the salt is in demand, about twenty tons per week. The two largest factories are those of Messrs. BRAMWELL and the Hurler and Campsie Alum Company. The value of the annual product is estimated at one hundred and forty-five thousand six hundred pounds sterling.

The manufactory of Messrs. BRAMWELL was established about eighty years ago, at which time prussian blue only was made in it, a considerable quantity of which was sent annually to China, and used by the Chinese, it was believed, for coloring green teas; a Spring shipment was always made of about two thousand pounds sterling in value, which was often followed by another in Autumn. It was first sold at two guineas per pound, made up in neatly finished one-pound packages, but had fallen in 1815 to ten shillings and sixpence, and about 1820 to two shillings and sixpence. For the last ten or fifteen years the price of prussian blue has averaged one shilling and ninepence per pound.

The Editor begs to express his thanks to Mr. GEORGE BLAIR of Glasgow, for his kind assistance in the compilation of this and other articles.

LEAD.—*Plomb*, French; *Blei*, German; *Plumbum*, Latin.—This metal is of a bluish-grey color, with a strong metallic lustre when recently cut; but when exposed for a short time, its brilliancy disappears, and gives place to a very thin coating of basic carbonate of the oxide of lead. Owing to its softness it leaves a streak on white paper, and may be easily cut with a knife. It is highly malleable and ductile, but is deficient in tenacity, when compared with all the other ductile metals; a wire one-tenth of an inch in diameter being capable of supporting a weight of only thirty pounds. It may be easily rolled out into moderately thin sheets and likewise drawn into wire; but from its want of tenacity, the latter operation cannot be performed so freely as with gold, platinum, silver, copper, or iron. The specific gravity of lead is 11·445 when subjected to pressure, as in rolling; but in mass it is somewhat less, being 11·350; its chemical symbol, is *Pb*—derived from the Latin term *plumbum*—and its combining equivalent 104.

HISTORICAL NOTICE.—In the articles on COPPER and GOLD it has been stated that these metals were brought into use at a very early date, and it seems probable that *lead* was known at least as early as copper. Mention is repeatedly made of this metal in the book of Exodus, and in various other parts of holy writ. It would appear from BECKMANN, indeed, that some doubt exists as to the true meaning of the word rendered *lead* by the translators of the scriptures, although he does not deny its very great antiquity. The Phenician colony in Spain drew largely upon Britain for this metal, and also for tin; and it is stated by CAMDEN that lead was obtained from Cornwall, Cumberland, and other places in England, before the Christian era. During the incursions of the Romans, it is certain that it formed an important article of commercial interest; and that it was used in considerable abundance, may be inferred from the specimens which have been discovered from time to time, bearing Latin inscriptions. After the departure of the Romans, the Saxons continued to work the lead mines, one of which, near Castleton, was dedicated to Odin. That the mines near Wirksworth were worked before the year 714, appears from the discovery of a sarcophagus of lead, lined with linen prepared in that locality. In the year 835, the lead mines of Wirksworth were surrendered to one

HUMBERT, on payment of an annual rent in that metal to the value of three hundred shillings, for the use of Christ Church, Canterbury. In Doomsday-book the mines in the Peak, and the Wapentake of Wirksworth, are referred to as the peculiar property of the sovereign, and those of Derbyshire, were designated *The King's Field*. In the ages of alchemy, lead was regarded as a semi-metal, and bore the name of *Saturn*, owing probably to its bluish-grey color.

SOURCES.—Lead is found in various combinations in mineral strata, and on rare occasions in the native state. Kerry in Ireland, Carthage in Spain, and Alston Moor in Cumberland, have afforded specimens of lead in this state, sometimes associated with galena, and at other times disseminated therewith in an argillaceous or a silicious rock.

The ores of lead are numerous, but are found in very unequal proportions; that from which the metal is extracted being for the most part galena, or bisulphide of lead. The most important of them are the oxide of lead or massicot, chloride of lead, bisulphide of lead or galena, carbonate, phosphate, sulphate, arseniate, and chromate of lead.

Oxide of lead may be regarded as being derived from the sulphide in the presence of other bodies which exhibit an affinity for the sulphur. It is found only in small quantities, and usually associated with galena.

Chloride of lead is another very rare natural combination, which is found in small quantity in the Mendip hills, generally deposited upon a matrix of binocide of manganese, and crystallized in rectangular prisms, with the angles and edges sometimes truncated.

Carbonate of lead—sparry lead ore—is remarkable for its transparency and lustre when in its purity. Several varieties of this ore are known. It is found in the form of acicular crystals, in compact masses, and often presenting a fibrous, lamellar, and earthy appearance. They all, with the exception of the earthy species, possess a peculiar lustre, like that of white lead. Earthy carbonate of lead presents several shades of color—brown, green, or blue—dependent upon the nature of the metal associated with it. The mineral is very brittle, and its fracture has a waved conchoidal appearance. Its specific gravity varies from 6 to 6·7.

It is met with in comparatively small quantities and is confined to a few localities. At Leadhills and Wanlockhead, two well-known Scotch localities yielding this metal, the carbonate occurs with other minerals, particularly with phosphate, sulphate, and other combinations of lead, accompanying galena in transition-slate. It occurs in the mines at Alston Moor, at Keswick, and in some parts of Cornwall, particularly at the mine of St. Minvers. In many of the continental mines, particularly in Saxony and the Hartz, it is eviscerated. Being a mineral rich in lead, it is easily smelted. A black species of carbonate of lead is sometimes found, which owes its characteristic color to small particles of galena being disseminated throughout the crystals. The most extensive deposit of carbonate hitherto discovered is that at the mine à la Motte, Missouri, in America, where millions of pounds of metal have been extracted from this mineral. When treated before the blow-pipe on charcoal, it decrepi-

tates and changes color to a yellow, then becomes red, and finally is reduced to metal in the inner flame, the charcoal being coated with litharge. Heated with fluxes it gives rise to a diaphanous glass. Acids readily act upon it; carbonic acid being evolved with effervescence, and a lead salt of the acid being produced.

The following analyses have been made of this mineral:—

	Crystals of carbonate of lead from			
	Lead Hills. Klaproth.	Zellerfeld. Westrumb.	Nertschinsk. John.	Teesdale. J. A. Phillips.
Protoxide of lead,...	82·00	81·20	84·5	83·50
Carbonic acid,.....	16·00	16·00	15·5	16·50
Lime,.....	—	0·90	—	—
Iron,.....	—	0·30	—	—
Loss,.....	2·00	1·60	—	—
	100·00	100·00	100·0	100·00

The formula by which its composition may be expressed is PbO CO_2 .

Sulphate of lead is a mineral associated with carbonate in the mines of the Leadhills and Wanlockhead in Dumfries-shire, Scotland. It is found in quantities in Parry's Mine in Anglesea, and at Mellanoweth in Cornwall, where it is associated with galena, from which it gives evident indications of being produced by oxidation. Sulphate of lead has been found at Clausthal and Zellerfeld, in the Hartz, and various other mines on the Continent; although the quantity is too small to attract the attention of the metallurgist.

Its color is sometimes grey or yellowish, frequently tinged blue or green by oxide of copper; its crystallized form is that of a rhombic prism, with dihedral summits; but when the crystals are short, they assume the form of the octahedron. Generally the crystals are possessed of the same transparency and adamantine lustre as those of the carbonate, so that from appearance the two may be often confounded. With acids, however, the sulphate of lead affords no marked reaction, and this forms one distinguishing feature of the two compounds.

Before the blow-pipe the sulphate decrepitates, and then melts; in the oxidising flame it fuses into a transparent globule, which on hardening turns milk-white; in the inner flame it effervesces, owing to the evolution of sulphurous acid, and is quickly reduced to the metallic state. Samples of this mineral afforded to KLAPROTH the annexed composition.

	Anglesea.	Wanlockhead.
Protoxide of lead,.....	71·0	70·50
Sulphuric acid,.....	24·8	25·75
Water,.....	2·0	2·25
Loss,.....	2·2	1·50
	100·0	100·00

Its density has been determined by STROMEYER, and found to be between 6·23 and 6·3, and its chemical symbol in the pure state, is PbO SO_3 .

Phosphate of lead is a mineral of rare occurrence, although it is met with in many of the lead mines of Cornwall, and at the Lead Hills and Wanlockhead in Scotland. It crystallizes in hexagonal prisms, which are sometimes transparent, though more generally of a bright green, or brown, and sometimes of a fine orange color, derived from the presence of a small quantity of chromate of lead. Before the blow-

pipe, on charcoal, it melts in the outer flame into a globule which crystallizes on cooling, and becomes brown; in the reducing flame, the lead appears bluish, is luminous while hot, and on cooling crystallizes with large facets of a lighter color. Its specific gravity is from 6.5 to 7.0, and its centesimal composition, according to the analyses of KARSTEN and WÖHLER, as follows:—

	From Bohemia.	From Cornwall.
Phosphate of lead,	89.268	89.110
Chloride of lead,	9.918	10.074
Phosphate of lime,	0.771	0.682
Fluoride of calcium,	0.137	0.130
	100.094	99.996
		From Zschopau.
		Wöhler.
Oxide of lead,		82.29
Phosphoric acid,		15.73
Chlorine,		1.98
		100.00

Chromate of lead is a very beautiful mineral, of a deep or hyacinth red color, and crystallized in oblique rhombic prisms, the cleavages of which show it to be translucent on the edges; it possesses an adamantine lustre, and gives an orange-yellow streak. It is, however, very rare, being found only in the Brazils, and at Beresof in Siberia. An artificially-prepared chromate of lead, forms the *chrome-yellow* of painters. Specific gravity of the native mineral is about 6, and its composition corresponds with the formula PbO, CrO_3 .

Sulphide of lead—*Galena*; *Bleiglanz*, German; *Plomb Sulfuré*, French.—This is the most diffuse, and at the same time the most abundant ore of lead known; it forms veins and beds both in the primary and secondary rocks. At Freyberg in Saxony, it is found in veins in gneiss; at Sala in Sweden, it is met with in the primitive limestone; and at Clausthal and Newdorf in the Hartz, Przibram in Bohemia, and several other districts, clay-slate forms the repository of the metallic veins. The grauwacke of Dumfries-shire and the killas of Cornwall are traversed by lodes in which the mineral is contained; whilst in Derbyshire, Cumberland, and the other northern districts of England, and also several other localities on the Continent, it is extracted from amidst the mountain limestone. Valuable deposits of galena are worked at many other places besides those mentioned above. Wales and Ireland afford large quantities of the mineral. In several of the French departments it is found in considerable abundance, especially at Huelgöet and Poullaouen in Brittany, at Pontgil and Puy-de-Dome, and Villefort in the department of Lozère. Catalonia, Grenada, and the granite hills of Linares in Spain afford sulphide of lead. Extensive deposits of galena occur in the United States, particularly in Missouri, Illinois, Iowa, and Wisconsin.

Galena frequently appears under different forms, and is variable in its composition. Usually, it has a metallic lustre, and a leaden-grey or blackish-grey color. The primary form of its crystal is the cube; but it occurs in the form of octahedra and its varieties. Its structure is lamellar, and its cleavage, which is highly perfect, parallel to the planes of the cube. The specific gravity of the mineral is 7.5 to 7.7, and, when pure, it is composed of lead and sulphur, in the ratio of 86.55

of lead, and 13.45 of sulphur. The amount of lead, however, is subject to variation, owing to the presence of more or less silver, which is invariably associated with it, and also that of other metals, such as antimony, zinc, iron, copper, and arsenic. The following analyses of samples of galena show its usual composition:—

	Brudant.	Westrumb.	Thomson.
Lead,	79.6	83.00	85.13
Sulphur,	13.4	16.41	13.02
Silver,	7.0	traces	—
Loss,	—	0.59	1.85
	100.0	100.00	100.00

It may be remarked here that the presence of silver, notwithstanding the proportion may be so large as the one-fifth of the whole, does not materially alter the external characters of the galena; but when silver is present in that amount, other metals, such as antimony and bismuth, are also contained in the mineral in appreciable quantities. The richest silver-lead ore is that found at Tarnowitz in Silesia, which contains about a fifth of its whole weight of silver; the usual proportion of this metal is, however, from 0.0001 to 0.003 per cent., and the ore is designated by the Germans *Weisgültigerz*.

The principal varieties of this mineral are *specular galena* and *blue lead*. The former is found in some of the Derbyshire mines, where it forms very thin coatings on the walls of the veins, so as to give the latter the appearance of looking-glasses. On this account it is designated *slickenside*; it explodes with a loud report when accidentally scratched in the mine. *Blue lead* is a kind of galena which is of frequent occurrence, having a hue between leaden-grey and indigo-blue. Other compound sulphides of lead with sulphides of silver, antimony, and bismuth are known; but these will be referred to afterwards.

Galena is a protosulphide, and is therefore represented by the symbol PbS .

PREPARATION OF PURE LEAD.—As prepared from the ores of lead by the metallurgical processes in ordinary use, and which will be described presently, the lead of commerce is impregnated with other metals in small quantity, such as silver and tin, and occasionally traces of arsenic, antimony, copper, iron, and zinc, when the ores operated upon contain these metals. To obtain chemically pure lead, it is necessary to work upon the ordinary product with such reagents as will cause the separation of these metals. The method recommended is to heat the nitrate of oxide of lead in a crucible, and to reduce the litharge so produced with charcoal in a covered crucible, or with hydrogen gas at a red heat, presupposing that the lead salt is quite pure; but should it contain nitrates of other metals, such as silver and the like, these will pass into the reduced lead. This fact has been repeatedly proved, and even when great care has been bestowed upon the preparation of the lead salts with a view to their reduction, traces of silver have been detected in the resulting metal.

When lead absolutely free from silver is required, it is necessary to dissolve the lead of commerce in nitric acid, and to crystallize the nitrate thus formed by

concentrating the clear solution; then precipitate the metallic base from the fluid with sulphuric acid; wash well the insoluble sulphate of lead, and finally reduce the latter by fluxing it with pure carbonate of soda and ground resin in a lined Hessian crucible. The button of metal which is thus obtained may be relied upon as being *absolutely pure*. The nitric acid has the effect of precipitating any tin and antimony as oxides; and during the subsequent crystallization of the lead salt from the clear filtered liquid, much of the silver will be left in the mother liquor, and the last traces of this metal are got rid of by precipitating the lead as a sulphate, and washing thoroughly. A very pure lead, so far as freedom from silver is concerned, is obtained by reducing the litharge which results from the furnaces of cupellation, as those at Freiberg in Saxony, and this is well adapted for the assayer's use. It may also be prepared by electrical agency, as by introducing a bar of zinc or iron into a solution of nitrate or acetate of lead carefully prepared; but by this means absolute purity is not insured, as the easily reducible silver, if contained in the salt operated upon, will likewise be precipitated.

CHEMICAL PROPERTIES OF LEAD.—The affinity of lead for oxygen is very great, even at ordinary temperatures; but this is increased when its temperature is elevated. Under the latter condition, it burns in the air with a bluish-white light, and affords oxide of lead or litharge. FARADAY has shown, that when finely divided, this metal is more inflammable than gunpowder. Nitric acid acts energetically upon lead, converting it into an oxysalt of this acid; acetic acid likewise dissolves it, but sulphuric and hydrochloric acids have only a feeble action upon it, especially in the cold. With the aid of heat, however, concentrated sulphuric acid dissolves it with the evolution of hydrogen.

At a red heat, hydrochloric acid vapor acts upon lead, producing a chloride of the metal and liberating hydrogen. This metal is capable of uniting with all the non-metallic elements, with the exception of hydrogen, borium, silicium, and carbon; with all the metals, except iron, it enters readily into combination, giving alloys which are of considerable importance in the arts, and some of which have been described under the heads, *ANTIMONY, BISMUTH, et cetera*. Its oxides, which are numerous, are employed for various useful purposes, and one of them, the protoxide, commonly known as litharge, readily combines with all the oxygen acids, forming salts, some of which are used in the arts to a very large extent. In the form of sheet lead and lead piping, this metal is applied to a great variety of purposes. To the metallurgist it offers a ready and advantageous means of obtaining silver and gold in their purity, by alloying them with it, and subsequently removing the lead from the compound metal by cupellation.

PRINCIPAL LEAD MINES.—Before entering upon the details of the processes involved in the production of metallic lead from the ores, it may not be uninteresting to lay before the reader the chief mines producing galena, and some of the circumstances connected with them, as stated by URE.—The principal

mines at present worked in the world are the following:—

1. Poullaouen and Huelgöet, near Cairhaix in France, department of Finisterre, being veins of galena, which traverse a clay-slate resting upon granite. They have been in operation for upwards of three centuries; the workings penetrate to a depth of three hundred yards, and in 1816 furnished five hundred tons of lead per annum, out of which one thousand and thirty-four avoirdupois pounds of silver were extracted.

2. At Villefort and Viallaz, department of the Lozere, are mines of this ore, said to produce one hundred tons of lead, with eight hundred and eighty avoirdupois pounds of silver.

3. At Pezey and Macot, to the East of Montiers in Savoy, a galena mine exists in talc-schist, which produces annually two hundred tons of lead, and about twelve hundred and thirty pounds avoirdupois of silver.

4. The mine of Vedrin, near Namur, in the Low Countries is opened upon a vein of galena traversing compact limestone of a transition district.

5. In Saxony the galena mines are so rich in silver as to cause the lead to be regarded as a secondary product, or entirely overlooked.

6. The lead mines of the Hartz have been likewise considered as silver ores.

7. Those of Bleiberg, on the Eifel, are of the same description.

8. The galena mines of Bleiberg and Vallech in Corinthia, in compact limestone.

9. In Bohemia to the South-west of Prague.

10. The mines of Joachimsthal and Bleistadt, on the Southern slope of the Erzgebirge, produce argentiferous galena.

11. There are numerous lead mines in Spain, the most important of which are those in the granite hills of Linarès, upon the Southern slope of the Sierra Morena, and in the district of the small town of Canjagar. Enormous masses of galena are extracted sometimes from the mines of Linarès. There are mines of sulphide of lead in Catalonia, Grenada, Murcia, and Almeria, but the ore of the last locality is worked for the silver it contains.

12. The lead mines of Sweden are very argentiferous, and, like the last mentioned, are worked to extract the silver.

13. In the district of Daouria the lead mines are numerous and rich, lying in a transition limestone which rests on primitive rocks; their lead is neglected on account of the silver.

14. Great Britain is, of all countries in the world, that which annually produces the largest quantity of lead. According to M. VILLEFOSSE, in his *Richesse Minérale* published in 1819, this kingdom had furnished twelve thousand five hundred tons of lead, being more than the rest of Europe produced; it appears, however, from more recent documents, that the above estimate is too low. Mr. TAYLOR in 1822 rated the total produce of the United Kingdom per annum at thirty-one thousand nine hundred tons, a quantity fully two and a half times greater than that stated by VILLEFOSSE. TAYLOR distributed this product among the different districts as follows:—

	Tons.
Wales—Flintshire and Denbighshire,	7,500
Scotland—in transition-grauwacke,	2,800
Durham, Cumberland and Yorkshire—in carboni- ferous lime	19,000
Derbyshire—probably in carboniferous lime,	1,000
Shropshire,	800
Devon and Cornwall—transition and primitive rocks,	800
Total,	31,900

Hence it may be seen, that the adjacent parts of the counties of Durham and York furnish of themselves nearly three-fifths of the total product.

In 1835 the entire quantity was estimated by TAYLOR at 46,112 tons, of which 19,626 tons were furnished by Northumberland, Durham and Cumberland; the mines of Mr. BEAUMONT of themselves yielding ten thousand tons. The annexed table shows the increase in 1847:

	Lead Ore, Tons.	Lead Tons
England,	59,614½	39,507½
Wales,	18,147½	12,294
Ireland,	2,251	1,380
Scotland,	1,159	822½
Isle of Man,	2,575	1,699
	83,747	55,703

15. In the United States, the most remarkable lead region—and, according to BOOTH, probably the largest in the known world—where the galena is disseminated in beds of greater or less extent, is in Wisconsin, Iowa, Illinois, Missouri, and Kentucky.

The former three may be regarded as a distinct region of ninety miles from East to West, and sixty miles from North to South. Another district is in Missouri, to the South of the river so named, about eighty miles North and South, and fifty miles East and West. The lower part of Illinois, and part of Kentucky, appears to be a third district. In the first the lead found is very pure, and it is remarkable besides for the enormous crystals of galena which it produces; the second district gives often a less pure lead, which is largely associated with very pure barytic minerals; and in the third, much of the galena contains sulphide of antimony. Although extensively explored, this immense metallic region of the Mississippi valley remains to be fully developed. The best argentiferous vein yet opened in the United States, is probably that in Davidson County, North Carolina.

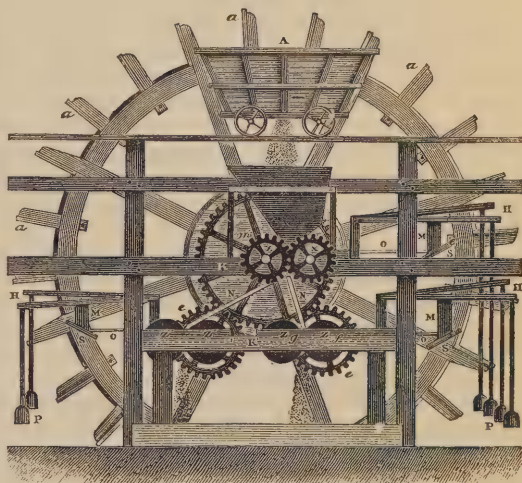
PRELIMINARY OPERATIONS.—Rarely is galena found of such purity as to be at once in a fit state for the action of the fire; it is generally compounded with the stony substances of the strata in which the deposit exists, and also with other minerals of a different nature. The crude product raised from the mine is, therefore, submitted to various processes of dressing, to bring it to an average standard richness. In England these preliminary operations are divided into three classes, namely, *the sorting and cleansing of the ore, the grinding, and the washing.*

Sorting and Cleansing the Ore.—At several of the British mines this operation is performed at the mouth of the mine, by the aid of sieves constructed of iron wire, the strands running parallel at an inch distance, thus forming openings one inch square. The material is thus separated into two batches, and, by using finer gauzes, into more varieties. Sometimes the clay, or

mud, is removed from the ore by placing it on a sieve with small meshes and agitating the whole in water. In many parts of Derbyshire, however, the ore is merely stirred about with a shovel in a trough filled with water; but this method, which is termed the *standing buddle* system, is obviously very imperfect. Another apparatus, called the *running buddle*, serves at once to sort and cleanse the ore. It is similar to the inclined plane used for copper ore. This contrivance, which was formerly the only one in general use at Alston Moor, has been supplanted by another called the *grate*. This is a grid constructed of iron bars one inch thick, and twenty-four to thirty inches long; these are fixed parallel to one another, and horizontally, at a distance of one inch apart. A wooden canal above the grate, conducts a stream of water over its middle, and an inclined plane set beneath it, and leading to a hemispherical basin, serves to recover the metallic powder which is detached from the mass.

Grinding.—After assorting the ore it is crushed to fine powder. Formerly the *bucker* was in frequent request, but is now giving place to the crushing machine, which effects a considerable saving in time and labor, and is, therefore, coming very rapidly into general use. This machine is represented in the annexed drawing—Fig. 319—the description of which is taken from the latest edition of URE's excellent Dictionary. It is composed of one pair of fluted cylinders, x x, and

Fig. 319.



of two pair of smooth cylinders, z z, z' z', which are immediately used for crushing the ore. The two cylinders of each of the three pair turn simultaneously in an inverse direction, by means of two toothed wheels upon the shaft of every cylinder, which work by pairs in one another. Motion is communicated by a water-wheel, the circumference of which is represented by a a a. One of the fluted cylinders is placed on the prolongation of the shaft of this wheel, and which carries besides, a cast-iron toothed wheel, gearing into two others, e e, fixed upon the ends of the two smooth

cylinders. Above the fluted cylinders is placed a hopper from which the ore with which it is charged from the waggon, A, and which advance upon tramways, till they come directly over the hopper; their contents are emptied through a trap-hole in their bottom. Below the hopper there is a small bucket called a shoe, in which the ore is shaken down, and which throws it without ceasing upon the cylinders, in consequence of the constant jolts given to it by a crank-rod attached to it and moved by the teeth of the wheel, *m*. The shoe is so regulated, that too much ore can never fall upon the cylinders so as to obstruct their movements. A small stream of water which is conducted into the shoe, spreads over the cylinders and prevents them from getting overheated. After the ore has passed between the fluted rollers, it falls upon the inclined planes, *N N*, which turn it over to one or other of the pair of smooth rollers.

These are the essential parts of this machine; they are made of iron, and the smooth ones are case-hardened, or *chilled*, by being cast in iron moulds. The gudgeons of both kinds move upon brass bushes, fixed upon iron supports, *x*, made fast by bolts to the strong wood-work basis of the whole machine. Each of the horizontal bars has an oblong slot, at one of whose ends is solidly fixed one of the plummer-blocks or bearers of one of the cylinders, *f*, and in the rest of the slot the plummer-block of the other cylinder, *g*, slides—a construction which permits the two cylinders to come into contact, or to recede to such a distance as circumstances may require. The movable cylinder is approximated to the fixed one by means of the iron levers, *H H*, which carry at their ends the weights, *P*, and rest upon wedges, *M*, which may be slid on the inclined plane, *s*. These wedges then press the iron bar, *O*, and make it approach the movable cylinder, by moving the plummer-block that supports its axis. With such an arrangement, should very large or hard pieces of ore fall between the cylinders, one of the rollers would recede, and let the piece pass without doing any injury to the mechanism.

Besides the three pair of cylinders which constitute essentially each crushing machine, there is sometimes a fourth which serves to crush the ore when not in large fragments; for example—the moderately rich pieces, called cuttings, and the poorer kinds or chats produced by the first sifting. The cylinders composing that accessory piece, which, on account of their ordinary use are called *chats-rollers*, are smooth and similar to *z z z' z'* in the foregoing figure. One of them is usually placed upon the prolongation of the shaft of the water-wheel, at the opposite side of the principal machine; and the other which is placed alongside, receives its motion from the first by means of toothed wheel-work. The ordinary stamping process is in some places combined with the use of the crushing rollers, especially if the gangue be too hard for the latter to grind.

Washing.—After the operation of grinding comes the process of washing, properly so called. This is effected in various ways, such as by the *jigger*, the *inclined plane*, the *dolly-tub*, *et cetera*, all of which are so obvious in principle, and bear so much resemblance to similar apparatus already described in the

articles COPPER and GOLD, as to render a detailed description unnecessary. It may be stated, however, that in general much waste is occasioned in the English establishments in cleansing the ore, and the washing is not carried to the same degree of perfection as in other countries; doubtless from the circumstances that fuel in this country is plentiful and cheap, and labor is dear, while in Brittany and other localities the reverse is the case. In Cumberland the washing of the ore is usually let by the piece, and the men are paid according to its richness; thus, two shillings and sixpence is paid for cleansing fifteen hundred-weight of one kind, and for others, a sum ranging up to ten shillings, according to the quality of the ore.

THEORY OF LEAD SMELTING.—The smelting of lead ores with a view to the metals which they contain, demands no little amount of attention, to perform the operation in the most effective manner. The details of the process differ considerably according to the position of the works in relation to fuel, the nature of the ore, and its peculiar richness in silver, *et cetera*. So far as regards the reduction of the metallic lead, the principles of the various reactions may, however, be referred in most cases to the decomposition which takes place at a high temperature, by the mutual effect of an oxidised compound of lead and the sulphate, whereby the non-metallic elements are driven off, generally as sulphurous acid, and the metal is left. To bring about such a change it is customary to submit a portion of the galena to a preliminary roasting in contact with air, during which considerable quantities of sulphate of lead are produced by the oxidation of the sulphur and metal of the galena. This being done, the roasted and the crude materials are apportioned and heated in a furnace with due precautions, till the lead flows off, leaving a residue of the crudities of the ore, together with a portion of the unreduced substance. Much of the tact and knowledge of the smelter is shown in the manner in which the admixture is made, and in the subsequent application of the heat. And without knowing the reactions which take place, the operator can never be certain of success, but is subject to the risks and hazards arising from the different qualities of ore and imperfect roasting.

Indeed, the knowledge of the behavior of the galena under the influence of a high temperature, is the key to a comprehensive view of the whole business of lead smelting. When sulphide of lead—galena—is heated in a close vessel, out of contact with air, no change takes place beyond fusion, if the heat be sufficiently intense. This is not the case, however, if air be admitted, and allowed to flow over the fused mass; for then not only will the sulphur be oxidised, but a portion of the metal will be volatilized. Hence it is, that in operating upon lead ore, in particular kinds of furnaces, large quantities of the lead are driven off in vapor.

When the temperature applied is low, and the air freely circulates through the ore, the sulphide is converted into sulphate of lead, which resists a higher temperature, and is consequently more fixed. A mixture of sulphate of lead and of sulphide, affords upon the

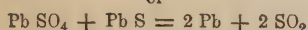
application of heat sulphurous acid and metallic lead, which react upon one another, as represented in the formula:—



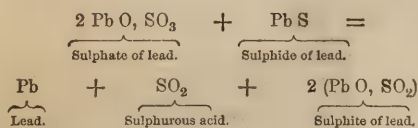
Resolved into



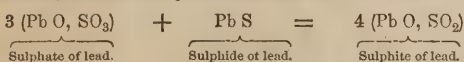
or



From this it may be seen, that by the action of the heat, one equivalent of the sulphate and one of the sulphide afford two equivalents of lead—that is, the whole of the metal which they contain—and two equivalents of sulphurous acid. By making the composition of the charge, from which the metal is to be eliquated, as near as possible to the above formula, there is no doubt but that the most perfect and economical decomposition will follow, and nothing will be left to desire beyond the regulation of the proper heat. It is not so, however, when the ratio between the sulphate and sulphide in the charge is altered, and more especially if the sulphate be in excess. Thus, if instead of an equal number of equivalents of the two ingredients, one of the sulphide and two of the sulphate be employed, the effects will be less advantageous; for in this case, only one equivalent of metal will be obtained, as the equation shows.—



A further increase of the amount of the oxidised compound would be productive of still less satisfactory results, and hence, if the ratio of the sulphate to the sulphide of lead be as three to one, no metal will be obtained, as shown by the formula:—



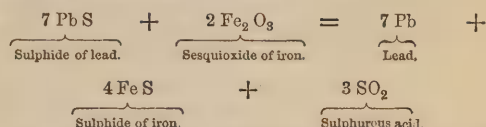
but instead, four equivalents of oxide of lead—Pb O—and four of sulphurous acid result. From these facts the obvious inference is drawn, that an excess of the well-roasted ore, which represents the sulphate of lead, must be avoided when compounding the charge. By employing a larger quantity of the galena representing the sulphide of lead, than is stated in the first of these formulæ, the consequences are not so bad as those just explained; for in this case, a portion of the sulphur, usually amounting to one-half, passes off as sulphurous acid, and the remainder is left united with the metal as a subsulphide of lead, which requires a much less amount of roasted ore for its reduction than the ordinary galena; neither does it require such a high temperature: and, owing to its entering into rapid fusion, it forms a layer upon the reduced metal, whereby the latter is preserved from the oxidising influence of the air.

Sulphide of lead is decomposed, without the intervention of an oxide of this metal, in a very perfect manner

by metallic iron, which takes up the sulphur from the lead, and forms therewith sulphide of iron:—



The heat required to effect this change is, however, much more elevated than that which answers for the preceding decompositions. An oxide of iron, such as results in one of the processes to which pyrites are subjected in the manufacture of sulphuric acid, would answer the purpose of the iron much better; for a lesser quantity of the material would suffice to reduce a large weight of the galena, and at a comparatively low degree of heat. In this case the change which would result is symbolized in the annexed equation:—



A double advantage may be derived from the adoption of this method of decomposing the galena, namely, the reproduction of iron pyrites, which may be utilized in the manufacture of sulphuric acid.

Of all these reactions the simplest in execution is that wherein metallic iron is employed, for only a mere heating is necessary to produce the lead. In large works, however, this is never resorted to, unless the mineral possesses such properties as necessitate the application of iron. That which is most general is the first-mentioned, in which a sulphate of the metal is produced, and this, mixed with galena, is subsequently acted upon by the heat to separate the metal. By a preliminary roasting the galena is converted into sulphate of lead, either in an open heap or in a roasting furnace. The method of heating the subsulphide of lead is frequently resorted to with advantage, as by it large quantities of metal are obtained, together with protosulphide of the metal which remains, and may be further operated upon.

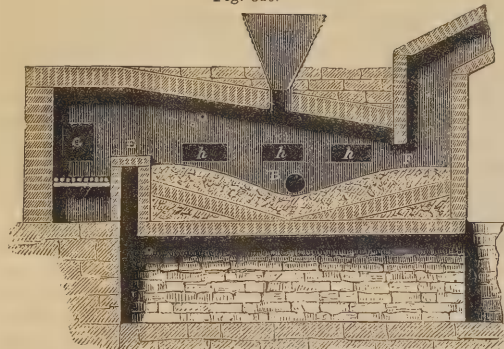
THE FURNACE.—Three kinds of furnaces are used by lead smelters. In England and Wales the reverberatory form is exclusively employed, and no other affords more rapid results; the *Scotch Furnace* has been adopted at Alston Moors, and in some places on the Continent; and the high or tuyere furnace is employed where the ore is refractory or fuel is scarce.

The reverberatory furnace, called the cupola, is of very ancient origin, and has long been in vogue in North Wales, whence the models were brought to Derbyshire about the year 1747 by a company of Quakers. Long before this, the lead ore of Derbyshire and the North of England was smelted in very rude furnaces, called *boles*, the fire being urged by the natural force of the wind. For this reason the furnaces were always constructed on the Western side of an eminence. To these succeeded furnaces urged by bellows, similar to those of a smith's forge, and worked by water-power.

The form of the reverberatory is represented in plan, Fig. 320, and in elevated section, Fig. 321. Generally, the sole of the furnace, A, is eight feet in length by six in breadth, and is constructed of the fused slags

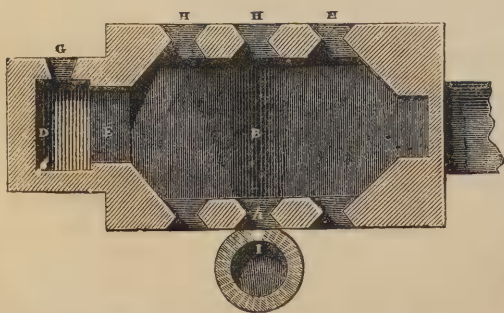
from the preceding operations, worked into the necessary form, during the time they are in a semi-fluid

Fig. 320.



state, by a strong iron rake. The shape of the sole is that of a shallow basin, in which the fluid metal collects at the deepest part, and is drawn off by a tap-hole shown in the section at B. By means of a solid bridge, E, of firebrick, the fire, D, is separated from the hearth; it is usually about two feet thick, and about one foot in height, leaving from fourteen to eighteen inches space between it and the arch for the flame to pass over. As shown in the drawing, the arch, C, gradually declines towards the further extremity of the hearth, from which it is elevated only six inches, the height from the deepest part of the depression in the bed being only two feet. At the extremity of the furnace, opposite the fire, there are sometimes two openings, separated by a triangular prism of firestone, which lead to a flue, F, a foot and a half wide and ten feet long, which is recurved towards the top, and runs into an upright chimney fifty-five feet high. This flue, for a short distance from the furnace, is covered with flat tiles closely jointed in fireclay, but which may nevertheless be easily removed. Such an arrangement is necessary in order that the *lead fumes*, which at a high temperature are freely sublimed, may be cleared away and the freedom of the draught insured. One of the sides of this furnace is called the *laborer's side*, being that from which the fire is supplied with fuel through the door, G; on the

Fig. 321

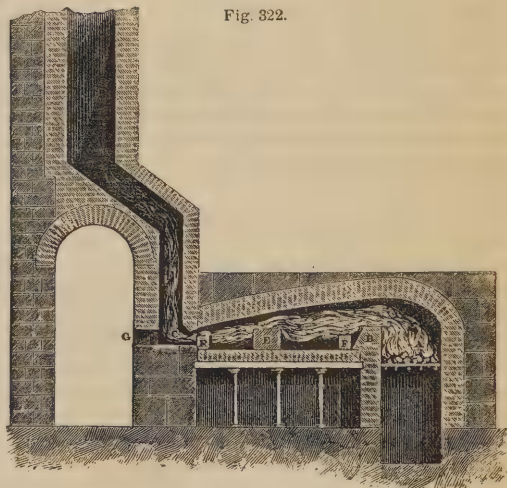


same side are three other openings, H H H, which are closed by sliding plates, and vary in area from six inches square to about eight inches by twelve. When

necessary, the charge is stirred through these openings, and they are also useful for admitting air when the process of roasting requires it. Opposite is the *working side*, in which are five apertures; three corresponding with those on the other side, and similarly secured, and the other two, below them, used for running off the metal and scoria. Towards these last the bed of the furnace inclines in such a way, that the part which is opposite is nearly up to the aperture H, whilst at the tap-hole it is eighteen inches below H, on the same level. The lead flows into a cast-iron pan, I, set in a niche a little under the side. There is in the middle of the arch an opening, to which is fitted an iron hopper, where a charge of ore is deposited whilst that in the furnace is being worked; and when the latter is drawn off, the material in the hopper is let into the furnace, by drawing a slide.

The preceding is the kind of furnace employed at Grassington in Yorkshire, and in which the roasting and smelting are conducted. In those localities where the two operations are conducted separately, as at

Fig. 322.



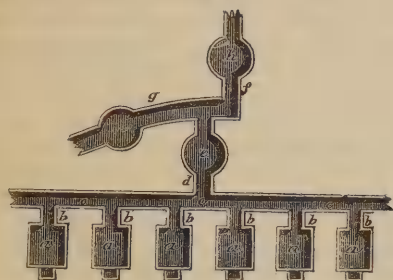
Redruth and other places in Cornwall, the roasting furnace employed is that represented in Fig. 322. A is the fire, and B the fire-bridge; C C, separate ducts by which the smoke passes off to the chimney; E E, working doors, which allow the workmen to spread and stir up the charge of ore as required; and F F, smaller apertures serving the same end, and admitting air for the combustion of the sulphur of the mineral. The sole of the furnace is a cast-iron plate, upon which layers of firebrick are accurately fixed together, the whole being supported upon pillars, as shown in the drawing. Besides the apertures already mentioned, there are others, G, generally at the end opposite to the fire, through which it is rabbled at intervals. The size of this furnace is smaller than that in which both the roasting and smelting of the ore are performed.

At the works near Holywell, North Wales, the furnaces employed are of that kind in which the roasting and smelting are performed successively; they are very similar in form to that already described, only that there is no opening for running off the slags. The hearth is

hollowed out below the middle door of the furnace, the back and ends being made to slope towards this part. Twenty-four inches is the ordinary depth from the bottom of this basin to the sill of the door; but it varies a little according to the kind of ore operated upon. In the other details of the hearth and arch these furnaces are similar to those already mentioned. In this locality, however, the flues from all the furnaces enter one main, which leads to a chimney disposed as represented in Fig. 323.

Here the furnaces are shown as at *a a a*, and the separate flues, *b b*, opening into a main channel, *c c*, five

Fig. 323.



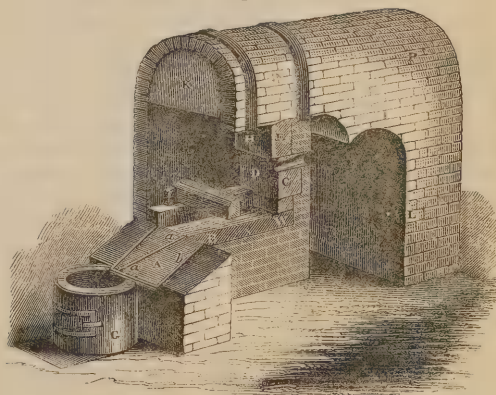
feet deep by two and a half wide. Another one, *d*, six feet deep by three in width, opens from the latter into a circular chamber, *e*, fifteen feet in diameter, wherein, as well as in the conduits leading to it, the *lead-ashes* volatilized from the furnaces are intercepted. From *e* the smoke is conducted by a similar flue, *f*, which enlarges as it approaches the chimney, and where it is joined by the flue, *g*, from another department of the furnaces, to a depth of seven feet and a breadth of five. The chimney has a diameter of thirty feet at the base, tapering to the top, where it measures twelve, including the thickness of the walls; its height is one hundred feet; but as it stands upon an adjoining hill, which is about sixty feet above the level of the furnaces, the total height of the flue may be said to be about one hundred and sixty feet. Such an arrangement is necessary, in order to draw off, out of the range of the inhabitants, animals, and vegetation of the neighborhood, the enormous quantity of sulphurous acid which is evolved from the thousands of tons of ore worked annually.

In many parts of England, more especially in the counties of Durham, Cumberland, and Northumberland, the smelting of the lead ores is conducted in the *Scotch furnace*, or *ore hearth*. It is shown in Fig. 324, and consists of a rectangular cavity of masonry, *a b w*, twenty-four inches in length by a breadth of twelve, and a depth varying from twenty-two to twenty-four inches, the whole inclosed in an arched hood, *p*. A considerable portion of the hood, on the near side, is removed to show the interior arrangements. The cavity is entirely lined with cast-iron, the bottom portion, *b w*, being one entire piece, having a ledge five inches in height and two in thickness surrounding every part of it, except on the side facing the *workstone*, *A*, placed at one end of the rectangular construction. The ledge upon the side, *B w*, is removed to show

the interior of the cavity. The workstone, *A*, is likewise surrounded by a ledge, *b*, on all sides except that near the hearth, and which either rests on the ledge surrounding the hearth bottom, or is united to it and forms part of the casting. In either case it is fixed at an incline of about six inches. On the back edge of the furnace bottom is placed a prism of cast-iron, *C D*, called a *backstone*, six and a half inches square in section, and twenty-eight in length, on which rests the nozzle of the tuyere. Above this is placed another cast-iron prism of the same length, and eight inches in height, which is known as the *pipestone*; it has a cavity in its centre for the introduction of the tuyere, and projects about two inches over the hearth. A third stone, *E H*, is fitted on the latter, and completes this side of the furnace, making its total height from the sole-plate twenty-five and a half inches. Two prismatic castings, called *bearers*, are placed along the lateral sides, twenty-six inches long and five square, and projecting slightly over the edge of the workstone as well as of the posterior backstone; these contribute effectually to give solidity and fixity to the parts. These bearers support, through the intervention of several ranges of firebricks, a piece of cast-iron of the same dimensions as the lowest backstone, and which is called the *forestone*. This piece is in contact at each of its extremities with another mass of cast-iron, six inches cube, and supported on the brickwork; this is called the *keystone*. Finally, the spaces left between these keystones, at either side, are filled up with other blocks of castings similar to the latter.

When the workstone, *A*, is not connected with the sole-plate, *B w*, the space between them is filled up with a cement formed from ground bone-ash and galena, thoroughly mixed and pressed firmly into it. Before the workstone, and set in masonry inclosed in a cast-iron jacket, is the lead-pot, *G*, into which the freed metal flows through the channel, *a a*, which is sunk beneath the surface of the plate. It is placed close to the furnace, in order to prevent the escape of lead

Fig. 324.



fumes as much as possible. This is more completely effected by the hood, *p*, in which is a flue communicating with a chimney, and in which is left a small door for the introduction of the ore and fuel. The movable iron plate, *K*, in front admits of being raised or depressed at pleasure, whenever the draught requires

it; and the blast, which is forced through the tuyere, is regulated by a valve placed in a pipe, which is approached by the door-way, L, left open for this purpose. Heavy iron bands are employed for binding the brick-work more firmly, as shown in the figure.

Smelting in Reverberatory Furnaces.—It is seldom that any other kind of furnace is adopted for lead smelting in England, besides those above-mentioned. The routine of working which the English smelter pursues when the reverberatory furnace is employed, will now be described.

The fact has been already stated, that the process of smelting is modified according to the nature of the ore. Generally speaking, the average richness of the English ores of lead is about seventy-five per cent. of metal; but in many specimens there is found not more than twenty per cent.; and, in fact, ore is often met with varying between these extremes. The remaining constituents are composed of sulphur, the stony matter of the rock in which the *lode* is found, *et cetera*, and which consists, for the most, of sulphate of baryta, carbonate of lime, silicates, and sometimes—as in some of the ores at Holywell—carbonate of zinc, and the like. In order to produce a fusible compound, which will melt at as low a temperature as possible, a judicious admixture of two, three, or more kinds of ore is made, according to the nature of the non-metallic impurities; and it is often found necessary to have recourse to fluxes. When, however, the gangue is of such a nature as to melt readily, such additions are unnecessary. A properly-conducted analysis of the ore will always enable the experienced manager to judge of the additions that are best calculated to favor the separation of the impurities.

In the lead works in the neighborhood of Alston Moor, as well as in those of Derbyshire, the charge is composed sometimes of as many as seven varieties of ore, and weighs only sixteen hundreds of one hundred and twenty pounds each; but in the very extensive works belonging to Messrs. WALKER, PARKER, and Company, the charge is twenty-one hundreds, and is rarely composed of more than two or three kinds of ore. In the latter works this weight of ore is put into the hopper; and, as soon as the furnace is brought to a dull red-heat, or after drawing out the slags from the last charge—if the furnace has been working already—the slide in the neck of the truncated cone is withdrawn, and the ore is allowed to precipitate itself upon the bed of the furnace, where it is spread out into an even layer, through the furnace doors at the back. No effort is made at this period to urge the heat; it is rather allowed to sink; and only a few spadefuls of coals are thrown upon the grate at intervals, to maintain the heat at the moderate standard required. After spreading out the ore, all the working doors, as well as the outlets for running off the slags and metal, are closed, and the damper is lowered. As soon as the ore becomes heated, and the sulphur begins to escape as sulphurous acid, if any rich slags remain from a preceding operation, they may be thrown into the furnace at the opposite doors furthest from the fire, and spread out like the ore. Air enters the furnace through a rectangular slit over the tap-hole; this is left open all the time that the roasting continues. After the charge of ore attains a

dull red heat, and the sulphur begins to burn off, the heat produced is nearly sufficient to carry on the roasting, independently of the fire in the grate; still, this is maintained, but only feebly. At the expiration of a quarter of an hour, the ore is well turned over with the paddles, so as to present a fresh surface, and to cause the evolution of a fresh quantity of the sulphur. One hour and three quarters are devoted to this part of the operation, the intervals between the rabbling of the charge being occupied in casting the lead from a previous charge into pigs. In the course of the roasting of the ore, some metal is produced from the reaction of the rich slags thrown in at the upper door upon a portion of the galena; this metal is drawn off at the proper time. Coal is added generally to effect the reduction, and rabbled with the molten mass some short time previous to the metal being drawn off. Whilst the smelter is tapping off the reduced lead, and throwing the scoria—which floats upon the bath—back upon the furnace, the assistants are stirring up the ore with their paddles. The slags from the bath of metal, as well as the rich ones from the previous charge, being thus partly smelted, and the ore roasted or oxidised to a certain extent, all the doors of the furnace are opened, and the ore is thoroughly turned over towards that side on which they work.

At this period the vapors of sulphurous acid have considerably diminished, and the temperature of the interior of the furnace becomes lower. The lead, which before this rabbling and cooling was beginning to ooze out, is checked. Some coal is now thrown upon the fire; the damper is slightly raised to increase the draught—the doors of the furnace being all closed during the time that the firing is taking effect. This is recognized as the *second stage*, or *firing*; the first being the *roasting* of the ore. In about half an hour the furnace assumes a red heat, and the material contained in it begins to flow down the incline of the sole towards the basin. The doors at this juncture are opened, and the smelting matters pushed by the smelter to the front of the sole, near the bridge, where they are spread out by his assistant from the opposite side. A little quicklime is now thrown upon the bath of metal through the middle door, and the ore and melting matter is worked through the doors at the back for a quarter of an hour; then spread out upon the sole. Meanwhile the smelter, with a long rake or paddle, forces the slags from the surface of the metallic bath towards the bridge.

A little respite is now given to the operation, the doors being left open for a short period; during which the lead remains in repose, and the metal, which was forced back with the slag, descends again into the basin. It is assumed that the cooling of the furnace at intervals, in this manner, not only facilitates the separation of the gangue from the metal, but shortens the time of smelting in every way. Some fuel is thrown upon the grate, to maintain a moderate heat; and the workmen resume their rakes, and turn over the slags and ore. When this is done the doors are closed, and the grate is charged with the third firing; the damper is entirely drawn, and the furnace is left to itself for three quarters of an hour. This *third firing* is given three hours to three and a half

after the charging; and at the end of the fourth hour the doors are again thrown open, and the charge stirred by the assistant opposite to the smelter's side, for the purpose of facilitating the flow of the metal into the basin of the hearth. The slags are once more pushed from the surface of the bath of metal by the smelter, and spread with the ore by the assistant. If the galena should happen to be silicious, a portion of the oxide of lead is taken up by the silica during the preceding period, and flows down upon the reduced matter in a matt. To decompose this a quantity of quicklime is thrown in from the front, agitated with the mass slightly; then the doors are once more secured, and the fire is replenished.

At this period the practice is to throw a little slack into the furnace, with the view of assisting in the reduction of the oxidised compounds of lead which may still exist, as well as to prevent the oxidation of the metal. This is the period of the *fourth* firing, and lasts forty minutes; so that its effect takes place in about four hours forty minutes from the hour of charging. Now the doors are opened, the smelter pierces the tap-hole, and allows the reduced metal to flow out into the basin sunk in the floor outside. Quicklime is thrown upon the slags which remain, in order to dry them; he then pushes them towards the back, whence the assistant draws them out at the back doors.

Thus the smelting of a charge of ore of twenty hundred, at the Dee Bank Works, usually occupies a period of four hours and a half; but when the slags, instead of being dried up, are melted, a further firing is necessary, and the operation occupies a longer time. Generally speaking, the furnace is ready for the reception of another charge in six hours; so that, in the twenty-four hours, there are four charges worked off by every furnace. The week's work extends to twenty-two charges, generally, although the standard is limited to sixteen. Unless the ores are very refractory, the quantity of lime required for each charge amounts to one hundredweight; but some ores are worked which take as much as two hundredweight of this agent. The lead from the charge of twenty hundredweight of ore averages from fifteen to sixteen hundredweight. The richer slags which form on the bath of metal are worked with the succeeding charge, in the manner described; but the remainder are smelted—by a process to be described further on—in *slag-hearths*, built on the German principle. It is often found necessary, when very fusible slags are produced in the furnace, or the metal becomes more or less oxidised, to employ billets of wood, in the same way as the *polling* is effected in the refining of copper; only that, in the case of lead, it is not performed within the furnace, but in the pan without, whilst the lead is hot. The quantity of coal employed for the smelting of each charge weighs, on an average, about half a ton.

In the Grassington works, Yorkshire, the ore is composed of galena, mixed with carbonate of lead, and a gangue of carbonate of lime and sulphate of baryta. Here, as at Holywell, the charge is generally twenty hundreds. The period of roasting extends from three to three and a half hours, and the melting for metal succeeds almost in the manner described. Quicklime,

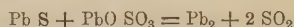
mixed with slack, is used to dry the slags, which are spread upon the sole of the furnace; and the melting for metal, and drying of the slags, are repeated three times in succession. Fluoride of calcium—fluor spar—is sometimes used as a flux, and the bath of metal in the basin of the furnace is always kept covered with lime. Seven to eight hours are occupied by the working of the charge, and the metal obtained weighs from sixty-one to seventy-two per cent of the ore. Owing to the materials being less refractory, the consumption of coals here is somewhat less than at Holywell.

At Lea, in the neighborhood of Alston Moor, the ores smelted are, for the most part, of two kinds—namely, an almost pure galena, and another ore of lead, which has the annexed composition:—

	Centesimally.
Sulphide of lead,	55.00
Carbonate of lead,	23.00
Sulphate of baryta,	19.00
Clay,	3.00
	100.00

In the reverberatories at Pezay, in France, fir-wood is used for fuel, of which about four stères are required for smelting each charge of one thousand two hundred and fifty kilogrammes, or twenty-five hundredweight of the ore, the richness of which averages about seventy-six per cent. of metal.

In all the works mentioned, and in fact wherever the reverberatory furnace is employed, the principles of the operation are explained thus:—During the first stages, a greater or less quantity of sulphate of lead mixed with oxide is produced; the several rabblings which are given to the charge during the period that the temperature is retained at a low degree, tend to increase these substances, and to mix them more intimately with the ore, so that when the firing for the production of metal is given, the reaction,



as formerly described, may take place. The partial cooling of the furnace after the second firing, is supposed to forward the same ends, inasmuch as the temperature which, if continued, would melt the materials and considerably retard oxidation, is slackened, and after the proper interval, the charge bears to be stirred as when in its most friable state.

Smelting in Blast Furnaces.—The use of the blast furnace involves the necessity of a somewhat different treatment. The *Scotch furnace* or *ore-hearth*, described at page 465, may be taken as the type of this kind of furnace when adapted to the smelting of lead ores.

Generally very rich ores are operated upon where the Scotch furnace is employed; and these are subjected before smelting to a preliminary roasting in a furnace of the reverberatory class.

From nine to eleven hundredweight of ore constitute a charge, and two and a half to three hours are required to effect their calcination; so that about nine charges are drawn during twenty-four hours. The heat of this furnace is kept purposely lower than the melting point of the galena, but sufficiently high to effect combustion of the sulphur with the oxygen, whereby it is converted partly into sulphurous and partly into sul-

phuric acid. Evidence of these changes is observed in the heavy dense fumes which fill the furnace and escape into the chimney. When a portion of the charge softens and becomes somewhat agglutinated, a fresh surface is presented to the flame by rabbling, and moving the hotter material to a colder part of the hearth. When slime ores are operated upon, the temperature is kept such as to render the mass somewhat pasty, in order to prevent the loss which the draught would occasion if the ore retained its friable quality. The roasting of the charge being effected, the material is drawn out by the door, and falls into a tank or well of water, whence it is subsequently raised and dried before submitting it to the operation of smelting. In this state it is a compound of oxide of lead, sulphate, and subsulphate, with undecomposed sulphide. Roasting the mineral in heaps was a practice once common enough, but is now obsolete, at least in England and the neighboring countries.

The roasted ore and coal are introduced into the smelting furnace after the latter has been heated by a preliminary firing, and the blast is thrown in either by a good condensing engine or by a fan worked by steam. To heat the furnace, the practice in the English smelting districts is to fill the cavity with peat, cut into the usual prismatic form, taking care that those towards the front are regularly placed in layers, one above another. A few ignited coals are placed immediately before the tuyere or nozzle, by which the blast enters, and the air is forced in gently, in order to ignite the mass. Some small coal is also thrown on the peat, when it is thought that the heat produced by the peat alone is insufficient to bring the furnace to the proper temperature. When the whole of the fuel is ignited, and the furnace has acquired sufficient heat, the *browse* from a preceding charge, if there be any, is thrown upon the ignited mass, and the blast continued as before. In a short time the portion of browse that remained on the hearth, together with that added, softens, and is drawn out upon the workstone by means of a large rake called a *goveloch*. Here the experienced workman is enabled to distinguish and separate the poor slag from the richer material by the color; the former, which has a shining grey appearance, is thrown with the spade in a heap to the right of the operator, and the latter is set aside to be again returned to the furnace. If the browse retains much slags, or, owing to its being very fusible, comes out in a pasty state, some quicklime is added, which, by uniting with the silica, causes the material to become more refractory, and at the same time disposes the lead compounds present, to yield up the metal with greater facility in the subsequent operation. This base is employed also to effect the opposite change of rendering a refractory slag less so, but in much smaller quantity than when it is used, as the saying is, to *dry* the mass. The grey slag, which is thrown to the right, and which contains from a fifteenth to a tenth of its weight of lead, is subsequently smelted in what is called the *slag hearth*, while the richer material, consisting of semi-reduced ore, mixed with fragments of coke and clinkers, and termed *browse*, as already mentioned, is mixed with some slack, and reintroduced into the furnace. A brick of peat is placed

before the nozzle of the blast-pipe, in order to spread the current, and the whole is heated for about a quarter of an hour, at the end of which the materials are raked out on the working-stone, where some lead is sweated from the mass, and a portion of grey slag separated. Some small coal and a greater or less quantity of lime are again thrown into the furnace, a square of peat is placed before the venthole, the browse is reintroduced together with a small quantity of fresh ore, and the furnace urged for fifteen minutes longer, when the material is drawn out as before, and the grey slags separated, as well as the portion of metal which becomes reduced. Thus every quarter of an hour the *browse* is returned into the furnace, with the necessary addition of fuel and fresh ore; and, at the same interval, some lead is separated from the mass on the workstone, and flows into the receiving-pot. The operation is continued uninterruptedly for fourteen or fifteen hours—termed the *shift*—in which time from one to two tons of metal are obtained. The furnace is then allowed to cool for some hours, before another shift is commenced. Lead prepared in this way is esteemed for its purity, which arises from the comparatively low degree of heat applied in its preparation, being inadequate to the reduction of any other metals excepting the lead and silver.

At Pezay, in France, the operations conducted in this kind of furnace are much the same as have just been described; but there is a division of the work, the first part being distinguished as the *fluxing* or *melting*, and the second as the *sweating* or *eliquating*.

The ore which is occasionally treated in the Scotch furnace, when it contains much carbonate of lead, is not subjected to a previous roasting, but at once submitted to the smelting operations described.

The Slag-Hearth.—In England, as well as at Pezay and other places, the slags from the reduction by the ore hearth, and also from the reverberatories containing a variable amount of metal, are reduced in what is called the *slag hearth* in the English establishments, and *fourneau a manche* by the French.

This furnace is seen in section in Figs. 325 and 326, in which A shows the cast-iron plate forming

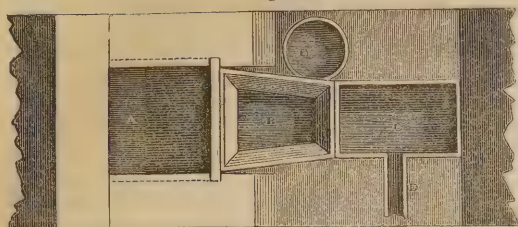
Fig. 325.



the base of the furnace; B, the pot or basin in which the lead is collected, and which is filled with cinders, *et cetera*; C is the tank containing water, and used to cool the slags which flow into it, after passing over the basin, B, and depositing therein the lead; and D shows a pipe which supplies the tank with cold

water. The form of the furnace is generally that of a rectangular prism, twenty-six inches in length, twenty-two in breadth, and thirty-three in height. The plate of iron, A, forming the bottom, is slightly inclined to the front, and on each side of it are bearers, as in the ore

Fig. 326.

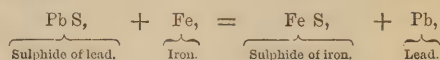


hearth, for supporting the fire hearth, which consists of two stout plates of cast-iron about twenty-six inches long by twelve inches broad. By this arrangement a space of about five inches is left between these plates and the bottom of the furnace, and an additional height of two and a half inches is gained by placing upon them a row of firebricks. In every other respect this furnace differs but little from the ore hearth, only that the temperature is much higher in it than in the latter. From the basin, B, the accumulated metal flows by a pipe into the metal pot, E, whence it is cast into pigs.

At the Dee-Bank Works of Messrs. WALKER, PARKER, and Company, to which allusion has already been made, there are eight of these in operation for working off the slags from the reverberatory smelting furnaces. Peat is used to heat the furnaces when first set in operation; this is lighted in the usual way and the blast set working. The peat is surmounted by a layer of coke, and when the temperature rises to the melting intensity, a layer of the slags, or scoria, is introduced. After this the temperature is kept up without intermission, and the furnace is charged with successive layers of coke and slags as the matter sinks in the furnace. The materials enter into fusion ultimately; but before this change is effected, there is a deoxidation of the sulphate of lead in the higher part of the furnace, and a subsulphate or sulphide produced instead, which, acting upon the undecomposed sulphate, liberates the lead of both, the sulphurous products being volatilized. The oxide of lead which might also be produced by the reaction of the excess of lime present, is likewise reduced by the charcoal to the metallic state. By virtue of its gravity, the lead separated descends through the molten mass. The metal obtained in this way is never large in quantity, and is accounted of inferior quality, owing to the great heat at which it is produced, reducing other matters, such as iron, *et cetera*, and which are alloyed with the lead.

Smelting Silicious Galenas.—In many Continental localities where the galena is very silicious, a process of smelting is followed, different in its nature and characteristics from that which has been detailed, as well with reference to the reverberatories, as to the high furnaces. For the difference of treatment, a direct necessity exists, inasmuch as were such silicious galenas worked by the *method of reaction*, that is, roasted with the view of generating a quantity

of sulphate of lead which might be made to react upon the unaffected sulphide, so as to precipitate the metal from both, a very serious loss would be incurred; because instead of inducing such a change by the fusing temperature finally applied to the ore, a combination of the oxide of lead and silica arises, and the silicate so produced, besides being difficultly decomposed, has no action upon the sulphide and sulphate of the metal, and, consequently, a large quantity of metal would pass off unreclaimed. The process adopted is founded upon the reduction of the sulphide of lead by metallic iron, whereby the negative element is transferred to the latter metal, and metallic lead separated, as shown in the equation:—

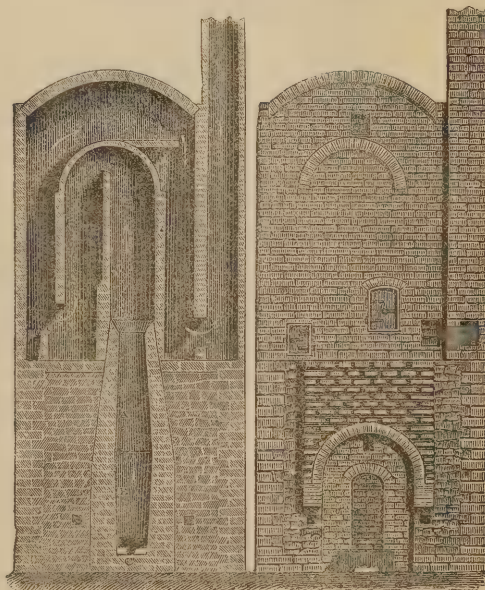


As is evident, the decomposition of the galena is perfect, and takes place in equivalent proportions, so that, by the use of twenty-eight parts of iron—one equivalent—one hundred and four parts of lead—also its equivalent—is produced.

At Clausthal, a quantity of ground and washed ore is taken and mixed with various other products, resulting from foregoing operations, together with a proportionate quantity of granulated cast-iron, and the scoria which are detached from this metal when working it under the hammer, *et cetera*, and the whole is fused in a small high or blast furnace, such as is represented in the annexed engravings. Figs. 327 and 328 show a front elevation and section, and Figs. 329 and 330 a

Fig. 327.

Fig. 328.



side elevated section and plan. The shaft, A B, is about twenty to twenty-three feet high, and about three and a quarter in breadth at the widest part. Usually the shaft interiorly presents the appearance of two inverted crucibles, the lower one, or B, contracting towards the bottom, and the upper, or A, towards the top. At the

base of the shaft is found the crucible, the base of which is formed of two grit-stones placed so as to form a channel at their junction. Upon these stones a mixture of clay and charcoal is firmly pressed,

Fig. 329.

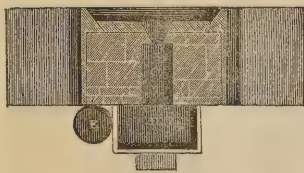


so as to face the whole up to the furnace part, leaving a cavity in the middle, as indicated by C and D in the figures. An aperture connecting the crucible, D, with a second crucible, E, Fig. 330,

by means of a gutter or pipe, permits the fluid matters in the former to run into the latter. The blast is introduced by two tuyeres placed in the face opposite the tryp. The mineral is charged on the tuyere side, and the fuel on that which

is opposed to the blast, and as the heat advances, the scoriæ which attach themselves to the nozzle are quickly cooled, and form an elongation of the latter of about

Fig. 330.



three inches, which enters into the furnace. This incrustation, called the *nose of the tuyere*, is of importance, inasmuch as it conveys the blast to the fuel, and all the oxygen being

combined in this, oxidation of any of the mineral constituents is prevented. Indeed, the proper management of the *nose* requires all the care of the smelter, as upon it much of the success of the reduction depends. The superior part of the furnace is kept at as low a heat as possible, in order to prevent the volatilization of the sulphide of lead. But, in addition to this precaution, the volatile product traverses from the mouth of the furnace, by a number of chambers, before it enters the chimney, so as to intercept the *lead ashes* which volatilize. These chambers are emptied periodically, and the product smelted with others in the usual way. In working this furnace the melted matters flow out continually into the crucible, D, and when full the connection with E is opened, when the contents are transferred to the latter, the metal forming the under part, and the slags the superior. When the aperture becomes closed by the cooling and solidification of the scoria, the obstruction, is removed by an iron bar and hook. The scoria which covers the metal in the outer crucible, is composed of a subsulphide of lead, sulphate of lead, particles of iron, and other substances. It is called the *first lead matt*. After being removed by an iron hook from the bath, the metal is poured through a metal cullender or sieve, to separate fragments of slag, and then cast into pigs.

If the scoriæ be poor in lead, they are rejected, but the richer products are retained to be worked up with a further quantity of roasted ore; but sometimes they are collected till there is a sufficient quantity to be reduced separately.

The original mixture is composed generally of—

- 34 parts of mineral, containing about twenty-four of pure galena.
- 4 to 5 parts of the debris of the cupelling furnace, and impregnated with litharge.
- 1 part of the first litharge—called *abstrichs*—formed in the process of cupellation.
- 39 parts of scoria obtained from the first fusion of the mineral, *et cetera*.
- 4½ parts of granulated iron.

REGNAULT states, that this mixture yields nineteen parts of metal, and seven or eight parts of first matt, containing two and a half parts of metal.

At Tarnowitz in Upper Silesia, the rich mineral obtained there, and containing about eighty per cent. of lead, is treated in a blast furnace like the last-mentioned, with about twelve per cent. of old iron or shot, and as much of the rich matt from the preceding as is thought necessary, together with thirty-six per cent. of the scoria from the same operation, to confer fusibility. About fourteen per cent. of coke are consumed, and the products are sixty per cent. of lead, and twenty-four of matt rich in lead. Most of the scoriæ are rejected. The campaign, or smelting period, continues six days uninterruptedly, in which time thirty tons or more are smelted on an average. The poorer ores, yielding only fifty per cent. of lead are smelted in a high-blast furnace.

In this case the additional matters are, for a hundred of the ore—

- 32 parts of matt from the smelting of rich mineral,
- 12 „ debris of cupelling furnaces, *et cetera*,
- 10 „ scales from the iron forges, and
- 24 „ scoria from the refining.

Forty-three per cent. of coke are used, and the produce of metal amounts to about forty per cent. of the ore operated upon. Each smelting campaign lasts a week, and the produce during this period averages from twenty to twenty-two hundreds of metal.

Generally speaking, those minerals which are rich in silver, and contain large amounts of gangue of a silicious nature, when subjected to the preceding treatment, give a matt which still retains a portion of the noble metal, and on that account is reserved to go through a second fusion.

PURIFICATION OF LEAD.—In almost every case, the lead which is obtained from galena and other ores contains more or less silver, varying, in the English ores, from twelve or more ounces per ton of lead smelted to two ounces or less. In other varieties of lead ores, such as those worked in many establishments on the Continent, the yield is greater, averaging as much as nine per cent. of the lead. When the precious metal is in so large a proportion, the lead is termed workable metal, that is, in a fit state to be cupelled for the silver; but as most of the lead produced in Great Britain was found to yield only quantities averaging, for the richest, ten ounces per ton or thereabouts, and often as low as two, the trouble of recovering this was thought

to be more expensive than the gain in silver, and consequently it was left in the lead. A very simple and unfailing method, however, is now pursued, founded upon a property of the alloy of lead and silver, whereby such lead as contains only about two ounces of silver to the ton of metal can be economically worked for the recovery of the silver. To this process reference will be made presently. Besides silver, there are other impurities found in much of the lead produced on the Continent—more especially in such as is reduced from ores containing the tersulphide of antimony, blende, and the like—owing to an alloy of these metals with the lead being formed. Of course these metals destroy in a great measure the characteristic properties of the lead; so much so, that sometimes it cannot be employed, in many of its applications, till it has been submitted to a process of purification; and when the impurities alluded to exist only in very small quantities, the quality of the metal is so deteriorated, that it will not resist the air or liquids, or work under the roller with satisfaction. Such impurities are occasionally detected in small quantities in some of the English lead; seldom arising from the native ores, however, but rather from parcels of foreign imported mineral. It will be evident that the latter impregnations are much more injurious than silver; for, notwithstanding that this metal renders the lead hard under the roller, it enables it to resist the action of the air better; whereas the other impurities mentioned destroy, to a great degree, the natural power of the lead to resist the air. Traces of iron are frequently found in the lead, when ferruginous gangue or pyrites is associated with the ore; the iron is never removed, however, by any special process, owing to the amount being too minute; nevertheless, the quantity, even though it be only a small decimal part of a per cent., is found to be highly injurious in the manufacture of red lead and carbonate of lead from the metal.

The method adopted for removing the antimony, tin, copper, zinc, and other foreign matters, is often tedious and expensive. It is founded upon the oxidation of those metals, and the separation of the dross of mixed oxides from the lead. To effect this, the smelted metal is re-melted in a reverberatory furnace, through which a copious draught is instituted, and allowed to remain in this state, the scum of oxide being removed from time to time till the most part of the easily oxidised impurities are separated.

To purify the metal, a variable period is required, dependent upon the proportion of the impurities present; hence it happens that whilst some kinds are sufficiently februated in twelve hours or thereabouts, other kinds require a prolonged treatment of several weeks. The dross is a mixture of the oxides of the metals present as impurities, and of lead; and from the color, when drawn out, an opinion is formed as to the extent of the purification. In addition to this, however, the refiner takes out a sample in the ladle, and pours it into a small mould; and, as it cools, he observes the change on the surface, and concludes accordingly. When the impurities are nearly removed, the surface of the assay assumes a peculiar flaky crystalline appearance,; and as soon as this is recognized,

the bath is cleaned from the dross; and the metal, retaining the whole of the silver originally present, is allowed to flow out into the pot, from which it is afterwards ladled into the moulds.

If this lead, thus deprived of the brittle and easily oxidised metals, be sufficiently rich in silver, it is submitted to a process of cupellation in a furnace similar to that represented in the annexed drawings—Figs. 331 and 332—which represent it in plan and section. In these A is the fire; B, the bridge; C, the cupel, which is movable, and composed of a sash or frame of iron bound by a rim of the same, presenting at the under part four transverse bars on the plan of that described at page 284—Fig. 229. The refractory materials, consisting of bone-ashes and very fine *cinders*, are placed on, and well beaten together. After

Fig. 331.

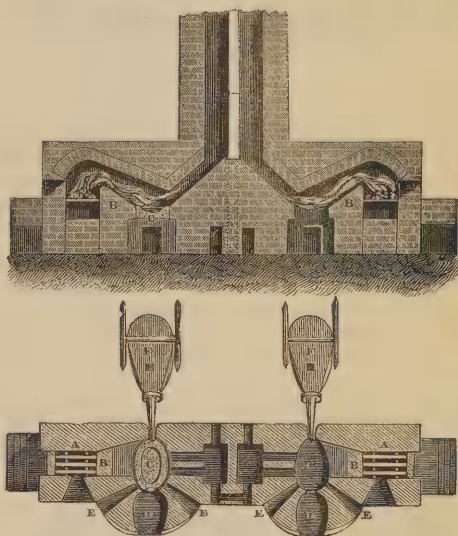


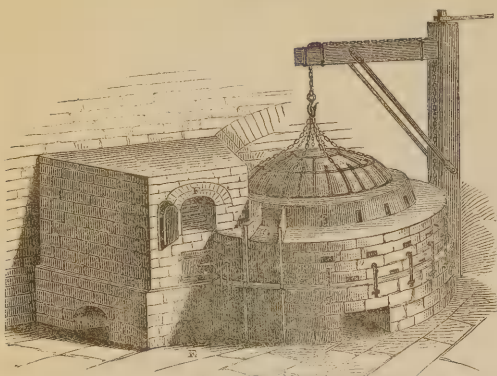
Fig. 332.

the whole is dried, it is inserted in the furnace as represented. EE are openings, either for introducing the pigs of rich metal or the melted alloy into the cupel; FF, means for forcing the blast; but in large works, where several refining furnaces are in operation, the air is urged upon the metal by means of a fan, driven by steam-power, and connecting pipes. The oxide of lead or litharge, produced in the course of the operation, falls into a receptacle, DD, beneath the cupel, and is periodically removed.

The furnace which is in use at Clausthal in the Hartz, is shown in Figs. 333 and 334, next page. Fig. 333 is a front elevation; Fig. 334, a plan on a level with the fire-bridge and tuyeres. A glance will be sufficient to show that this is a kind of reverberatory furnace, the bed of which is circular, and hollowed in the middle a little more than ordinary. The fire-grate, F, is shown at the side, with the draught and ash-oles, E. aa, are the apertures through which the air is blown into the furnace for the oxidation of the lead, which is introduced at the opening, F, in the form of discs; the lead,

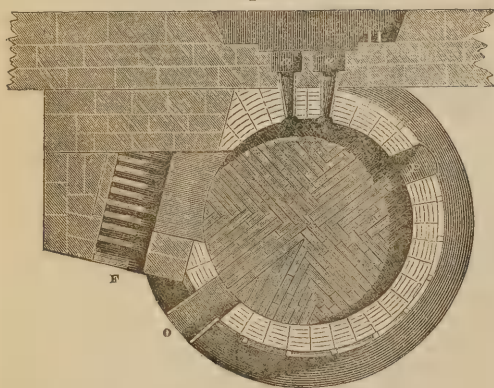
thus deprived of its metallic characters, is emitted as litharge in the fused state through the opening, O, and falls upon the floor of the refinery, or into pots. A riveted plate-iron dome covers the sole of the fur-

Fig. 333.



nace; it is furnished with tackle, as shown in the drawing, by which it can be raised at pleasure. Much attention is given to the formation of the sole of the furnace. The first bed is composed of scoria, well beaten together, and hollowed as a sphere; and upon this a similarly-shaped one, of bricks placed closely together, is formed; and a third overlays the latter. It is constructed of *marl*, and beaten down firmly; but in the most cases, it requires renewal at every fresh charge;

Fig. 334.



the old material, which had become saturated with litharge, being employed afterwards with the matt and mineral in the smelting operations, as already detailed.

The furnace being in order, the charge of metal, amounting to one hundred and sixty quintals, is introduced, and the fire lighted; in a short time the lead begins to flow, and, as soon as the whole has melted, the blast of air through the tuyeres is forced upon the bath. The melted lead under this influence rapidly oxidises, and becomes covered with a blackish coating of oxide of lead, mixed with other impurities, and which, when removed, constitutes what is termed the *abstrichs*. This coating of oxide does not fuse,

but forms a solid covering, which would impede the oxidation of the lead, unless removed. Some charcoal powder is thrown in upon the metal from time to time; and, by the aid of a bar of wood, fixed crosswise upon the end of a bar of iron, the workman draws the *abstrichs* towards the door, O, through which they fall upon the floor of the refinery. After the removal of these matters, the blast is kept up, and fusible litharge begins to appear, and flows out at the aperture before-mentioned; the first portions, however, are very impure, owing to other foreign matters existing with the lead, and are consequently retained, to be *revivified* in the reverberatory or blast-furnace. After a while the product assumes a better color, indicative of its being purer; and, when it has appeared of the proper shade, it is collected for marketable or commercial litharge, and sold as such. When this happens, the blast is urged to effect the removal of the lead as quickly as possible, and the force of the stream of air kept up, till the entire of this metal is removed, and a disc of metallic silver remains.

The proper period for arresting the oxidation of the lead by the blast, is indicated by what is termed the *brightening* of the assay. Whilst the oxidation proceeds, the appearance of the metallic bath is much more luminous than the walls of the furnace; this arises from its temperature being more elevated, for not only does the bath acquire its heat from the fire, but also from the oxidising material, which develops much caloric. As soon, however, as the lead is removed, or nearly so, the temperature of the metallic residue falls to the mean degree of the furnace, and instead of remaining very brilliant, as it was before, it appears tarnished. On the other hand, when the last portions of lead become oxidised, very little remains upon the surface of the bath besides a pellicle of melted litharge, which diminishes rapidly, and presents in succession all the rays of the prism, and, finally, is torn asunder when the surface of the unoxidisable metal makes its appearance. It is this rapid succession of optical phenomena to which the above epithet of brightening is applied.

As soon as this appearance of the bath is observed, the workman throws some hot water on the surface of the disc of metal remaining, and after that some cold water, both of which rapidly reduce the temperature so much as to enable him to remove the silver. This residue is not absolutely pure, however, but contains from one-twelfth to one-sixteenth of its weight of lead, which is removed from it afterwards in the *refining* process, which will be described under *SILVER*. The hundred and sixty quintals of lead obtained from the *schlich* at Clausthal afford quantities varying from three hundred and ninety to four hundred and fifty ounces, according as the metal is obtained from the crude *schlich* or roasted matt, which is generally the richer. Thirty hours are occupied in cupelling the charge. The litharge which is produced towards the close of the operation contains a notable amount of silver, and on this account it is separated from the rest with the view of afterwards recovering the precious metal.

The *abstrichs*, cupel bottoms, and rich slags are afterwards passed through a blast furnace, whilst the

yellow and red litharge find their way, after being finely ground or reduced to powder, into the market. Sometimes, however, the better quality of litharge is reduced. This depends on the demand and the relative value of the metal and the litharge. Generally the lead produced from the fine litharges commands a better price, owing to its being very pure. Abstrichs and the first litharge that is produced in the cupellation are frequently smelted by themselves, especially when they are of an antimonial nature; and the impure lead thus produced is sold at a lower figure for the manufacture of shot.

Pattison's Process.—It will be evident that the oxidation and reduction of lead, when it contains only the one-thousandth of its weight of silver, would be unremunerative if this quantity were to be recovered by the method just described; and much less remunerative would be the cupellation of metal containing not only not the one-thousandth part, but as low a proportion as one-thirty-thousandth part of silver. By a method, however, discovered by H. L. PATTISON of Newcastle-on-Tyne, so small a quantity as one ounce of silver per ton of lead may be recovered with advantage. This beautiful process—like many others the result of an accident—was discovered in 1829. It is founded on the circumstance that an alloy of lead and silver, when cooled with occasional stirring, so as to be at or near the point of solidifying, crystallizes to some extent; and the part so crystallized is found upon examination to contain a very much smaller quantity of silver than the fluid matter which remains, or than the original alloy.

The application of this principle, which is known as *Pattison's process*, is extremely simple and manageable. Generally a series of eight or ten cast-iron pots, each capable of holding about five tons of molten lead, are arranged in a gallery of brickwork with a fire-place beneath each. The middle one of the range is charged with *original* lead, varying, as to the quantity of silver, from twenty or more ounces per ton to two. When the whole is melted the fire is withdrawn, the surface of the metal is carefully skimmed, and the fluid matter stirred by means of an iron spatula. After a brief interval, crystals begin to form and fall to the bottom of the pot, whence they are removed by another workman with a perforated ladle; all the fluid metal being separated by shaking the contents of the latter, which the workman effects by springing the handle on the edge of the pot. These crystals are deposited in the next pot, to the *right* of that in which the metal is first melted, in proportion as they are formed, till about the four-fifths of the weight taken has been transferred. The remaining one-fifth, which is now considerably more enriched with silver than at first, is ladled out into the first of the series towards the *left* hand. A new charge is again put into the middle pot, and transferred in the same way to the right, which may be designated No. 2. When enough of metal has been ladled into the latter to constitute a charge, it is in turn heated, and the crystallized lead melted, after which the process of separating the lead, after it has crystallized, is proceeded with as before, allowing about a fifth to remain, but which is transferred back to

No. 1. In this way the operations are conducted, till the whole of the pots come to be filled with metal holding more or less silver, according to their position in the series, at which time the work may be carried on with the whole, the poor metal passing always to the *right* from the extreme *left*, and that which is rich in silver traversing the pots in the opposite direction. Hence it follows that those to the right must contain metal which is being gradually deprived of silver, while that in the series to the left, must become richer in silver as they recede from the middle one.

During the working of the metal in the vessels, the ladles which are employed are apt to become chilled, as well during the draining of the crystals as when they are withdrawn from the fluid metal for any length; in either case the perforations being stopped by the fluid alloy solidifying in them, and to prevent or remedy this the temper pots are employed. These are about two feet in diameter, and filled with melted lead, the temperature of which is much more elevated than that in the working-pots, so that when the ladle is cold, or its grate obstructed by pellicles of the cooled metal, its immersion for some minutes in this pot will heat it to the proper degree, or free it from the obstructions referred to. Very little attention is necessary to comprehend how the purification from silver may thus be effected, and how the operation, with some slight attentions, cannot fail to be successful. The principal point to be attended to, apart from keeping the metal well stirred with the slice, and carefully removing the crystals, is the regulation of the heat, and which should merely border on the melting point of lead. When beyond this, very few crystals will form, and the process will be slow; practice, however, is the best guide in this particular. The following analyses of the assortments in this process may not be uninteresting:—

	Skimmings	Skimming reduced.	Market crystals.	Market lead.	Rich lead from crystallizing process.
Lead,	98.10	99.72	99.9	99.9	99.8
Antimony, ..	0.28	trace	trace	trace	trace
Copper,	trace	trace	trace	trace	trace
Iron,	1.40	0.28	0.1	0.1	0.2
Lime,	0.22	—	—	—	—
	100.00	100.00	100.0	100.0	100.0

It is to be supposed, however, that a greater or less proportion of silver is contained in all the above, although it is not taken into account in the analyses. The concentration of the alloy is not carried on beyond three hundred ounces per ton at the works above-mentioned. When the silver has accumulated to this proportion, the rich lead is cast into bars about two inches square, and is known by the term *lead riches*.

PATTISON'S invention is now applied in almost all the lead works of the United Kingdom, and within the last ten years, it has been adopted in the principal lead foundries of France, Spain, and Prussia.

Cupellation of the lead riches.—This operation is performed in a furnace of the reverberatory class, having a contracted bed of a particular construction, and designated the *cupel*, or *test*. This apparatus, with the

whole process of cupellation, is fully described at page 284, under the article GOLD. At the smelting works of Messrs. WALKER, PARKER, and Company, where the *riches* holding about three hundred ounces of silver to the ton are cupelled, the process is continued in the same furnace till the last traces of the lead are removed, and the silver is left pure. In the eight refiners at this establishment, there are produced weekly from six to

eight bars of silver, each weighing a thousand ounces. The litharge which does not find its way into the market, is reduced in the reverberatory furnace, by mixing it with small coal or slack, and eliquating it on the bed, which is coated with slack to the depth of two or more inches. In the refining process, the products obtained besides the silver have the following composition at the different stages of the process :—

	Unfallen litharge, common.	Fallen litharge, common.	Fallen litharge, best.	Test bottoms.	Fumes from refining furnace.
Oxide of lead,	99·7	99·6	99·7	59·60	97·00 carbonate of
Sesquioxide of iron,	0·3	0·4	0·3	trace	1·10
Teroxide of antimony,	trace	trace	trace	1·06	0·16
Oxide of copper,	trace	trace	trace	trace	—
Lime,	—	—	—	20·00	trace
Magnesia,	—	—	—	0·40	—
Phosphoric acid,	—	—	—	18·52	0·10 alumina
Silicious matter,	—	—	—	0·44	1·64
	100·0	100·0	100·0	100·00	100·00

USES.—Such are the processes resorted to for the extraction of lead from its ores; but before it finds its way into the industrial arts, it is converted by mechanical contrivances into the necessary forms. These are, for the most part, sheets and tubes; the former being employed largely in architecture, for protecting the roofs, *et cetera*, of buildings, for the lining of tanks in which water is retained, for the construction of evaporating pans, sulphuric-acid chambers, and numerous other purposes. Pipes, on the other hand, find their application in conducting and distributing water, liquids, gases, *et cetera*. And, latterly, lead has been spun into wire, in which state it has been found useful for horticultural purposes, by the resistance which it offers to atmospheric influences. It also enters into various other compounds of a metallic nature, and by its peculiar properties, confers great advantages.

Lead is manufactured into sheets by means of rolling, combined with pressure. The melted lead is cast into a heavy plate six square feet, or more, and about six inches in thickness; and when sufficiently cold to admit of its being lifted by the crane, it is placed on the bench where the heavy iron rollers are situated, and passed under them repeatedly, backwards and forwards, till it is reduced to the desired thickness. By means of screws the rollers may be adjusted at any required distance from each other. At the rolling department of the Dee Bank Works the heavy cylinders are eight feet four by twenty-two inches diameter, and the lead is reduced sometimes to only the sixty-fourth part of an inch in thickness.

The works at Chinese Lead Valley—the pipe-founding department of the same firm—are on a similar scale of magnitude and elegance; and the old process of producing pipes by drawing and rolling is quite discarded. Hydraulic pumps and properly-arranged dies—of which there are a series, producing lead pipes from the smallest gas-pipe to conduits three and four inches internal diameter—may be seen at work, and capable of producing any desired length of piping, of the most regular and homogeneous thickness and quality throughout. Without going further into the details of these very beautiful mechanical contrivances, the subject may be here closed so far as the smelting, purification, and manufacture of lead is concerned.

ALLOYS.—Lead enters into the construction of several alloys, many of which have been already referred to—see ANTIMONY, BISMUTH, *et cetera*, *ante*;—and pewter, or solder, so largely employed by the plumber, is a combination of this metal and tin, in the proportion of two parts of lead to one of tin; sometimes, however, the proportion is varied, according to the requirements of the plumber.

Shot-metal.—Another alloy of lead is in very general use for lead-shot, and is a combination of this metal with arsenic. Shot-metal generally contains also portions of antimony and iron; since lead which is of inferior quality, owing to impregnations of the latter kind, is reserved especially for this manufacture. Arsenic, however, being the recognized alloying metal, the others are not noticed, although their presence affects the proportions in which the arsenic is to be added. Generally, the limits are from three to eight or ten parts in a thousand; the lesser quantity being employed as the lead is more ductile, and the larger when it is hard. The arsenic may be incorporated with the lead while in a state of fusion, either in the form of arsenious acid—*white arsenic*—or of orpiment—*sulphide*; and by the reaction which follows, the arsenic is reduced to the metallic state and combined with the lead; while a portion of the latter is thrown off as sulphide or oxide of lead, according to the nature of the arsenical body employed.

To prepare shot-metal, a quantity of lead, amounting to two or three tons, is melted in a pot; and when the heat has been pretty well raised, the surface of the metal near the rim of the pot is strewed with ashes or powdered charcoal, and the arsenic is introduced in the centre, and stirred with the metal briskly; the pot is then covered, and left so for some three hours. During this time reduction of the arsenical compound takes place, and an alloy of arsenic and lead is formed. With a good quality of lead, the proportion varies from twenty to twenty-eight pounds of arsenic to the ton of metal. This quantity, however, is not combined; for, on removing the cover from the pot, and stirring the whole with the slice or spatula, a large quantity of the arsenic is thrown off with the litharge which is produced. Sometimes orpiment is used, and in small but successive quantities, stirring after each addition. The alloy

is tried by letting a little of it fall through a perforated cullender into water; if the particles thus produced present a lenticular appearance, the proportion of arsenic is too small; but when they are flatter, or hollow in the middle, or elongated, it is an indication of there being a deficiency of arsenic—the proper degree of saturation is arrived at when the globules are round.

When, by this proof-test, it is judged that the alloy is properly saturated with arsenic, the whole is cast into bars, and raised by an endless chain to the top of a high tower, where it is melted in a small pot, and cast in perforated cards fitting into a frame in the centre of the tower. Some expertness is requisite on the part of the founder in maintaining the lead at the proper degree of heat, and also in allowing a film of oxide to form on the interior of the card, through which, in passing, the metal becomes disposed into grains as it parts from the card. Though the management of this part of the operation is deemed important, doubtless it serves only to cool the metal; for if it were to pass through in a too liquid state, it would assume an elongated form, and not globular. There are, of course, for the various kinds of shot, special cards, with perforations corresponding to the size; only that the aperture in the card is much smaller in diameter than the globule of metal which is formed by passing the metal through it. At the base of the tower is a circular basin, five or six feet deep, containing water, and into this the shot falls. When the smaller shot is being cast, the temperature of the metal is somewhat higher than for the larger kinds, such as those known by the letters A, A A, and A A A; B, B B, and B B B; with the latter the metal is said to have acquired the proper temperature when a straw plunged into it will not char, but acquires a perceptible brownish color. The cards used at the Chester Works are rectangular, and about twelve inches by eight; in other establishments hemispherical disks are used for casting the shot; but these are not so convenient as the flat-bottomed cards.

The next step in the process is the removal of the shot from the well, and drying it on a rectangular stove, the top of which is of cast-iron, heated by a fire; on this it is moved about till all traces of moisture have disappeared. It now presents a greyish-yellow aspect. To assort the grains according to the respective sizes, the dried article is put into a long perforated copper cylinder, the perforations corresponding at regular distances with the size of the shot; and beneath such divisions boxes, marked Nos. 13, 12, 11, 10, *et cetera*, for the reception of such as fall through, the smallest being first, and the larger approaching the further extremity, where the kind indicated by B B B are received. A revolving motion is given to this cylinder; and besides, at each revolution, a clapper is made to fall against it on the top surface, so as to knock out any grains which may remain in the perforations. During this process the appearance of the shot is slightly altered on account of the friction; but still it retains its dull, grey aspect. To give it the bloom, it is introduced into a cylinder by a door, together with a small quantity of blacklead plumbago, and the whole made to revolve for some time; and when taken out, it is

found to have assumed the well-known dark-grey lustre or polish peculiar to this article.

Before it is ready for use, however, it has to undergo another treatment, by which the defective grains are separated, and none but the truly circular find their way into the sportsman's belt. This is done by a very simple, but ingenious and effective contrivance. An inclined plane, slightly levelling to the sides, with a box or receptacle for the shot to be tested at its head, and the central portion of which is perfectly level, serves to make this assortment. A small aperture in the bottom of the box, and partly closed by a slide, allows the shot to roll out upon the middle of this table, after which it descends the incline. If the grains be perfect, they move on the middle space till they finally fall with a bound into the box placed in the front for their reception; but the least inequality causes them to deviate towards the sides, where they drop off into the receptacles ready for their reception, whence they are removed to be again melted and recast. The perfect shot is put up into twenty-eight pound bags or packages, ready for the market. In the establishment of WALKER, PARKER, and Company, about ten tons are manufactured weekly on an average; the shot-founding department is unique in the extreme.

Lead is capable of entering into combination with all the metalloids in one and multiple proportions, and of giving rise to bodies which are saline or salifiable, according as the radical combined is capable or not of generating salts. Thus, with chlorine, bromine, fluorine, and sulphur, salts are formed; whilst with oxygen, it constitutes several compounds, of which one is salifiable, others neutral, and finally, a third class, under peculiar agency, manifest acid properties.

OXIDE OF LEAD—Syn. Litharge—*Massicot*, *Litharge*, French; *Glüss*, *Bleioxyd*, German.—There are several compounds of lead and oxygen known to chemists, such as the *sub* and *protoxides*, the *sesqui* and *peroxides*; but all are not of equal interest to the manufacturer. Indeed, of these only the protoxide and the peroxide of lead have been recognized as articles of commercial industry, although, for the most part, more or less of the sesquioxide finds its way adventitiously into both articles.

The protoxide may be prepared in the pure state by heating carbonate or oxalate of lead at a dull red heat in a crucible, in which a current of air is made to circulate, or in an open dish. Here the salt radical is dispersed, and there remains a straw-yellow substance, which is pure oxide of lead, provided the salts submitted to the process contained no adulterants. When the temperature at which it is produced is elevated, it assumes a brownish-red color, which in part disappears as it cools. It is very heavy, and on being fused and allowed to cool, it forms itself into crystals, which, if the refrigeration be sudden, appear as scales; but if gradual, they assume the form of yellow, translucent, hexagonal tables. Oxide of lead is slightly soluble in water, producing solutions which have a feeble alkaline reaction. In potassa or soda liquor, the oxide is easily dissolved, and in this reaction doubtless assumes the nature of an acid, and produces a plumbate of the alkali. If, however, the solution

be allowed to remain for some time exposed to the air, the heavy oxide separates completely, and is ultimately found in dodecahedral crystals. It possesses very powerful basic properties, and is capable of producing neutral saline bodies with the weakest acids. It also combines with many of the acids, in proportions to constitute soluble subsalts, which manifest an alkaline reaction. In the heat it vitrifies boracic and silicic acids, whence its use in the manufacture of glass, pottery, *et cetera*; with oils, also, it seems to enter into peculiar combinations, which confer on them the property of drying rapidly on exposure to the air. Oxide of lead is readily decomposed when heated with carbonaceous or sulphurous matters, metallic lead being formed, and carbonic or sulphurous acid. When obtained by precipitation of the nitrate or acetate of lead, by means of an equivalent proportion of potassa or soda, it assimilates water, forming a hydrate, which rapidly absorbs carbonic acid from the air. Oxide of lead is highly useful to the chemist, as it constitutes definite salts with most organic acids, and thus enables him to isolate the latter in his researches, or bring them into a convenient form, for the determination of their equivalents and constituents. Being so generally employed, it is evident that the greatest attention should be given to the determination of its equivalent. Such has been the case, and repeated estimations of its constituents and combining weight have led chemists to fix the latter at 112, its composition being as follows:—

	Centesimally.
1 Eq. of metallic lead,	104
1 Eq. of oxygen,	8
1 Eq. of oxide of lead,	112

The anhydrous oxide is represented, therefore, by Pb O, and the hydrate by Pb O, HO.

The preparation of oxide of lead, on the large scale, is effected by heating metallic lead in the air, and removing the film of oxide which forms upon it. The first stage in the manufacture of minium is the preparation of this oxide; for, as stated, the metal is oxidised, at a low temperature, with a current of air passing over it. This is the *massicot*, but it does not find its place in the market, although it is more adapted for many applications than the other form of the same body known as litharge. This may arise from the circumstance that, for the production of the massicot, an especial oxidation of the lead should take place, and at some expense; and besides, being finely divided and friable, it rapidly attracts carbonic acid from the air, and passes into the state of carbonate. On the other hand, the litharge is obtained as a secondary product, the production of which involves the manufacturer in no extra costs, and it resists air and moisture much better than the massicot.

Litharge is obtained by the oxidation of lead, raised to a high degree of heat by a blast of air, the temperature being so elevated as to fuse it. When the metal is pure, the litharge which it yields, with the exception of the first skimmings that constitute the abstrichs, is of good quality. Obtained according to this treatment, litharge is a yellowish, or yellowish-red, compact substance, crystallized in six-sided plates, and semi-

transparent. It was customary to designate the yellow and reddish compounds by the terms *silver* and *golden* litharge, from the supposition that the latter contained some precious substance, to which the difference of color was owing. It is well known, however, that a slight superoxidation of the lead, which takes place at a lower heat or during the cooling, when much exposed, is the only difference. Litharge is used in painting as a pigment, for the production of acetate of lead, and sometimes in glass and pottery establishments.

Minium, or *red lead*, is another oxide which forms a special branch of manufacture, and one which, to produce a superior article, requires much care in the operations, and also in the selection of the materials. The purest lead is required for this manufacture. If it contains antimony, iron, silver, or such substances as are met with in inferior qualities of metal, the minium which it affords is never of a good color; besides, it is rejected by the manufacturers of flint-glass, owing to its giving the metal a peculiar dulness, which they endeavor to avoid. The metal selected from the products of the purest ores is melted in a reverberatory furnace, with a spacious hearth or bed, ten feet by seven, and having a high bridge and arch, so that the flame and gases revolve from the latter to the metal over the entire space. The fire is never urged to render the interior hotter than a very dull redness. In consequence of the air passing into the furnace through the fire, and by the other apertures, a covering of oxide forms on the surface of the bath; this is raked aside by the workman, and a fresh surface exposed, which in a short time becomes coated as before, and cleared in the same way. This operation, which is called the *drossing*, is continued till the whole of the lead is oxidised, and a yellowish powder of oxide results. The process occupies about twenty-two hours. As the massicot, or litharge, is increased in quantity, it is carefully disposed into channels for the purpose of allowing contact of the metallic portion with the air, to favor its oxidation. After the metallic character of the lead introduced has disappeared, the oxide, or dross, is spread out on the sole, and turned occasionally, in order that any particles removed during the drossing in the semi-metallic state, or in that of suboxide, may be wholly converted into litharge. When completely oxidised, it forms a layer of two and a half to three inches thick on the bed of the furnace. At this period the powder is raked out into iron waggons at the working door, and conveyed to the coloring furnace, which is in every respect similar to the last, only that its temperature is somewhat lower. Here it is spread on the sole in a layer, and left exposed to the oxidising effects of the air passing through the fire in a partly undecomposed state, and also to that which enters at the doors, which, unless the temperature be too low, are left half or quarter part opened. To expedite the oxidation—to which the tint is to be attributed—the surface is renewed frequently, and sometimes enlarged by artificial channels, made in it with a pronged rake. Great attention is necessary to maintain the heat of the furnace at its due degree—that is, somewhat below dull redness, or between 550° and 600°—also, in exposing a fresh surface till the proper shade of color is attained.

Forty-eight hours are occupied at the Dee Bank Works, where a remarkably fine article is produced. The *red lead*, which now presents a beautiful bright-red hue, is removed, ground under iron disks, circulating in a revolving flat iron tray, and packed in casks for the market.

Minium has a very doubtful composition, and is regarded by many chemists as a mixture of protoxide and of sesquioxide of lead PbO , Pb_2O_3 , whilst others maintain that it is a mixture of oxide and peroxide, the latter acting as the negative radical of a salt $2PbO$, PbO_2 ; and some hold that it is neither one nor the other, but a compound containing four equivalents of metallic lead, and five of oxygen, and which may be represented by the formula Pb_4O_5 or $3PbO$, PbO_2 .

Minium is employed largely as a pigment in the paper-hanging manufacture, to communicate a rose, orange, and aurora tinge; for painting also it is in general use, and in the manufacture of glass and many kinds of pottery-ware, it is an indispensable ingredient, from the property it possesses of forming vitrifiable compounds with silica and alumina, which unite with the other silicates of the glass and ware, and thus render the body perfectly homogeneous.

There is another oxide of lead, known as the puce-colored oxide, which has not a general application, but is useful sometimes in analytical chemistry. Its gravity is 8.902 at 98°, and its composition

		Centesimally.
1 Eq. lead,	104	86.62
2 Eqs. of oxygen,	16	13.38
	120	100.00

Symbol PbO_2 . This body does not combine with acids; it is readily decomposed in the heat into oxygen gas, and protoxide of lead.

The salts of lead, important in a manufacturing sense, are the carbonate, the acetate, and chromate; the sulphate is sometimes prepared. Of these the acetate has been already described—See page 43, Vol. I.—so that only the others require to be noticed.

CARBONATE OF LEAD.—Syn. *White lead*—*Ceruse*, —*Blanc de plomb*, *Blanc de ceruse*, *de clichy*, French; *Bleiweiss*, *Kohlensaures Bleioxyd*, German. This substance is found in nature in small quantities, mixed with other compounds of the metal, in lodes of lead minerals—for instance, in Cumberland, in Scotland, in the Hartz, and in Bohemia; it is also found in many departments of France, such as at Saint Maria-aux-Mines in the Vosges; at Saint Saurier in Languedoc; at Poullaquen in Brittany, *et cetera*. Large deposits of it have been discovered in America, as at Mine à la Motte, and other districts.

In all these localities it generally happens that the carbonate is found associated with other minerals which constitute the bulk of the lode. In these cases it is almost always in the crystalline state, the figure being derived from the rhomboidal prism in some varieties, while other kinds appear as an agglomeration of very minute particles; and it is occasionally found in compact masses. Almost every variety is white or brownish-yellow, transparent, and very refractive, having a specific gravity varying from 6.070 to 6.558. The

natural product is never employed for any of the purposes to which white lead is devoted in the arts, and hence all that is consumed in this way is of artificial production.

Preparation.—Pure carbonate of lead may be prepared by precipitating a solution of pure acetate, or of nitrate of lead, with another of a carbonate of an alkali, filtering off the solution, washing the residue thoroughly, and subsequently drying the mass. So obtained, it is a white powder almost insoluble in water, but dissolved with evolution of carbonic acid in nitric, hydrochloric, acetic and other acids, which yield with this base soluble salts; those salt radicals, which constitute with the metal or its oxide insoluble salts, decompose the carbonate, set free the carbonic acid, and form an insoluble compound. Such are oxalic, sulphuric, and hydrosulphuric—sulphide of hydrogen—acids, *et cetera*. Even water impregnated with carbonic acid readily causes the carbonate of lead to dissolve; but, in this instance, there is no escape of carbonic acid, but an assimilation of that contained in the water. By the action of heat, as already signified, it is convertible into litharge or minium according to the intensity of the caloric and the duration of its application. Produced according to the above method, it is a compound of one equivalent of oxide of lead and one of carbonic acid; sometimes, however, it is met with as a basic carbonate—that is, a carbonate wherein is contained a proportionate quantity of base without being assimilated with its equivalent amount of carbonic acid. Sometimes when prepared on the large scale by certain processes, more or less acetate or sulphate and oxide of lead are found in it; but their quantity will be proportionate to the purity of the compounds taken, and the care bestowed in the manufacture. It consists of—

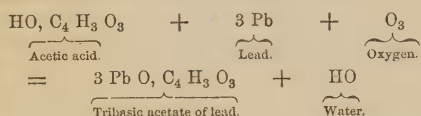
	At weight.	Centesimally.
1 Eq. of oxide of lead,	112	83.59
1 Eq. of carbonic acid,	22	16.41
	134	100.00

and its chemical symbol is PbO , CO_2 .

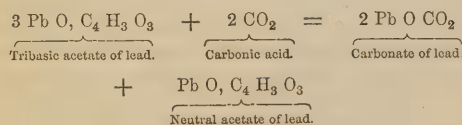
The manufacture of white lead, though of long standing, and comparatively very extensive, has been, till within a few years, very fatal to those engaged in the operations. M. DE RONLZ states that during the eight years ending in 1844, the number of patients admitted to one hospital—the *Hôpital de la Charité*—attacked with *lead colic*, amounted to one thousand one hundred and sixty-three, of which number four hundred and six were persons employed in the manufacture of white lead, and three hundred and eighty-five were painters. It is pleasing to state, however, that endeavors are now generally made by proprietors of white lead factories to remove the causes of the frightful mortality so long produced, by adopting proper machinery for the execution of such parts of the business as prove most dangerous to the health of the workmen, and by enacting rules which enforce the observance of every precaution on the part of the employed.

Carbonate of lead can be prepared in several ways, and of late years various methods have been introduced for its production, all of which may be said to be

modifications of two standard processes—namely, the Dutch method, in which the reactions are effected by operating on metallic lead with acetic acid, and decomposing carbonaceous matters at a comparatively elevated temperature, and without any other moisture than steam; and the other, wherein the carbonate is thrown down from a solution of basic acetate of lead by transmitting carbonic acid through it. These modes offer an unequal degree of advantage to the manufacturer; for although the second is the more rational, as will be seen afterwards, yet the salt produced is different in its molecular construction from that obtained by the first method, and on this account does not suit the wants of the painter or color-maker so well. The particles of the precipitated compound are comparatively large, and appear of a semi-transparent crystalline form; whilst the other is amorphous, its formation being effected by the successive decomposition of the smallest possible quantities of the basic acetate. Hence it is more finely divided, and presents a larger number of particles in a given bulk than the white prepared by precipitation. In principle, however, the two methods are the same, since the carbonate is produced in both by the decomposition of a basic acetate of the metal, the excess of the base being removed by the carbonic acid, and leaving a neutral acetate to react further on the metallic plates in one case, and on litharge in the other, so as to reconstitute a basic salt, which, as soon as it is produced, is acted upon as before. In this way the work proceeds; first, a basic salt is formed, and is decomposed, but yields by that reaction a body capable of producing the first substance an indefinite number of times. The nature of these changes will be more easily comprehended from the following equation, which explains them with special reference to the Dutch method:—



That is, with one equivalent, or sixty parts by weight of pure acetic acid, three equivalents, or three hundred and twelve parts of lead, and three equivalents, or twenty-four parts of oxygen,—one equivalent of the tribasic acetate is obtained. The second part of the process, so far as its chemical bearing is concerned, may be briefly explained thus:—



In this decomposition, three hundred and ninety-six parts, or one equivalent, of the basic acetate, is represented to yield two equivalents of its base to the carbonic acid present, thus producing two hundred and sixty-eight parts or two equivalents of carbonate of lead, and leaving the third equivalent of oxide combined with the whole of the acetic acid. The neutral acetate thus produced takes up two equivalents more from the metal unacted upon, and produces another

proportionate quantity of basic salt, which undergoes the metamorphoses above represented.

To bring about in the readiest and most inexpensive manner the modifications above shown, is the object to be aimed at in the manufacture, provided the product has that degree of divisibility and opacity which is possessed by that recognized as first quality in color and body.

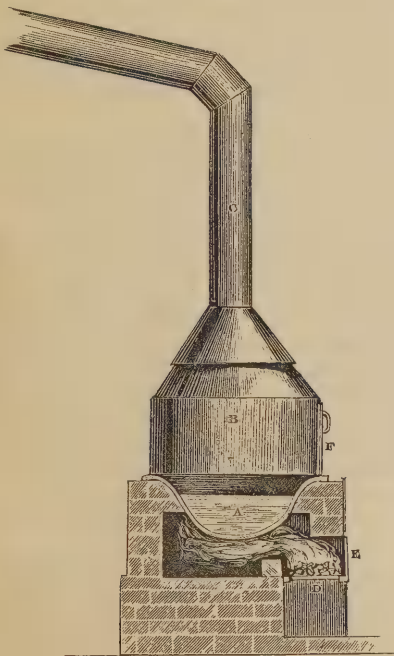
Dutch Method.—The first step in the old Dutch process, consisted in casting the lead into sheets in the following manner: the metal being melted was poured out upon iron plates, and as soon as the surface began to exhibit signs of consolidating, the iron plate was inclined, and the fluid lead allowed to flow back into the pot. The sheet of lead which was thus left was removed, the iron plate cooled in water, and another sheet cast in the same way. In this manner several hundredweights of lead were converted into thin sheets, in twenty-four hours, varying in thickness from one twenty-fourth to one forty-eighth of an inch. The plates so formed were bent in the middle, the bend being occupied by a slip of wood. A number of these was arranged in a wooden box, four and a half to five feet long, twelve to fourteen inches broad, and nine to eleven inches deep; the sheets being so disposed as not to touch one another, nor the sides or bottom of the box. An acid liquor, consisting of four quarts of acetic acid, and four of wine lies, was also put into the same receptacle, and the cover placed securely on. Sometimes the acid mixture was varied according to the ideas of the manufacturer. When a number of these was so prepared, they were introduced into a stove-room, where the heat was sufficiently elevated to cause the evaporation of the acid, so as to bring it into contact with the sheets of lead. The stove-room was of such a capacity as to receive about ninety boxes, and had only one door. A temperature, averaging 86°, was maintained during fifteen days, in which time the plates were acted upon by the acetic acid, and the carbonic acid from the fermentation of the wine lies, assisted by the air and moisture, so that they presented a thickness of a quarter of an inch, whereas, before the operation, they did not possess a twentieth. After this the plates were shaken, in order to detach the crust of white lead, which was subsequently ground and washed. Horse-dung was sometimes employed in this operation, to raise and maintain the temperature by its fermentation, in which case the covers of the boxes were secured by pasting paper round their edges, in order to guard against the discoloration of the white carbonate by the sulphide of hydrogen given off during the decomposition of the dung.

Such is an outline of the old process pursued in this manufacture; but for many years it has been conducted on a more extensive and simpler plan, which was first adopted by the Dutch themselves, and from them has been borrowed by the French and English. On this improved system, the work, instead of being performed in boxes, is executed in large rectangular spaces, inclosed by stout walls constructed of bricks or masonry, within which pots of acid, containing coils of sheet lead, are piled in *stacks*.

The several stages in the manufacture of white lead, by the new Dutch process, may be divided into the casting of the metal, the erection of the beds, or *heights*, in the *stack*, the taking down of the same, the screening or unscaling of the crusted lead, the grinding of the scales, the grinding of the white lead in water, the exsiccation, the grinding of the white dried loaves, alone or with oil, and the packing.

Casting the Metal.—A quantity of metal, of that quality which is deemed the best for the production of white lead, is put into a cast-iron boiler or pot, and melted; this boiler is very often exposed in the foundry, yet the method of inclosing it in a hood is to be preferred; for then, not only are the workmen protected from any fumes which may arise from the melted bath, but from spiritings which follow the accidental introduction of moist lead from the screening or unscaling apparatus. Fig. 335 is a vertical sectional view of this pot, showing the position of the hood used as a protection to it. In this figure, A is the pot wherein the lead is melted, and which is surmounted by the hood, B, in connection with the chimney by the tube, c. D represents the fire, E the fire-door, and F an aperture in the hood, which can be closed at pleasure, by a

Fig. 335.

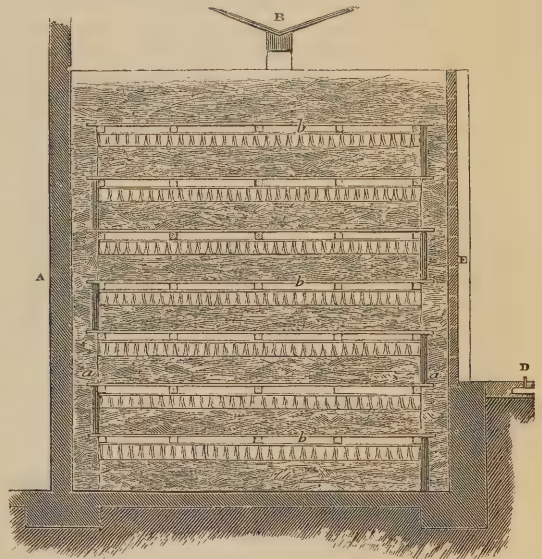


double sheet moving in grooves at either side. These plates are slid backwards, when the metal, which should be only a few degrees above the melting point, is to be drawn out in ladles to be cast in the ingot plate moulds. Thin plates, from sixteen to twenty-four inches long, four wide, and from two-fifths to one inch in thickness, are thus formed, which are afterwards rolled into a coil, to be introduced into the pots, where they are exposed to the chemical

effects of the acids and air in the subsequent part of the business. These pots have in the interior a ledge, *a*, whereon the coiled plate is supported, when they are charged in the stack. Latterly many manufacturers, and especially the English, employ the lead in the form of *grates* or *crates*, as it presents a greater surface, and permits a freer circulation than the former. They are formed by casting the lead on an iron slab, grooved by parallel, longitudinal, and transverse gutters, an inch apart, into which the fluid metal runs.

Construction of the Stacks.—The arrangement of the *stacks*, or *dung-pits*, is represented in Fig. 336, which

Fig. 336.



is a vertical section, filled with the several layers of dung, acid pots, lead plates, and boards successively. A represents the wall, and B the roofing which inclose these spaces. A corridor runs along the sides, in which is a railway, D, for transporting the waggons of dung, boards, *et cetera*, to the space where required. In the front of each of these a door, E, rises the whole height of the stack, to facilitate the introduction of the materials, but which is closed by boards placed cross-wise as the several beds are erected. The dimensions of these stacking-spaces vary in different factories, it being supposed by some parties, that the conversion succeeds best in large stacks, whilst others maintain that stacks of lesser dimensions afford better results; and, for reasons which will be presently adduced, doubtless stacks of a medium size operate best. The dimensions usually given average from thirteen to sixteen and a half feet in length, thirteen to fifteen wide, and about twenty high; and in extensive factories such a number are constructed as will permit the gang of workmen to erect and dismantle one daily, the others being in a proportionate stage of advancement as they are being approached. In this particular part of the manufacture very little improvement has been effected on the method adopted years ago.

These spaces are filled up with material, by a gang of workmen, who are generally paid a definite sum for the erection of the stack. A bank of dung which has been used previously, is raised round the walls of the pit, a foot in breadth, and of the height of sixteen to eighteen inches; in the space thus inclosed, fresh horse-dung to the depth of sixteen inches is spread. A layer of pots, eight inches high, and nine and a half diameter at the top, are placed side by side, till the whole space with the exception of the dimensions of the first embankment, *a*, is covered. Each of these pots, which are glazed in the interior, is charged with a gill and a half, or from that to two gills of common acetic acid, and a roll of sheet-lead; excepting a few which are placed towards the middle and at the corners, that are three quarters filled with vinegar. Ten to twelve hundred of these pots are placed in one floor, or *height*. After arranging the pots and supplying them with the necessary quantity of acid, and resting a spiral of lead on the interior ledge of each pot, another bed is formed, composed of triple or quadruple sheets of lead, laid horizontally upon the first, till the whole surface is covered. Planks, or stout boards, are now laid on the latter, and upon these another layer of lighter boards is placed, as seen at *bb* in the foregoing figures. A second bank of old dung is then formed round by the walls, and a new bed of dung spread as described, upon which a second layer of pots is deposited, and charged with acid and lead, in the same way as the last. This process is repeated, alternating the dung, the pots, lead sheets, and boards, till the pit is filled; only that the layers of dung are only twelve inches thick, from the first till the top covering, which is made with old dung, and of a thickness of twenty to twenty-four inches. Eight heights or layers of pots usually constitute the stack, but sometimes ten are introduced. At either end of the several beds, alternately, a space is left vacant, for instituting a draught from one bed to another, and increasing, at the same time that it equalizes, the effect. Every stack when completed contains for each bed or height, together with the boards, dung, and pots, about seven gallons of vinegar, or fifty-three in the entire stock of eight beds, and from one ton four hundreds to a ton and a half of lead, making from nine and a half to twelve tons of metal in the whole. Four men can lay two heights in a day, so that in four days they can complete a stack. In many establishments, gas is especially manufactured for lighting the premises, so that in winter the operations can be carried on with artificial light.

A period, varying from five to six weeks, is allowed for the conversion of the lead into carbonate to the fullest extent.

Although in those establishments where horse-dung is employed, it is reported that the health of the workmen does not suffer in consequence of the offensive smell which is evolved from these masses of decomposing matters, still the method adopted in England of using spent tanners' bark instead, is much more agreeable; and although in its operations it is slower than the former, the product is not liable to be darkened by sulphide of hydrogen, which the dung evolves during

the decomposition of its sulphur compounds. When tan waste is used, nine or ten weeks are required to carbonate the metal. Whilst the materials remain, the several layers of dung or tan enter into a fermentation, which determines a rise of temperature sufficient to determine the evaporation of the acetic acid and water from the pots; and these vapors, coming in contact with the metal in the presence of the oxygen of the atmosphere, effect its oxidation, and the formation of an acetate of lead, in which there is an excess of base. Carbonic acid is likewise evolved from the eremacausis of the organic substance, which decomposes the film of basic acetate, setting free a neutral salt to take up fresh quantities of the oxide of the metal, which is likewise broken up as before. In this way, the production of carbonate of lead proceeds in exceeding small portions; but the operation being continued for a length of time uninterruptedly, and a vast area of lead being operated upon, a considerable quantity is produced.

It is the minute state of division of the carbonate, arising from its slow and gradual production in small portions, which distinguishes the white lead produced in this way from the same compound when it is obtained by precipitation from the solution of the basic acetate; for in the latter case the particles are larger and semi-crystalline, and, when used with the brush, the white lead fails to cover the same space with a coat of opaque paint, as will an equal weight of the carbonate obtained by the Dutch method. This opacity and extreme division constitute what in the language of the trade is termed *body*; and notwithstanding that other modes of preparation, more desirable in a sanitary point of view than the one under consideration, have been suggested, yet the want of this body in the manufactured article condemns it in the painter's estimation.

A great drawback upon the Dutch method of operation is the irregular manner in which it proceeds; for sometimes the temperature in the centre of the stack is as high as 194° and even 212° , which causes the rapid evaporation of the acetic acid, and, the circulation of air being imperfect, a corresponding corrosion is not produced; on the other hand, the portion towards the walls often does not acquire sufficient heat to evaporate the acid, and, therefore, the production of carbonate is not as great here as might be expected. The best results are obtained when there is a due degree of circulation of air, and a temperature of from 100° to 120° is sustained.

Unscaling.—When the time necessary for conversion of the lead into carbonate has elapsed, the dismantling of the stack is begun. The superior layer of material is thoroughly removed, and afterwards the plates of carbonate of lead are exposed by taking off the boards and planks which had protected them. This being done, the carbonated plates and spirals in the pots are taken and deposited in small wooden boxes, in which they are carried to the part of the factory where the unscaling or screening is proceeded with. In the old system this part of the work proved eminently unhealthy; for the method pursued was calculated to load the atmosphere with a great deal of impalpable powder, which, being inhaled, poisoned the

operatives. The plates were taken up with the naked hands, and the crust of carbonate detached by striking them against one another; the larger part was thus removed, but a considerable quantity still adhered, and to detach it a number of the plates was laid over one another on a thick flag-stone and struck with a heavy mallet. Here the greatest danger was risked; for by the hammering of the plates, the surrounding air was loaded with the dust, which was productive of a double injury—that of a loss in the product, and of danger to the health of the workmen. Fortunately for the sake of humanity, science has come to its aid; and now, excepting in some isolated cases, the stripping of the plates is performed by machinery, which is so inclosed that no appreciable escape of the white lead takes place, and the air in the room remains pure and wholesome. At the establishment of M. LEFEVRE of Lille, in France, the following is the method adopted:—The men who take the sheets from the pots are protected by large lamb-skin gloves, in order that none of the lead may come into contact with the skin, and consequently they are not endangered, as no absorption can take place. The plates are brought in a small truck to the base of the machine, and lifted by means of an endless rope to which a bucket is attached, to a table, where the unrolled sheets which were in the pots, as also those resting upon them, are laid on an endless piece of leather, which carries them forward to a series of grooved rollers, between which they pass. The rollers reduce the matter to such a degree of division as to prepare it for the grinding-mills to which it is afterwards subjected. For this purpose it is first moistened, and then carried to the grinding-room, where it is passed under a number of horizontal millstones. Here it is ground and forced out into baskets by the centrifugal motion of the stones, through a sluice at opposite sides of the mill. From the baskets the fine paste is put into pots, and placed in the drying-house, where it remains for ten or twelve days.

The drying-house is a square apartment with solidly built walls, and furnished with shelves at particular distances; these are constructed of stout iron bars stretched longitudinally by the walls, and strengthened by uprights of the same metal. In winter, the apartment is heated by a fire of pit coal, surmounted by a huge canopy of cast-iron from which the calorific radiates to all parts of the room, thus raising the temperature of the air, and causing the expulsion of the water from the salt. In summer, the circulation of a current of air is sufficient to effect the desiccation, so that the mass of white lead contracts considerably, and also acquires such hardness as will resist handling. The loaves thus assume the form of the moulds, and as many of them as remain whole are taken out of these vessels, by inverting them on trays, which are afterwards deposited on shelves in another apartment, into which heated air is forced. Here a further quantity of moisture is expelled. Finally, the loaves are wrapped in blue paper, and put up in barrels for the market. The broken loaves are carried to a mill, where they are ground to powder, and packed in barrels, or made into paint by mixing with the ground white lead from eight to ten per cent. of oil.

Until these improved methods were introduced, the reduction of the white-lead to an impalpable powder presented the gravest disadvantages, besides being positively destructive to the health of the workmen. The grinding was generally effected under revolving head-stones, upon a cast-iron basin of the ordinary shape, the coarse material being introduced and withdrawn with the spade; and during this necessarily slow procedure, the dust arising from the agitation of the substance and its removal from one place to another, in the exposed manner in which it was done, had a rapid and injurious effect. It is the Editor's belief, that in most establishments of any repute, all these operations are now performed by machinery, and that to arrest any dust, water is employed where the various departments are not isolated from the remaining space.

The pulverization of the imperfect moulds is effected, in the factory already alluded to, by means of horizontal marble mills, enclosed by a metallic covering which is securely fixed in its place, so that any of the carbonate which might otherwise pass into the surrounding air is completely arrested.

Latterly, the French and Dutch manufacturers are adopting the English custom of compounding the white-lead with oil at once, and thereby preventing two grave inconveniences; for not only does the preparing of it in loaves and powder offer greater trouble to the manufacturer, but it is fraught with danger to the color-maker and painter, because rarely have the latter such arrangements as to effect the mixing without exposing the operator to the danger of inhaling the poison, and thus laying the foundation for lead or *painters' colic*. Till within the last few years they were generally compelled to perform this operation, and the frequent cases of lead poisoning gave rise to the popular term, by which the disease was recognized among this class of men. This danger is obviated now-a-days by converting the white lead into paint in the manufactories; it is done expeditiously and without risk in an apparatus entitled a *kneader*, somewhat like that used in large baking establishments. This is a cylinder, in which a square iron bar, furnished with arms, is fixed longitudinally. The latter is turned by means of a strap passing over a drum, and another in connection with the engine shaft. All the materials—white lead, and oil to the extent of eight per cent. of the lead compound—are introduced by the doors, which are firmly closed, when the machine is at work, by a lever, secured by a bolt. When the two are mixed the paste is drawn out, and if necessary passed through a grinding mill to render it more homogeneous.

Such is the general character of the arrangements in the well regulated factory of M. LEFEVRE of Lille. Here there is a large saloon at the disposal of the men, where they put on and divest themselves of their factory dresses, and perform their ablutions; and another which is used as a refectory, into which they are forbidden to enter in their ordinary working coverings. Gloves made of lambskin are supplied by the proprietor, and worn by all those who are exposed to handle or touch the white lead, so that the danger of absorbing any portion of the poison through the pores of the skin is avoided. All these precautions are not without their merited

return, since it is a rare thing, even in the course of several years, to hear of any ailment among the operatives brought about by the nature of their work.

On a par with the foregoing for the general arrangement, and the healthy atmosphere pervading it, is the factory of Messrs. WALKER, PARKER, and Company, previously mentioned. Here the arrangements for melting and casting the lead in crates are similar to those already described. The acetic acid is prepared on the premises. The stacks, also, of which there are thirty-four, are similarly constructed, only that the source of the carbonic acid and heat is tan, instead of the dung used by the Dutch and French manufacturers. It is usual to construct the beds of the several materials in the ordinary way, only that the layer of tan is somewhat thicker than if it were horse-dung. Another difference in laying down the bed of pots, with the exception of about two hundred to two hundred and fifty, is, that the lead is laid flat upon their mouths, in a layer of four, five, or six crates, each weighing about three pounds a voidupois. The pots, therefore, are simple internally-glazed vases, capable of holding a quart or thereabout, with the exception of the two hundred and fifty above alluded to; these have a ledge in their middle, upon which a coil of the crate lead rests, and are arranged round the circumference of the floor, and at intervals in the middle, for the purpose of supporting the planks, boards, and other overlaying materials. Acetic acid prepared from wood, and diluted so as to mark 1° on the acetometer, is poured into the pots, to the extent of about half a pint, excepting the larger pots which receive double the quantity. Proceeding thus with each layer, the stack is completed, and is left so for a period of eight or ten weeks. And here, it may be remarked, that the experience of the proprietors of the above works has proved to them, that with an acid marking 1·5°, or over, on the acetometer, the conversion of the lead into carbonate never proceeds satisfactorily, nor is the quantity nearly so large as when a weaker acid is employed; for in the former case too much neutral acetate of lead is formed, probably owing to the generation of carbonic acid and the circulation of air being imperfect, and partly passes off in the waters used in the preparation of the white lead afterwards.

In this mode of manufacture, no danger exists of the white lead being blackened with sulphide of hydrogen, but the greatest care must be taken to have the covering of each layer of pots perfect, lest some of the tan might fall through, in which case it cannot fail to produce a stain. Again, when the carbonisation is imperfect, the carbonate which is produced is of inferior quality, since it is largely mixed with a suboxide of lead, forming a bluish-grey coating on the unattacked metal. The only security against imperfect working in the stacks, is to employ a properly-diluted acid, to select a good quality of tan, and to effect a proper circulation of the air, since with bad tan, there is not sufficient fermentation to generate either carbonic acid, or heat to evaporate the acetic acid; and without the air to oxidise the metal, the repeated action of a small quantity of acetic acid, in producing a large amount of oxide of lead, is impeded. After the carbonisation of the lead,

the several layers of tan, wood, *et cetera*, are removed, when the pots will be found emptied of their contents, and the layers of crate lead swelled to double or treble their original thickness, owing to the formation of the carbonate of lead upon them.

The sheets are taken off, put into a small carriage, and conveyed on a tramway to the departments of the work where the parting of the salt of lead from the unoxidised portions of the metal takes place. Since the latter is the highest part of the machinery in the area where the cleansing, grinding, and other operations are effected, the railway mentioned is on the second story of the establishment.

Although in the works of Messrs. WALKER and PARKER, the hermetical sealing up of machinery is entirely dispensed with except in one particular, still, rarely is there seen an operation, which in itself is very dangerous, rendered so innocuous with such simple contrivances, as that of the preparation of white lead at the manufacture referred to. Here water is to be found almost in all parts of the factory where the parting and grinding is proceeding, and it serves most effectually to suppress the evolution of the minutest trace of white lead into the atmosphere.

The carriage loaded with the carbonated crates, is, when it reaches the working gallery, emptied into a hopper capable of being covered. This is surmounted by a water-pipe, terminating in a rose, which showers this liquid upon the lead. By the aid of fluted rollers, the crust of white lead is in a great measure detached from the metal, and both are delivered on the end of a rectangular ledge or trough, having a perforated zinc covering above its real bottom. On this there is always retained a quantity of water, and as the material is delivered from the rollers in the drum adjoining the hopper, a man with a small rake moves it back and forth on this with a view of detaching the crust, that was loosened and partly separated in passing between the rollers; the residuary lead still retaining some portions of white lead, is passed between another pair of channeled rollers, and falls upon another table like the preceding, where, by agitating with rakes on the perforated bottom of the trough, and the use of the water, the particles of lead remaining are thoroughly cleaned and removed to a receptacle, whence they are conveyed to the melting house and there recast into crates or pigs of *blue lead*. Whilst on the perforated troughs, the particles of white lead are assorted, and any metal as well as colored parts removed from that which is purely white. For this purpose considerable agitation and working with the rakes is necessary, but still as there is a sufficiency of water, there is not the least escape of carbonate of lead.

From these troughs the partly-drained salt is conveyed to the hoppers of a number of adjacent millstones, where it is abraded and given out from the sluice in a pasty state; these sluices deliver it into the boxes of other heavier mills placed below the former in a second tier. Finally, the white lead, thus reduced, passes through a third mill, and thence into a deep tub or vat, which also receives a stream of water from the pump; and by means of a rotating agitator the lead is so mixed with the water, that it is carried off in the sluice which

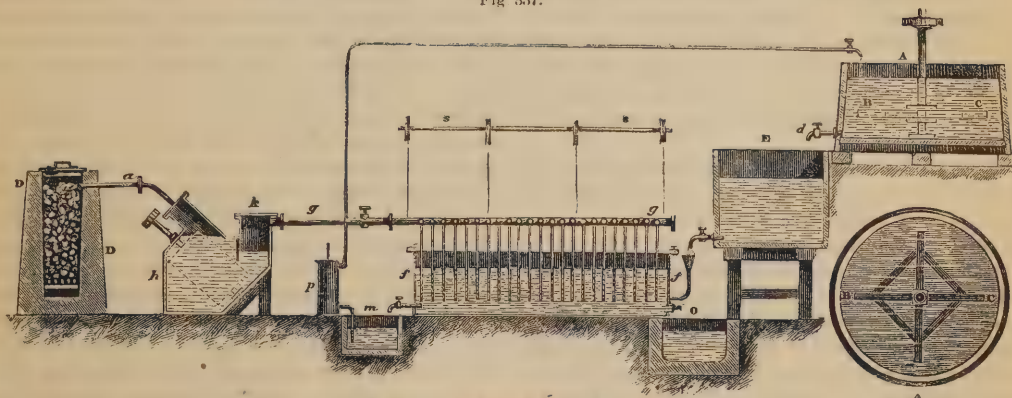
forms the outlet to the last vessel, to a series of large tanks or settlers, where the lead after a while precipitates to the bottom and leaves the supernatant water clear. After settling, the bright liquor is siphoned off into a sluice, which conducts it to a well, whence it is pumped up into the higher benches by a forced pump. In this way, the same water is available for a number of times, and each time it becomes purer and less liable to deteriorate the carbonate. The deposited white lead is then taken out with a ladle and put into flat-bottomed dishes, which are conveyed to the drying-house by the younger hands in the establishment. This is a room furnished with shelves of strong iron bars, well-supported all along the four walls; having a large iron casting in the centre, and which is heated by a fire placed outside the building. By the heat radiated from this casting, the temperature of the apartment is considerably elevated, and the moist white lead is dried in the course of a few days. It then appears as a pure white amorphous cake. To convert these into paint they are conveyed to a mill, and the powder passed through a bolter of the usual formation. Oil is next mixed with the ground white lead in a mechanical kneading-trough, and the paste ultimately passed through a mill, and the product packed into barrels for the painter. The mills for grinding the dried product, as well as the sifter, are secured by an envelope which permits no escape of dust; the kneader likewise is

securely closed, and the paint-mill like all the others, is almost enveloped in a box, which does not allow any of the matter to escape.

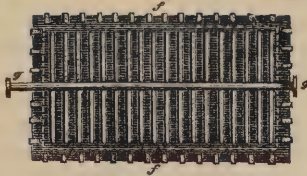
CLICHY WHITE.—Several years ago, THENARD established the principle, that when a neutral solution of a soluble salt of lead is put in contact with an excess of litharge, or oxide of lead, a basic salt is formed, which yields a part of its oxide to carbonic acid, the remaining portion forming a neutral salt with the acid. M. ROARD established a manufactory of white lead in which this principle was carried out by dissolving the litharge in acetic acid, obtained by the distillation of wood or vinegar, in order to produce the basic acetate 3 Pb O —a solution of 29° Twaddell, specific gravity 1.145—through which carbonic acid, obtained from the combustion of charcoal, coke, or limestone, was passed, with the view of throwing down two equivalents of the metallic oxide in the state of carbonate, and of leaving a neutral acetate of lead in the solution, ready to operate upon a fresh quantity of the litharge, and convert it into the basic salt mentioned.

The arrangements by which this process is carried on are seen in Fig. 337. A indicates a large tub, capable of holding four thousand four hundred gallons of liquid, in which the acetic acid is made to combine with the litharge, having an agitator, C B. When the solution attains a gravity of 29° Twaddell, it is drawn into the settling vessel, E, by the stopcock, d. The vessel, E,

Fig. 337.



which is constructed of copper plates riveted together, and has a capacity of four thousand two hundred gallons, is intended to intercept any particles of lead, iron, or chloride of silver, which might exist in the menstruum, and be carried over in suspension from A. From E the clear liquor is drawn into the decomposing vessel, ff, which is about twenty feet long, half this in breadth, and two feet in depth; it is replenished to the height of twenty inches, and holds about two thousand gallons. It is secured with a cover by clasps to the flanges of the side plates, as shown in the drawing. This cover is traversed by eight hundred pipes, which plunge to the depth of thirteen inches into the solution, the other ends being soldered to twenty branching pipes, which extend at right angles from a main, gg, at each side;



the latter is connected with the blowing apparatus, kk, which is supplied with carbonic acid by the furnace, charged either with coke or some other matter for generating the gas. The carbonic acid was at first obtained from

the combustion of charcoal; but at the suggestion of DUMAS, chalk and coke in the ratio of two and a half of the former, to one of the latter, was adopted with advantage. A small lime-kiln, DD, is used to burn this mixture, and the carbonic acid is drawn over through the pipe, a.

After the precipitation of the carbonate of lead, which generally requires twelve or fourteen hours, the contents of the tank are allowed to settle, and after this the solution of neutral acetate is drawn off into the

tank, *m*, and is hence transported by a force-pump, *p*, and a pipe, *n n*, to the tub, *A*, where it recombines with as much oxide of lead as it lost during the precipitation. In this way the neutral solution drawn off from *ff*, and which is found reduced from 29° to 7° Twaddell, can be made to circulate for an indefinite number of times, and be made the agent for the solution of the litharge, so as to bring it into a fit state for its conversion into carbonate by the carbonic acid. There is, however, a slight loss of neutral acetate each time owing to its being partly retained by the carbonate, and partly passing off in the washings, so that it is necessary in practice to renew the strengths of the solutions by the addition of a little acetic acid in the tun, *A*.

The deposited carbonate is removed after raising the cover by means of cords attached to the main pipe, *g g*, and pullies on the beam, *s s*, the clasps which secured it being unfastened; the white lead is brushed out through an opening, which is stopped at all other times by a plug, into the reservoir, *o*, where it is washed three times repeatedly by agitation with water and subsidence. The first washings are pumped into the dissolving tun, *A*. In this way the process is continued almost without interruption, excepting whilst the carbonate is depositing in *ff*, and during its discharge into the tank, *o*. After the washing, the product is dried and treated in all respects like that obtained by the Dutch process.

It has been suggested to dispense with the mechanical agitators employed in the dissolving tun above described, by substituting cylinders in which the litharge should be inclosed, and to allow the solution of neutral acetate to percolate them, almost in the same way that syrup is made to pass through the filters in sugar-refining.

PATENT PROCESSES.—Various patents have been obtained in England for the manufacture of white lead, mostly on the principle of THENARD.

One of these, taken out by Messrs. GOSSAGE and BENSON, was put in practice at West Bromwich, near Birmingham. In the establishment constructed for the occasion, the work of conversion was carried on in a large longitudinal trough, by mixing a small quantity of a neutral acetate of lead solution with moistened litharge by means of a travelling wheel, and, at the same time, transmitting heated carbonic acid over the mixture. The carbonic acid was in this case obtained from coke, and the white lead, when fully carbonated in the trough, wasedulcorated, ground in the usual way, dried, and subsequently mixed with the oil for the purposes of the painter. It is said that forty tons of white lead weekly were manufactured by this method, although for some time the establishment has been discontinued.

Another patent was taken out by Messrs. BUTTON and DYER for a process resembling THENARD'S; only that instead of a neutral acetate of lead being the renewing agent, a neutral nitrate was proposed. Both the neutral solution and the litharge were directed to be mixed and agitated together in a tub, the contents of which were retained at a boiling heat by means of steam passing up through the semifluid mass from a coil of pipe in the bottom. Carbonic acid was also

passed into the liquid to decompose the basic nitrate of lead oxide, and precipitate therefrom two equivalents of its base in the form of carbonate of lead. In this, as in the foregoing, the carbonic acid was directed to be obtained from the combustion of coke.

In 1833, a patent was obtained by JEAN BAPTISTE CONSTANTINE TORASSA for the preparation of white lead directly from the metal, simply through the agency of air, water, and carbonic acid. For this purpose the metal was granulated as in the manufacture of shot, and the grains agitated together with water in barrels; the lead dust produced during this abrasion was exposed afterwards to the air for oxidation and carbonisation. This method was tried at Chelsea some years ago by a joint-stock company, who, it is said, expended a hundred thousand pounds in erecting a factory for this process; but it has not answered the expectations entertained of it by the shareholders.

Another patent of a similar nature was taken out by WALKER WOOD in 1834; and in 1847, M. CANNEL specified the following method:—He constructs a hexagonal or octagonal cylinder of lead, six feet and a half long, and fifteen and a half inches or less in diameter, the lead to have a thickness of two to three inches. He incloses this cylinder in a frame made of rod-iron, to one end of which a crank is attached, and places the whole on a stand in such a way as to be readily put in rotation. By means of an opening, or bung-hole, in the middle of the cylinder, the materials, consisting of about two hundredweight of granulated lead and six and a half gallons of water, are introduced. At the other end of the cylinder there is also an orifice in the axis of the cylinder from one inch to an inch and a half in diameter, through which an elastic tube, connected with a bellows or other blowing machine, is passed, till it reaches about the middle of the cylinder.

In the machine thus constructed the materials, as specified above, are put, the bung-hole closed, and the whole rotated at the rate of forty-five or fifty revolutions per minute; this mode of operation is continued during five hours, when two-thirds of the lead will be found abraded to an impalpable powder, but retaining its metallic lustre. On opening the lateral orifice, this fine powder undergoes rapid oxidation, and a hydrate of oxide of lead is obtained. Finally, if the chamber where the blowing apparatus is fixed be charged with carbonic acid from the burning of charcoal, *et cetera*, on putting it in operation, a stream of this gas will be forced into the cylinder, and the oxide of lead will pass to the state of carbonate.

The mixture is then discharged from the cylinder into a tub beneath the lateral opening, and agitated with water, during which the metallic powder falls to the bottom, and the lead salt acquires a remarkable degree of whiteness. As it is somewhat difficult to separate the small metallic portions, M. CANNEL advises to agitate the mixture in a tub having openings at different levels, through which the carbonate may be drawn away. The pasty mass is thrown on cloth filters, and after the water has drained, pressed more or less; then dried in the stove-room and ground with oil in the ordinary way. To facilitate the oxidation in the cylinder, nitric acid may be added to the water to the

extent of one and a half to two pounds; or a saturated solution of neutral nitrate of lead may be substituted. The advantages of this method are, according to M. CANNEL, simplicity of operation, a larger product, saving of manual labor, and less chance of loss.

In 1841, Mr. H. L. PATTISON obtained a patent for the manufacture of white lead by means of bicarbonate of magnesia and chloride of lead. The magnesian salt is prepared by calcining coarsely-ground dolomite—magnesian limestone—at a red heat, by which the entire of the carbonate of magnesia is decomposed, whilst the carbonate of lime present is only very slightly affected. This powder is afterwards suspended in water within a cylinder of iron, furnished with an agitating shaft, safety valves, induction and eduction pipes, and carbonic acid is forced into it by a pump as long as absorption of the gas ensues. On drawing off the contents of the cylinder, a solution is obtained marking 5·6° Twaddell, and containing sixteen hundred grains of the carbonated salts per imperial gallon. A saturated solution of chloride of lead in water is now prepared, and which at a temperature of 50° to 60° will indicate a density of 1·008; consisting of one part of the lead salt dissolved in one hundred and twenty-six of water. Both solutions are then mixed together as rapidly as possible, taking the precaution to have the magnesian solution in excess. The quantities of each solution which ought to be taken must be determined by a trial test on the small scale. On running the two liquids in the proper proportions in two converging streams into a tank, from which the mixture issues by a tap-hole at the bottom into a settling vat, carbonate of lead mixed with a little basic chloride of lead, will be found in the latter after subsidence. To separate the chloride of lead which exists in it to the extent of one or two per cent., the dried compound is ground in a horizontal mill with a concentrated solution of potassa or soda, and letting the pasty mass stand for a day or two, after which the chloride of the alkali metal is washed out, and a compound is left, which, when dried and properly prepared, is represented to be equal to the best *ceruse* in body and purity.

Mr. LOTHAM's patent, sealed in the beginning of 1847, directs that a six-foot cubic apartment should be provided, in which by upright posts and horizontal wooden rods, the sheets of lead should be conveniently supported without touching one another; the sheets to be two feet long, one in breadth, and one-sixteenth of an inch thick. Beneath the floor should be a flue in connection with a furnace, by which the chamber may be heated to a temperature from 72° to 96° Fahr. On the floor is placed a tub in which are eight pecks of malt, two pounds of sugar, six pints of yeast, and twelve gallons of water. This mixture ferments, and ultimately gets mouldy, when it is drawn off into other vessels, in which it is mixed with two gallons of vinegar and heated by steam, after which it is gradually introduced by pipes to the floor of the chamber. It gives off acetic acid, which corrodes the lead, and the carbonic acid from the fermentation converts the oxide into white lead.

TOURMENTIN patented a process in 1847, for manu-

facturing white lead from the chloride of this metal. The latter compound was to be produced by grinding litharge, chloride of sodium, and water together, employing an excess of the litharge; basic chloride of lead was thus obtained, which, upon treatment with a stream of carbonic acid, yielded a precipitate of carbonate of lead, leaving a neutral chloride of lead in the solution. By drawing off the latter, and boiling it with chalk till, on testing with sulphide of hydrogen, the clear liquid gave no blackening, the portion in the solution was precipitated as carbonate, and afterwards separated from the lime salt by washing.

RICHARDSON prepares white lead by taking the crystals obtained in the desilverizing of ordinary lead by PATTISON's process, or metal otherwise reduced, and mixing with it from one to one and a half per cent. of vinegar, or a proportionate quantity of nitric acid, acetate or nitrate of lead diluted with water; and after turning the mixture over repeatedly, placing from twenty to thirty hundredweight of the mixture upon the shelves of a chamber lined with lead, slate, or stone. Heated air is admitted by a pipe furnished with a stop-cock, also steam to retain the compound moist, and carbonic acid from any convenient generator. Provided the temperature be retained at 96°, or thereabouts, the conversion of the lead will be effected in ten days or a fortnight. The salified mass is then removed and ground, then agitated with water, and any metal which separates returned to the chamber with fresh acid.

DISBROW RODGERS in a patent sealed in August, 1849, gives a process which consists in suspending sheets of lead on frames of wood in a steam-heated chamber, and thus exposing them to the joint action of acetic acid, carbonic acid, and steam; the acetic acid being derived from troughs of pyrolygneous acid into which steam pipes pass, or from other sources placed on the floor, and the carbonic acid from fermenting mixtures of yeast, sugar, malt, and water, also contained in troughs placed upon or sunk in the floor. Of course one condition of the success of the operation is, that the chamber be air-tight or nearly so, and a temperature of 80° maintained by the introduction of steam for a short period several times in the day. Every forty-eight hours this compartment must be entered, to renew the fermenting and acid liquors during the time that the process lasts, which is usually twelve days.

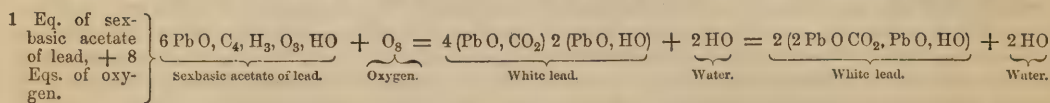
In 1853, M. CHENOT laid before the French Academy a process for the manufacture of white lead, which according to that gentleman offers facilities for the production of this article, that render it much more eligible than the established method. It consists essentially in the treatment of lead ores by metallic sponges, whereby a leaden sponge is precipitated, and this is subsequently exposed to the air and moisture, easily oxidises, and becomes converted into white lead. Pure galena, such as is known as *alquifoux*, is the ore employed by him; it is transformed into sulphate of lead by very careful roasting in a reverberatory furnace, the heat and working during the time being so controlled, that the matter does not enter into fusion. When the whole of the lead has thus been converted into sulphate, the product is mixed with iron or zinc sponges in a suitable vessel which contains an acidulous water, and is heated by steam, or

some other mode of artificial heating. The whole is thus left during a period extending to ten or fifteen days, with occasional stirring, at the end of which period the lead will be found at the bottom of the vessel, and a solution of the precipitating agent in the form of sulphate.

By decantation the supernatant liquor may be removed, when the residue is treated with a dilute sulphuric acid, to remove any particles of iron or zinc that may be present with the lead; but the solution, so produced, may be employed to moisten the materials of the next precipitation. After this liquor is drawn off, the residue is washed well with water till neither zinc nor iron, which of them soever may be employed, is detected in the washings; after which it is to be laid on trellises, in layers of .3937 to .7974 of an inch thick, and moistened. It will be changed in a fortnight or a month to a magnificent ceruse, of a beautiful white and velvety appearance. The lead sponge oxidised at a temperature of 392° gives the same results, and the tones of these compounds are superior to those now made, and are very powerful in their action. M. CHENOT, in the above communication, assures the Academy, that no manufacture can possibly be safer in a sanitary view than that of white lead, according to the foregoing process; that the product is perfect, and exerts a powerful action on fatty bodies, whilst, at the same time, the compounds are obtained with extraordinary simplicity and precision, without the expenditure of manual labor consequent on the other methods.

Theory of the formation of White Lead.—For a long time, although some general opinions were advanced with regard to the formation of white lead in the fermenting stacks, by the agency of acetic acid, air, and carbonic acid; still, till within a recent period, there existed a degree of uncertainty as to what the real changes were, in the minds and writings of scientific men. It has been already stated in general terms, that there is formed in the *stack* a basic acetate of lead which suffers decomposition, from the assimilation of the basic oxide by carbonic acid, leaving a neutral acetate to operate further upon the metal. Recent experiments have shown, however, that the substance produced is also a basic compound of neutral carbonate of lead, with a hydrated oxide of the metal, and the question was suggested—Why does not the carbonic acid present react upon the free oxide of the carbonate, as well as upon that of the basic acetate which is generated? It would seem

at first sight that such a result would be the most likely one to be produced, more especially since the basic acetate must necessarily be in contact with the metal, and that the gas must traverse the exterior coating of carbonate to influence it in any way. Knowing that white lead is capable of assimilating a larger percentage of carbonic acid than that which it yields, it is natural to infer, that instead of a basic compound, a neutral one of oxide of lead and carbonic acid should be obtained. Theory in this case would be in direct opposition to practice, and egregiously erroneous also. BARRESWILL has lately shown, however, that when anhydrous neutral carbonate of lead is added to a solution of the basic acetate of this metal, white lead of the composition above stated separates; and hence the first portions of the acetate which are decomposed by the carbonic acid, although such be a neutral carbonate, are thus changed by contact with an excess of the basic acetate into the ordinary white lead. It follows from this, that if there is a deficiency of the basic acetate of lead, the chief part of the corroded metal will be converted into neutral carbonate of lead, and that its qualities as a paint will be materially depreciated on account of the molecular structure of that body. This inference is strengthened by the experience of white lead manufacturers. There is little doubt of this being the true change which occurs; yet URE believed the metamorphosis impossible, from the fact that acetic acid is regarded by him as exercising a more powerful combination than any which carbonic acid is capable of exerting. It should be remembered, however, that in many chemical reactions the existing state of the elements frequently modifies the changes which in other respects they give rise to, more especially when the substances are capable, like lead, of producing compounds, the constituents of which are held together by a very weak affinity; and although carbonic acid alone does not expel acetic acid from its combinations with one equivalent of lead in the presence of water, the heat of the stack may be conducive to cause its expulsion in the presence of carbonic acid. URE assumed, that in the action of the acetic acid upon the lead a sexbasic compound is produced, which undergoes a kind of *eremacausis* that determines the conversion of the acetic acid into carbonic acid and water, the former of which is proportionate to the quantity of this gas combined with the ordinary white lead.



No reliable experiments, however, are extant to show whether any such combustion of the acetic acid takes place, or that the sexbasic compound of lead is produced in the stack.

It was also supposed that the oxidation of the metal did not take place through the medium of the oxygen of air, the stack being thought too compact for the due circulation of the volume necessary for this purpose; but rather that the acetic acid was the means of effecting, first the oxidation, and secondly, the carbonization; the extra carbon and hydrogen of the deoxidised acid being

evolved as a peculiar etherous combination. It is needless to say that this view was erroneous, for, in the first instance, the quantity of acetic acid employed bears no proportion to what would be necessary were the manufacture to proceed in conformity with these changes; besides, HOCHSTETTER and others have proved, that where atmospheric air is excluded, carbonic and acetic acids are insufficient to convert the metallic lead into the carbonate to the extent which occurs in the system commonly adopted.

Composition of White Lead.—From multiplied ana-

lyses, by several well-known chemists, of the English and foreign white lead of various factories, it appears that its composition almost invariably is, two equivalents of the protocarbonate of lead united with one of the hydrated oxide, and agreeing with the formula $2(\text{Pb O}, \text{CO}_2) \text{ Pb O}, \text{HO}$.

MULDER, in his researches upon white lead, arrived at these results; so also did HOCHSTETTER; and latterly the examinations of LINK and PHILLIPS corroborate the same. The precipitated compound, such as that prepared at Clichy, has a similar composition, owing to the fact expressed in the preceding, that by the reaction of carbonic acid or neutral carbonate of lead upon the basic acetate, a precipitate of analogous composition to the above falls. If the transmission of the carbonic acid be continued till the menstruum indicates the evanescent acid reaction peculiar to it, the whole of the lead will be carbonated, and a compound obtained, much less adapted for the painter than if the operation were not pushed so far. Previous to the investigations above alluded to, it was supposed that the Clichy white was a simple carbonate, and that the disparity of effect manifested by it, compared to the Dutch kinds, was owing to this; but PAYEN and URE proved by strict examinations, that the former variety when obtained in the cold from moderately dilute solutions, was composed of irregular plates finely divided, but the superposition of which did not offer the same degree of opacity as an equal weight of the Dutch white. It would appear, however, that when the compound is thrown down from hot concentrated solutions of the basic salt, the crystalline structure is considerably diminished, and the product is more opaque and spreads better under the brush of the painter.

Occasionally a species of white lead is produced by the Dutch method, which yields on analysis numbers corresponding to the formula $3(\text{Pb O}, \text{CO}_2) \text{ Pb O}, \text{HO}$; that is, three equivalents of carbonate to one of oxide of lead. It has a loose friable texture when drawn from the heights, quite distinct from the hard crates of white lead obtained when the metal is almost wholly converted; and is invariably the result of defective corrosion of the metal. This kind of white lead does not cover so well as the hard lead.

ANALYSIS OF WHITE LEAD.—The analysis of white lead as taken from the metal or from the drying-house is very simple, but becomes more difficult in the form of paint, for then not only do the oleaginous matters present inconveniences, but generally speaking various other mixtures, such as sulphate and carbonate of baryta, sulphate of lead, antimonial compounds, *et cetera*, are incorporated. It suffices, when the compound is dry and uncombined with oil, to desiccate a known portion of the average sample, reduced to a fine powder, in a water-bath as long as it ceases to lose weight, and note the loss thus sustained. The crucible may then be exposed to a dull red heat, for the purpose of expelling the carbonic acid; weighing as in determining the wa-

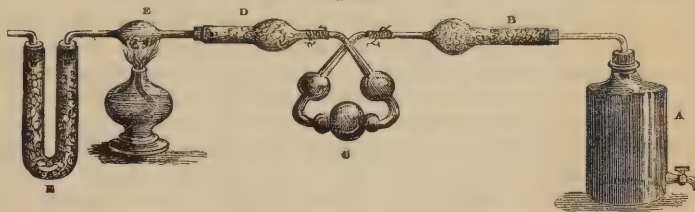
ter, and when this is done, setting down the loss before heating in the flame, and after. To insure that the whole of the carbonic acid is expelled, two weighings after prolonging the heat should correspond. Pure white lead yields:—

	Centesimally.
Oxide of lead,.....	86.377
Carbonic acid,.....	11.310
Water,.....	2.313
	100.000

Now if the percentage of water and carbonic acid in the sample examined coincide with these numbers, it will be evident that the sample is pure; but should the amount of carbonic acid found be greater than that given, it is a sign the preparation, though not adulterated, is still of inferior quality, since the proportion of the carbonate is increased in relation to the oxide present, and consequently if used as a paint, it loses in body through this constitution. Since a difference of 0.7 per cent. of carbonic over the foregoing numbers in the analysis, indicate that another equivalent of carbonate of lead is associated with the same weight of hydrated oxide, it is evident that the utmost care must be exercised in making a true estimation of the carbonic acid and water. If the latter should not be wholly expelled before experimenting for the carbonic acid, it is plain that an error would be made in the results, since any residuary moisture will be estimated as carbonic acid.

PHILLIPS has devised a plan by which all or most of the liabilities to error are obviated; but to manage the operation with success requires some skill and prac-

Fig. 338.



tice. He takes an apparatus fitted up as represented in Fig. 338, in which A is an aspirator connected with the chloride of calcium tube, B; this in turn is joined with the potassa liquor bulbs, C, the second chloride of calcium retainer, D, the tube, E, into which the sample to be analyzed is put, and the U-tube, F, holding, in one limb, pieces of pumice moistened with concentrated sulphuric acid, and in the other, partly fragments of fused chloride of calcium, and solid potassa. All the connections are made by means of corks, quill-tubing, and caoutchouc connectors. About twenty grains of the sample being carefully introduced into the bulb of the tube, E, and united at both ends, the flame of the lamp is cautiously applied to it, and at the same time a gentle stream of air drawn through, by turning the tap of the aspirator. As soon as the moisture is supposed to be expelled, the heat is increased, and the carbonic acid becomes thus liberated, but retained in the bulb apparatus, C. After the carbonic acid ceases to be emitted, and the residue in the bulb presents the well-known appearance of litharge, the parts, B, C, and

D, are quickly detached, and weighed. The acquired weight of B and C, combined, will indicate the carbonic acid in the sample, whilst that of D will show the water present. The oxide of lead is estimated in this way indirectly, since it constitutes the difference. When, however, impurities exist, this will not answer, and therefore, the weight of the impurity must be determined, or that of the oxide of lead combined with carbonic acid, as well as that associated with it as hydrate. If the impurity be of an insoluble nature, such as sulphate of lead or baryta, the carbonate must be dissolved out by acetic acid, the residue washed, dried, ignited, and weighed. Should the insoluble portion be a mixture of the sulphates of lead and baryta, and that the quantities of each are to be found, the most expeditious course is to heat the contents of the crucible with sulphide of potassium or of sodium, keeping the vessel covered. After a quarter of an hour's heating, the flame may be removed, the contents of the vessel washed out with hot water, filtered to remove the excess of alkali, and the residue treated with dilute nitric acid. Sulphide of lead produced in the preceding operation is thus dissolved, and after filtering off the liquid and washing the residue, the metallic oxide may be removed from it in the form of sulphate, by adding sulphuric acid in excess, and diluting. The latter precipitate is then to be filtered, washed with a very attenuated sulphuric acid, dried, ignited, and weighed. If from the entire residue the amount of sulphate of lead obtained in this way is deducted, the difference will be the barytic compound used. When carbonates of baryta or lime are added, these compounds do not part with their acid at the same temperature at which the white lead yields its carbonic acid, so that the estimation of the loss by heat, managed so as to be barely at a dull redness, will represent the proportion of the valuable compound existing in it. The residue may be examined for carbonic acid in WILLS' apparatus, and its amount will give indirectly the weight of carbonate of lime or baryta present in the sample.

ADULTERATIONS.—All the white lead which is manufactured into paint is more or less sophisticated, and chiefly with barytic compounds. The practice is carried on to such an extent, in some cases, that more than three-fourths of the mineral constituents of the paints are adulterants. This is invariably done at the manufactory, and, unless specially required, the white lead is never ground *per se* with the oil; and, therefore, the various qualities of white lead are in some respects synonymous with the extent of spurious matter incorporated with it. In Belgium there are several kinds—the *Kremser white* being unadulterated, but the others largely so: thus, *Venetian white* is a mixture of heavy spar and the subcarbonate of lead, in equal proportions; *Hamburg white*, of two parts of heavy spar and one of the plumbous compound; and that known as *Dutch white* contains three-fourths of sulphate of baryta. Many of these compounds are mixed with a small quantity of charcoal, indigo, or prussian blue, so that the dead yellowish shade which they present may be enlivened to a brighter hue.

Before leaving the subject it may be stated, that of late years efforts are being made to supersede the

manufacture of carbonate of lead entirely, by substituting for it other compounds, which, when mixed with oil, give a white paint. Of these, the principal are oxide of zinc, the teroxide of antimony, sulphate of baryta, *et cetera*; but the oxide of zinc comes nearer to the true substitute than the others: for this enters into a combination with the oil, just as the oxide in the white lead gives rise to an oleate that considerably aids in the extension of the paint on the surface, and causes it to form, at the same time, a perfect coating.

Oxychloride of Lead.—This is a compound lately introduced by Mr. PATTISON, who has obtained a patent for its manufacture. It is described as possessing properties which are superior to those of white lead, inasmuch as it does not so readily blacken with sulphide of hydrogen as the latter body. To prepare it, the patentee dissolves pure chloride of lead in water at the temperature of 212° , in quantities averaging five-sixths of a pound to a cubic foot of liquid. Soda, potassa, lime, or baryta in the caustic or hydrated state, may be employed to precipitate the lead from the solution, but as lime is the cheapest, it is of course preferred.

When lime is the precipitant, a saturated solution of it is made in cold water, in which case a cubic foot of the liquid will contain one-half of the equivalent of the lead contained in the plumbous liquor. If the water employed to prepare this liquor contains soluble sulphates or carbonates, a corresponding quantity of the lead will be precipitated in the form of sulphate or carbonate, and consequently more chloride of lead should be employed than above specified, so that the lime may not be present in excess, in which case it would dull the aspect of the preparation. The solutions being thus prepared, they are suddenly mixed, for which purpose the patentee employs two tumbling-boxes of sixteen cubic feet capacity, and placed over a cistern or tank into which the two boxes, when full, are inverted, and cause the two liquids to mix instantaneously. Basic chloride of lead having the composition represented by the equation $Pb\ Cl, PbO, HO$, that is, an equivalent of chloride and of oxide of lead, falls; and after complete subsidence, the clear supernatant liquor which contains chloride of calcium and a trace of lead, is siphoned off to another tank, and there mixed with a further quantity of lime-water. Should any of the lead salt escape decomposition, it is here converted into the hydrate which falls to the bottom of the tank, and may be recovered. It would appear that when the oxychloride of lead is employed as a paint, the oxide contained in it gives rise to an oleate of lead, and, in consequence of this saponaceous matter, is capable of spreading over an extended surface like ceruse. URE, however, found that water removes the chloride of lead from the paint compounded of this article, and, consequently, that it is not so effectual as the carbonate or white lead.

Physiological Effects of Lead and its Compounds.—With the exception of one or two of the most insoluble compounds of lead, all the others are known to have very active poisonous properties. The sulphide of lead, the sulphate, and sulphite, if possessed of such, are not,

however, so virulent as those salts of the metal which are soluble in water, or in dilute acids. It is to be remarked, that miners of galena are seldom, if ever, incapacitated by any derangement to their health arising from saturnine poisoning; when, however, they chance to be removed to the smelting establishments, after a while occasional indications of the physiological effects of lead on the system are observed. Dr. SCOFFERN, when, a few years ago, advocating the use of acetate of lead for the purification of saccharine juices, affirmed the innocuousness of sulphite of lead, owing to its insolubility; but no well-confirmed proofs exist of the truth of the assertion.

Lead, *per se*, is supposed to have no effects on animals; nevertheless its ready solution by the fluids and juices in the stomach, brings it into a state in which it is rapidly absorbed into the system, and thus becomes poisonous. Therapeutically considered, the preparations of lead have sedative and astringent properties, since they diminish the volume and frequency of the pulse, and reduce the secretive functions. Thus, when it is employed for some time, the arteries become reduced in size and activity, as indicated by the smallness and slowness of the pulse; hence its use in checking hæmorrhage, whether natural or artificial, and in reducing the temperature of the body. These characteristic effects extend to the secreting and exhaling vessels, as may be known from the dryness of the mouth and throat, the thirst, *et cetera*, which succeed its absorption. If present in quantities, other very decided indications are observed, such as the well-known leaden discoloration of the gums, of the buccal mucous membrane, and of the teeth; the peculiar taste and odor of the breath; the lead jaundice, and ultimately general emaciation. The coloration of the gums, membrane, and teeth is recognized by a leaden or slate-blue line from one-twentieth to one-sixth of an inch in breadth, which forms on the margin of the gums, nearest to the incisors in either jaw, whilst the rest of the gums appear of a bluish-red tint; the membrane lining, the gums, and cheeks are also of a bluish color, and the lower part or neck of the teeth are stained brownish. It would appear that these various shades of color are occasioned by sulphide of lead, produced doubtless by the traces of sulphocyanogen which is known to exist in the saliva flowing from the glands of the mouth. Saturnine breath is known only to those who are affected by lead through the respiratory organs, such as persons engaged in the manufacture of the compounds of this metal already referred to. Emaciation, which is another of the most marked of the primary effects of lead, shows itself more evidently in the face of the patient, giving to it a careworn, wrinkled, and aged appearance. When the lead accumulates in larger proportions, whether by accident or long-continued use of small quantities of plumbous compounds, it gives rise to various diseases known as *lead colic*, *anthralgia*, *paralysis*, and that which is characterized as *encephalopathy*, and which manifests itself by different morbid phenomena, such as delirium, coma, and convulsions, with or without loss of one or more of the senses. Physicians have observed, that patients are liable to several of these at once, although the most frequent of them is the lead colic.

Lead Colic, the symptoms and characteristics of which need not be entered upon here, is generally accompanied by the blue coloration of the gum, and this enables the practitioner to define the variety of the complaint.

Lead Anthralgy. It shows itself by pains in the limb. These usually become acute by paroxysms, are diminished by pressure, increased by motion, and are accompanied by cramps and hardness of the painful parts. In this case also, the blue line of the gums shows whence the disease springs.

Lead or Saturnine Paralysis. This ailment is characterized by the loss of voluntary movement of the parts affected, owing to the want of the power of contracting the muscular fibres of such parts. It is more frequently observed in the upper extremities, although the lower are also liable to be affected by it. The extensor muscles are more frequently diseased than the flexor, so that it manifests itself most frequently in the hands, arms, and legs. Pain is experienced frequently in the affected parts, and sometimes also in the region of the spine. Generally, lead paralysis, succeeds the saturnine colic, although it may come on whilst the patient is suffering from the latter. This disease is likewise distinguished from others of a similar nature, by the blue line in the gums which is very marked at its commencement.

In all these forms of disease as well as the cerebral ailments classed under *saturnine encephalopathy*, it is the general opinion, that the greatest effects are produced from local causes, arising from the inert compounds which the metallic base forms with the albumen, *et cetera*, of the tissues and parts which absorb it. At first sight it would seem, since such a combination is capable of being produced, that absorption could not take place; but though slow in this respect, when compared with other substances, experience has demonstrated its presence in the brain, spinal cord, and other parts of the body, to which access could not be made, excepting from the respiratory organs or the stomach. Some persons are so susceptible to poisoning influences, that the vapor from lead paint even has been stated to enter the system, and produce symptoms of a most alarming character, as recently noticed by Dr. WATSON, the eminent physician of London.

Poisoning by Lead.—When compounds of lead are taken in such quantities as to be destructive to life, the physical indications which are observed differ with the form of combination of the metallic oxide; thus, for instance, the acetate of lead acts as an irritant, but the carbonate—white lead—has no such action, or at best only a very indecisive one; the same may be observed of the oxide and other compounds of lead, especially those of limited solubility. The general physiological effects already mentioned, are guides which do not fail to point out the cause when death or violent attacks through the poisonous action of lead follows.

Antidotes.—Two classes of agents are known which lessen or destroy the poisonous effects of lead; these are sulphide of hydrogen and the soluble metallic sulphides, and sulphuric acid and the soluble sulphates. With the first class, black sulphide of lead is immediately formed, and as this body is almost inert, if not innocuous, the further deleterious action of the lead salt is

averted, as soon as the metallic base is changed to the form of sulphide. In a similar way the sulphuric acid and the sulphates act, only that a white sulphate of lead is generated in this case. It is doubtful, however, whether the sulphates and sulphuric acid operate as an efficient antidote, since it is probable that portions of this salt are dissolved by the chlorides of the alkali-metals, which are always present in the stomach, and likewise by the alkaline acetate, which is formed when a soluble sulphate is administered in cases of this saturnine poisoning. For the most part the first class antidotes are applied topically, in the form of a bath, and the second internally, in that of draught, *et cetera*; the former decompose any lead which may be on the skin, and convert it into sulphide, thus preventing its absorption; and the latter check the progress of the poison interiorly.

Acute lead poisonings are rarely observed, excepting they arise from inadvertence or accident, either purely so or malicious; but the first stages of slow poisonings are very frequent, and well known to most of the general medical practitioners in every large town, as well as in the rural districts. The source is almost invariably found to be the water employed for domestic purposes, the lengthened use of which causes a depression of spirits, emaciation, and, finally, colic and paralysis. Several cases of this description have come under the notice of the Editor, wherein whole families were affected, and though the leaden indications in the gums were undiscerned—as their medical attendant in many of them appeared baffled by the continued and frequent complaints—still, carefully conducted analyses proved that lead was the undermining agent. Iron-glazed pipes and pumps, with slate or cemented cisterns, were recommended for adoption, and with a very marked effect, the health of the individuals being completely restored. Many waters containing lead are preserved as by an antidote from effecting any injury to the consumer, and are consequently quite safe for consumption. The substances that react thus are the sulphates, phosphates, and carbonates of the alkalies, and also the sulphates, carbonates, *et cetera*, of the alkaline earths; in fact any neutral salt, the acid of which is capable of combining with lead or its oxide, and of constituting an insoluble compound, has this effect. It is owing to the presence of one or more of these, that mineral or spring water, though passed through lead pipes and retained in cisterns of that metal, remains for the most part unimpregnated with lead. So small a quantity as three or four grains of a sulphate or a phosphate in a water, prevents after some time the corrosion of the metal; carbonates have a similarly marked effect, more especially the soluble bicarbonate of the alkaline earths, since an oxycarbonate of lead is formed, which is one of the most insoluble combinations of lead, only one part being taken up by four million parts of water. It must, however, be remarked that these salts do not protect the lead from the solvent action of waters which contain *nitric* or *nitrous* acids in solution. These two acids are products of the decomposition of animal matter, and any water containing them will infallibly act upon lead; and, consequently, it would be highly dangerous to pass such a water through leaden pipes, or to store it in leaden

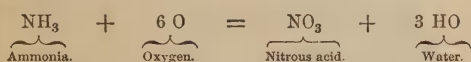
cisterns. All of these insoluble precipitates, after accumulating for some time on the sides of the cistern and on the interior of the pipe, form a solid coating, which in a measure isolates the metal from contact with the water, and, consequently it is protected, and the water remains good and wholesome. Chloride of sodium acts also as an anticorrosive substance to the water, but its effects are less certain than those of the compounds above referred to, since the chloride of lead is much more soluble than either the sulphate, phosphate, carbonate, or similar salts. As it frequently occurs, however, that in spring waters there are appreciable quantities of nitrates, and even free nitrous and nitric acid, as in a water from the private well in the neighborhood of Birkenhead examined by the Editor; the action of such waters upon lead becomes exceedingly marked, and not unfrequently do they give notable indications of lead being in solution after some time, even though they contain sulphates. In these cases the active solvent agent is still left in the water, and continues to act upon the metal, even after the entire sulphuric acid present has combined with the oxide of lead dissolved. Water, therefore, which retains nitric acid either in the free state or combined, whether it be mineral or catchment water, is not so safe for storage in leaden cisterns. In like manner, the water which retains decomposing, organic, nitrogenous matters in solution or suspension, is unsafe so far as regards the action on lead; for as stated above, the transformation of the elements of such by the *eremacausis* which they undergo, tends to produce, first ammonia, and by a further process of oxidation, nitrous or nitric acid, and at the completion of this change their corrosive action becomes very remarkable—so much so, indeed, as to cause the solution of several grains of lead per gallon. Besides the fact, that waters containing organic decomposing matters are in themselves unhealthy, their subsequent effect upon lead renders them doubly so.

MEDLOCK has latterly patented a method, whereby the nitrates which exert such a powerful action upon lead are removed, together with the organic matter, if the latter be not present in great excess. It consists in suspending coils of iron wire or pieces of sheet-iron in the water, and after a stated period filtering off the deposit which forms. By this means the nitric acid is decomposed by the iron, which is transformed into sesquioxide and falls to the bottom, whilst nitrous gas is set free and oxidizes the carbonaceous matters, which remain still in the fluid so as to yield carbonic acid and a lower oxide of nitrogen.

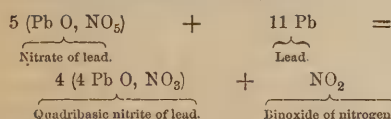
From experiments made upon some of the water lately supplied to Liverpool, and which proved itself to be a most eligible subject for examination, from the quantity of organic matter, both animal and vegetal, and nitrates, which it contained, the Editor arrived at very satisfactory conclusions, that the object proposed by the patentee may be completely fulfilled.

Action of Water on Lead.—When water which has been purified by distillation from pure caustic potassa, and kept out of contact with the atmosphere, is poured over clean sheets of lead, and so retained for a considerable period, no solution of the metal will be observed to have taken place, nor will the examination of the water indicate that any of the metal has been taken up. This

will not be the case if a comparative experiment be made with rain-water, however carefully collected, even in the open country; for with this the metallic lustre is soon dulled, and a film of carbonate and of oxide of lead forms on the plates, showing that a chemical action must have occurred; and besides, if the liquid is chemically treated, distinct evidence of the presence of lead in solution is found. The same observation will be made with regard to distilled water and lead, when the vessel containing them is exposed to the air, though not to the extent of the former. In these instances, there is a compound of oxide and carbonic acid corresponding to *white* lead, formed through the intervention of the carbonic acid with which the water—in case of rain-water—is charged, or it absorbs this gas in the experiment with distilled water. If the vessel be freely exposed, portions of this carbonate are dissolved; but independently of this, the carbonic acid which is always imbibed from the air, proves much more effectual for its solution, and, therefore, a considerable part will manifest itself to chemical tests, after some lapse of time. Another agent in rain and other waters, that acts with great rapidity on lead, is *nitrous acid*; and latterly Dr. MEDLOCK has shown, that ammonia, by its transformation into this, is capable of ultimately causing the water in which it is present, if retained in contact with lead, to become poisoned. The annexed equation exhibits the interesting transformation:—



Of course, some of the nitrous acid will be constantly metamorphosed into nitric acid, oxidation continually going on. This chemist affirms that the nitrate of lead produced in contact with the metal, is speedily transformed into the quadribasic *nitrite*, with evolution of binoxide of nitrogen, which, by combining with another equivalent of oxygen, re-forms nitrous acid. The production of the lead salt is thus explained:—



MEDLOCK, *contrary to all preceding views with regard to the action of certain waters on lead*, thus correctly sums up:—

Firstly. The action of any water on lead is entirely due to the presence of *nitrous* and *nitric acid*, resulting primarily from the decomposition of organic matters, and of ammonia contained in the water.

Secondly. Waters deprived of these acids, and of substances capable of producing them, *have no action on lead*, and may be conveyed with perfect safety through leaden pipes, or stored in leaden cisterns. To store or collect water containing a nitrogen acid in cisterns or tanks lined with lead, as is usually done for domestic use, is highly pernicious, since the injuries arising from taking lead into the system, and stated above, may follow. And as no other more convenient means for the storage of water and its conveyance are known, especially in small quantities, the first question

relative to the sanitary value of a water which ought to present itself to municipal or corporate bodies, as well as to private individuals, is, does it exert a solvent action upon lead, or does it contain a nitrogenous acid, or any compound likely to produce one. It is true that water which would dissolve this metal in abundance, and, therefore, be rendered unfit for use, is by the presence of certain mineral ingredients rendered less liable to do mischief.

LEATHER.—*Cuir*, French; *leder*, German.—Leather is the compound which the fibrous matter of the skin of warm-blooded animals forms with various substances of an organic and inorganic nature. It remains in a great measure unaltered under the joint influence of air and moisture; and in this behavior differs considerably from the skin, *per se*, since the latter, if subjected to the action of the forementioned bodies, readily undergoes a species of fermentation that resolves itself into the putrefactive kind, and quickly destroys the integument of the skin.

HISTORICAL NOTICE.—Of the early history of leather little is known; still the meagre allusions met with in old records are sufficient to show that it is of high antiquity. Like many other manufacturing arts of long standing, the preparation of leather from the skins of animals originated with the Oriental people, but of the methods adopted nothing is stated to inform the reader of the present day, beyond the remark that alum was used as a tanning agent by the Saracens.

It is recorded that leather was employed among the Romans, long before they acquired the knowledge necessary for its preparation. In those and subsequent epochs it was in request for sandals and other articles appertaining to dress. In the middle ages, it is stated that several uses were made of this article, both personal and domestic, and although the manufacture must have experienced a corresponding impetus, still the mode of tanning or treating skins at that period is in oblivion. According to FOSBROOKE, the Britons in early times exported the skins of their slain animals, but afterwards learned the methods by which they were converted into leather. This is evidenced by the accounts extant of the large tanning establishments which they had, and which were usually erected on the banks of some rivulet, across which they constructed dams for the purpose of intercepting the water for their use, and frequently to the detriment of a large tract of country, which the water occasionally submerged.

Travellers have related that the conversion of the skins of animals into leather is practised by the aborigines of savage nations. Thus, Sir ROBERT SOUTHWELL describes the methods by which the savage tribes of South America prepare skins to make leather:—

On the skin being taken off the animal, the cerebral matter is extracted from the skull, and both it and the skin are dried in the sun's rays. During the exposure, the skin is kept stretched, so that no shrivelling of the hide takes place. When the hunting season terminates, the dried skins are steeped in water, and the hair detached by the use of an old knife; after this, they are placed in an earthen pot with the powdered brains, and afterwards heated to 95°, or thereabouts. By this

treatment the cerebral matter is converted into a kind of soap, which forms a lather with the water remaining in contact with the skins, and it makes the latter very clean and pliable. After remaining immersed for some time, the skins are taken out and stretched in every direction by means of thongs, and a frame formed of upright stakes and cross-pieces. During the exsiccation upon the frame, they are rubbed with a smooth stone, or hard piece of wood, so as to expel the water and fat from the pores of the hide.

Whether the leather employed by the ancient Hebrews and their contemporaries, and of which girdles, *et cetera*, were made, as stated in the book of Kings, was prepared in a similar manner, is unknown. Whatever methods were pursued, it is evident that the making of skins into leather was a business confined to a few who made it their trade, in the beginning of the Christian era, and that the manufacture has been since progressing slowly. Regarding the choice of materials for tanning, such as the barks of trees and the like, it is unknown whether those now in use were then recognized as possessing the virtue of converting skins into leather, or whether the discovery is due to the tanners of the middle ages. It is certain, however, that the scientific principles of the business were not at all, or at best but very imperfectly understood, before the end of the last and beginning of the present century. The investigations of DEYEUX, SEGUIN, MACBRIDE, PROUST, Sir HUMPHREY DAVY, and several other chemists, explained the nature of the changes which took place, and attributed them to true chemical combinations. These researches, therefore, led the tanners to the comprehension of the scientific principles upon which their operations were based, and likewise opened up new sources of improvement. Since then, however, the progress in this art has been much less marked than that of other branches of trade in which chemistry has been a handmaid; and though numerous experiments have been tried, and many patents granted for new processes and improvements, no very decided advantage has been gained to show that the modern system is superior to that practised prior to their introduction. This is the more unaccountable, considering that the growth of social refinements, and increased wants, as likewise the universal impetus which trade, commerce, and manufactures have received during the last half century, created so great a demand for leather as to render it one of the most important articles of manufacture. This is especially the case in England, where—apart from the consumption of this article in boots and shoes—so much of it has been used in connection with machinery, in the manufacture of carding and other apparatus employed in the cotton trade, for saddlery and carriages, in upholstery, bookbinding, and a variety of other branches which are year by year springing up, that the consumption is almost outstripping the production.

MC'ULLOCH considers that the leather manufacture ranks third or fourth in importance, being inferior in money value to those of cotton, wool, and iron, whilst others are disposed to think that it is quite as important as cotton. A glance at the extent of this branch of trade will show at once how much it has merited the

above rank. MC'ULLOCH estimates the number of persons employed in the tanneries alone as exceeding twenty-eight thousand three hundred; and those engaged in the subsidiary trades to which leather gives rise, such as the currier, boot-maker, saddler, *et cetera*, average two hundred and twenty-five thousand, among whom there is expended annually from seven and a half to eight millions sterling in wages alone. The value of the manufactured goods reaches to no less than nineteen or twenty millions annually.

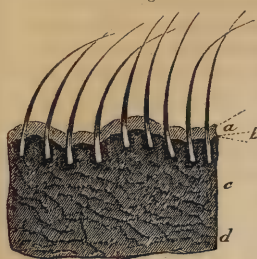
It is plain, however, that without some very great changes or modifications of the old slow process of tanning, the extensive demands for leather, which may be inferred from the preceding, could not have been met. Such modifications have been introduced more especially during the last fifty years, in which time mechanism has done far more than chemistry to expedite the operations and improve the appearance of leather. The mission of chemistry has hitherto extended little further than discovering tanning agents, and extracting the tanning principle, which, when the hide is prepared by mechanical pressure and other treatment, yields up the tannin more readily than the bark. It is nevertheless a fact, that as the operation has been quickened thus far, the quality of the leather has deteriorated proportionably, and hence when a fine kind of leather is required, recourse must be had to the old methods for its preparation.

Proximate Principles of Leather.—As may be inferred from its nature, leather is formed by the combination of the substance of the skin with any other compound which has the property of rendering it impure, and elastic. Many substances possessing these properties in relation to skins of animals, are known to exist both in the organic and inorganic classes; but the one most generally employed, as well as the most efficient, is tannin. That a firm chemical union of the two bodies, such as that above referred to, exists, is evidenced by the modified form of the materials, and the physical appearance and chemical behavior of leather, when subjected to microscopical and chemical examinations. The principle in the skin esteemed by the tanner is, as will be shown later on, a gelatino-fibrous compound which constitutes the basis of leather; and the combining agent—tannin—partakes of an acid nature, so that, by uniting with the gelatino-fibrous material, the former is, as it were, thereby salified, so that it is no longer subject to the ready putrefactive change which the skin undergoes under the influence of air and moisture. As the gelatino-fibrous principle forms only one of several others in the hide of the animal, so the tannin or tannic acid constitutes only one among many other substances in the sources whence it is extracted. In order to render the comprehension of the scientific nature of the business of the tanner as easy as possible, it will be necessary to dwell somewhat in detail upon the materials which he employs, so as to exhibit their respective nature, and show how they mutually affect one another. And firstly,—

THE SKIN.—Strictly speaking, the skin of animals is composed of two parts, the *corium* or *cutis*, and the *cuticle* or *epidermis*: the former is the portion

which enters into the composition of leather, and forms the true skin, and the latter constitutes the exterior covering in which the fur, wool, or hair of the animal

Fig. 339.



is rooted. Some anatomists, however, distinguish three distinct parts in the skin, namely, the *corium*, the *rete mucosum*, and the *cuticle*. These several parts are illustrated in Figs. 339 and 340, the former showing the position of the hair, and the latter the magnified layers of which the skin is compounded. In both, A represents the epidermis; B, the rete mucosum, in which the roots of the hair are embedded; C, the fibrous tissue of the true skin; and D, the cellular tissue beneath the latter, showing the fat cells,

by him, is that for removing the hair and epidermis, both being useless.

The corium, deprived of the epidermis, is a substance organized of a number of fibres ramifying and intersecting one another in every position; leaving, however, interstices contracting in size as they reach the outer portion, and which are more or less charged with fluid matter that serves to renew the cuticle and keep the skin pliant and moist. On treating the skin with water these matters are removed, and ultimately there remains but the fibrous portion saturated with water. In this state it appears semitransparent, and, if the water be expelled by a gentle heat, it assumes the physical appearance of horn, constituting only about thirty-two and a half to thirty-three per cent. of the raw hide. From WEINHOLT'S researches, it appears that the skin deprived of the epidermis and its subjacent fluid, as also of the mucous membrane and fat on the interior, affords forty-three per cent. of solid matter, yielding—

	Centesimally.
Fibrous matter,	74.42
Uncoagulated albumen,	3.49
Extractive matter—soluble in water; in- soluble in alcohol,	17.44
Extractive matter—soluble in alcohol, ...	2.32
Fatty matter and loss,	2.33
	100.00



a, in Fig. 340, and sweat glands, b, with the follicles, h, through which this secretion passes out to the surface of the skin.

Behavior of the Epidermis and Cutis with reagents.—When the fresh skin is immersed and macerated repeatedly in water, the matter of the cuticle is separated from the fibrous substance of the cutis, not by the solution of the former, but, as it would appear, by dissolving an extractive matter amounting, according to WEINHOLT'S analysis, to about eight and a half per cent., and which is probably to some extent intermediate between the horny matter of the cuticle and the cutis; weak acids also abstract it, but solutions of the alkalies and of many of their salts are more effectual for bringing about the separation, since these agents dissolve it. The epidermis, which is analogous to horn, does not combine with tannin or any other substance by the agency of which leather is produced. Hence it becomes useless to the tanner; and therefore, the first process to which hides and skins are subjected

Digestion in water removes the albumen and extractive matter taken up by this menstruum; in alcohol, the further portion of extract dissolves, and ether separates the fat with which the residue is impregnated. If the corium, deprived of the epidermis, be treated with boiling water, it dissolves, with the exception of a little fat and some nervous filaments; and when the liquid is evaporated slowly, a gelatinous residue is left, which, when the entire skin is operated upon, forms the glue of commerce.—See GLUE, *ante*, Vol. II., page 181.—This effect of the water does not arise, however, from the solution of the gelatin which, as might be supposed, the skin contains, but it modifies the components of the fibrous tissue so as to bring them into this compound. The same property is possessed by acids and alkalies in a more powerful degree, since the change is effected by these agents at the ordinary temperature.

Fibrin, albumen, and their modification, gluten, behave in a remarkable manner towards tannin or tannic acid, and by the transformation of the fibrous matter of the corium during the operations to which the skins are subjected in the tanning into a semi-gelatinous mass, they conjointly produce leather.

TANNING MATERIALS.—The second principal component of leather, such as that manufactured into boots and shoes, *et cetera*, is *tannin* or *tannic acid*, a substance of vegetal origin, and very extensively disseminated in plants and trees. For a long time the agent which gave such virtues to oak bark, in converting prepared skins into leather, was little known, and, consequently, the peculiar relation of the proximate principles of this article could not be understood, notwithstanding that, in the absence of this knowledge, the leather manufactured was sometimes of prime quality. LEWIS was the first who drew attention scientifically to the subject. He observed, during an investigation of the nut-galls,

that they contained a substance which gave a black compound with a sesquisalt of iron and precipitated isinglass. DEYEUX, who also studied the point, noticed this substance, but considered it a peculiar resinous matter. It was not, however, till SEGUIN published the results of his labors, that any definite account of it was given. This chemist showed that the unknown body differed from the acid of galls—gallic acid; that it combined with animal matters, more particularly albumen and gelatin, and formed with them unalterable bodies, the analogues of which constituted the main bulk of leather. Since then, manufacturers have given great attention to this principle in the tanning material, and the consequences are that a greater variety of substances producing tannin, available for making leather, have been discovered, and that considerable expedition in the process has been attained. Although the forementioned chemists, with DAVY, CHEVREUL, PELLETIER, LEGRANGE, GUILLOT, HATCHETT, TROMSDORFF, RICHTER, and PROUST, may be justly said to have given a scientific exposition of tannic acid and its behavior, and likewise pointed out its quantity in those plants that yield it most abundantly—still several more recent investigators have contributed to the stock of information on this subject. According to WAHNLENBERG, tannin exists only in perennial plants, and almost solely in the permanent parts. For example:—1. In the perennial roots of certain annual plants, as the septfoil and bistort or snakeweed. 2. In the bark of the trunks and roots of nearly all perennial trees, especially in the true cortical portion. 3. In the trunk and sap of many trees. 4. In the leaves of perennial plants—in small quantities. 5. In the leaves of different varieties of oak; of the *rhus coriaria*—sumac; of the *arbutus uva ursi*—bearberry; of the *arbutus unedo*—strawberry, *et cetera*, in large proportions. 6. In the capsule of the unripe fruit of the *quercus suber ægilops*—valonia oak; *juglans regia*—walnut; *asculus hippocastranus*—horse-chestnut; and *terminalia chebula*. 7. In the pulp of the fruit of the *punica granatum*—pomegranate; *rosa pimpinellifolia*; *garcinia mangostana*—mangosteen; and in the different species of anona.

Of the principal tanning materials imported into England, the following table exhibits the names, although a considerable quantity of oak bark—*quercus pedunculata*—is obtained in this country:—

Common title.	Botanical name.	Whence imported.
Oak bark,	<i>Quercus pedunculata</i> , . . .	Flanders, <i>et cetera</i> .
Larch bark, . . .	<i>Pinus larix</i> ,	Scotland.
Mimosa bark, . .	<i>Acacia sp.</i> ,	New South Wales.
Babool bark, . .	<i>Acacia arabica</i> ,	Bengal.
Cork-tree bark, .	<i>Quercus suber</i> ,	Laruch, Rabat, <i>et cetera</i> .
Hemlock bark, .	<i>Abies canadensis</i> ,	United States.
Sumach,	<i>Rhus coriaria</i> ,	Sicily.
Valonia,	<i>Quercus ægilops</i> ,	Smyrna, Trieste, Morea.
Divi divi,	<i>Cæsalpinia coriaria</i> , . .	{ Maracaibo, Rio de la Hache, Savanilla.
Myrobalans, . . .	<i>Terminalia sp.</i> ,	Bengal.
Algarobilla, . . .	<i>Prosopis Pallida</i> ,	Valparaiso.
Terra japonica, .	<i>Acacia catechu</i> ,	East Indies.
Cutch,	" " " " " " " " " "	Calcutta, Singapore.
Kassu,	<i>Areca catechu</i> ,	Ceylon.

Besides the foregoing, which are partly well known in the trade, other astringent substances have been brought before the public, to be employed *per se*, as tanning

materials, or with oak bark as an adjunct. These are various extracts from species of the *acacia* tribe: gambier, the extract of the *nuclea gambier*, from Singapore; mangrove bark—*rhizophora mangle*—from Arracan, Malabar, and Singapore; turwar or cassia bark; avaraputtai, Tangada jigota—*cassia auriculata*—from Vazigapatam; saracondraputtai—*cassia fistula*—from Madeira and Tinnevely; saul-tree bark from the Saul forests; pomegranate rind; darunka pucker—*dadima jegota*—from Kemaon and Vizagapatam; dalumka khola from the vicinity of Calcutta; jamoon-bark—*eugenia jambolana*—and pearl-bark, from Cuttack; samak-bark from Singapore; vangay or gum-kino—*pterocarpus dalbergoides*—from Malabar; kino, or astringent extract of the *Buchanania latifolia*, from the district of Chota, Nagpore; majoophul or gall-nuts—*ficus infectoria*—from Nagore, *et cetera*; tamarisk gall—*tamarix indica*—from Bombay and Lahore; several kinds of myrobalans; gaub, the fruit of the *diospyros glutinosa*, from Calcutta; hag-plum tree—*spondias lutea*—abundant on the banks of the river Berbice, and commonly used in British Guinea for tanning; courida bark—*aviceennia nitida*—a tree very common on the Eastern coast of Demerara, *et cetera*.

MORFIT remarks:—1. That tannin is never found to any extent in the interior of the trunk of trees. 2. That it does not exist in poisonous plants, nor in those with a milky or viscid sap. 3. That its proportion is greater in young than in old plants. 4. That the tannin is converted to bitter principle, as the plant increases in age. 5. That it is most abundant in the cortical layers of the bark, and is usually absent altogether in the epidermis. 6. That the proportion of tannin in bark varies with the season, decreasing as the severity of the winter increases; and, 7. That the two extremes of quantity are attained in winter and spring.

These remarks admit of an important practical application with reference to the most suitable time for the barking of trees, *et cetera*. But before discussing this subject, it will be necessary to enter more minutely into the nature of the tanning principle.

TANNIC ACID OR TANNIN.—By examining any of the numerous substances mentioned above, it will be found that they yield a product which is capable of precipitating a solution of gelatin, and also of giving a greenish or bluish-black one, with solutions of sesquisalts of iron. To matter exhibiting this reaction, and having an astringent taste, the title of *tannin* was given, irrespective of whatever difference might be exhibited upon further comparison. Now, many of those bodies, which in common with the true type of tannin—that which is extracted from galls—precipitate gelatin, and so far show that they are eligible for tanning materials, are known to differ in their characteristics; for instance, some possess acid properties, whilst others are devoid of them; and although towards gelatin their reactions are similar, their atomic constitution is widely different. Regarding their effect in converting skin into leather, this dissimilarity is not so very material as when the components of each are compared. A distinction is also made with respect to the physical appearance of the precipitate they afford with a sesquisalt of iron, and by

this all the known tanning materials are divided into two classes. In the first of these are placed gall-nuts and the barks of the several oaks, and the second includes the quinquina, the cachou, gum-kino, pine barks, *et cetera*. The tannin afforded by the first throws down a bluish-black or purple combination, whilst the precipitate afforded by the second is greenish. Experiments have shown that such distinctions are not very marked, since the tannic acid from nut-galls or oak bark, in the presence of an alkali, will occasion a greenish precipitate when added to a sesquisalt of iron, and a bluish or violet compound when acids are present. HATCHETT first observed that many plants contain a carbonaceous principle, which, when acted upon by nitric and sulphuric acids, according to the method of CHEVREUL, yield a substance which, like the tannins of the foregoing barks and fruits, throws down gelatin, and renders it imputrescible. This variety has been designated artificial tannin; but, in the present state of chemical science, it could not be compounded with the natural products. BERZELIUS, GEIGER, WALT, and CAVALLIUS, are of opinion that tannin, from whatever source it may be obtained, is identical, and that the difference of the reactions with the iron salt must be attributed to impurities which are accidentally present. STENHOUSE, in his more recent researches, has shown that such is not the case, but that all those forming precipitates with sesquioxide of iron, varying from the color of that which the tannin of nut-galls affords, must be regarded as a distinct substance, in which case there seems to be an almost endless variety. Even when the iron reactions of some tannins agree, and also appear analogous in other chemical relations, the same chemist states that the composition is frequently diverse. Hence he distinguishes the various kinds of tannin by the source; thus, that obtained from nut-galls he calls from gallotannic acid; from oak bark, quercitannic acid; fustic—*moris tinctoria*—moritannic acid, and the like.

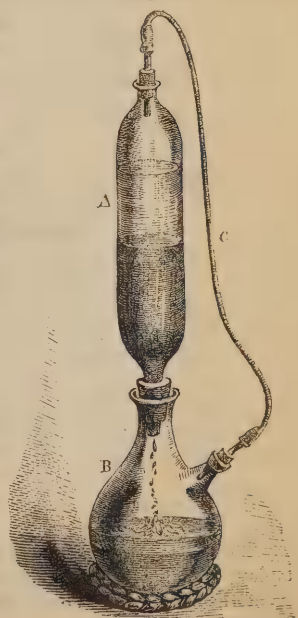
Preparation of Tannic Acid.—It is very difficult to prepare tannic acid of absolute purity, so much so that none of the methods in use for its extraction can afford a product free from foreign matters. When extracting tannin on the small scale, nut-galls are selected, as they yield the largest product. A quantity of these is dried and reduced to powder, and subsequently exhausted of the tannin with water by moistening with this liquid, then subjecting to pressure. The extract thus obtained, if employed with fresh portions of the powdered galls successively, becomes highly saturated with tannic acid. Filtration cannot of itself clarify the opaque inspissated liquid; but on mixing it with a little dilute sulphuric acid, and agitating, a precipitate of the suspended matter forms, and may be removed by filtering it through linen or paper. To the clarified liquid a solution of carbonate of potassa is cautiously added, till it almost ceases to deposit any matter from the menstruum. The crude tannate of potassa thus obtained is separated from the liquid, washed with ice-cold water, or with water at as low a temperature as possible, and dissolved in boiling dilute acetic acid. On cooling the latter, a brownish deposit containing acetic acid parts from it, and must be removed by passing the liquid through the filter.

A solution of subacetate of lead is now added to the filtrate, and the resulting tannate of lead, removed and washed thoroughly, then disseminated in water, and a current of sulphide of hydrogen passed through till the whole of the metallic base is converted into sulphide. By evaporating the liquid after the separation of the sulphide of lead in the hollow of a flask, containing some carbonate of potassa, the tannin is procured in the form of gummy transparent scales of a yellowish color. In this state, however, the tannin is still impregnated with a little gallic acid and brownish matter, which may be removed by treating the powdered substance with successive portions of ether. The tannic acid is thus left in combination with the brownish matter; but by repetition of the process, this impurity, as well as the gallic acid, is dissolved out, and the tannic acid remains nearly colorless.

This substance may likewise be prepared by treating the clarified extract of gall-nuts, as above directed, with ammonia till almost neutralized, and to the menstruum chloride of barium is added till it ceases to throw down a precipitate. The flask is then filled with water, and allowed to repose till the whole of the tannate of baryta has deposited. Any gallic acid which may have been formed, remains combined with the base in the supernatant liquid, and may, consequently, be removed by decantation and washing. During these operations, a small portion becomes decomposed and colors the baryta salt greyish; on treating the latter with acetic acid, however, this impurity remains, whilst the tannate of baryta is dissolved. To the liquid thus obtained, subacetate of lead is added, and the plumbous salt proceeded with, as directed above.

When the substance is to be obtained in its greatest state of purity, recourse must be had to the process known as that of PELOUZE, but which was first broached by LAUBERT. The latter chemist directed the formation of an extract of sixty grains of powdered nut-galls in one hundred and twenty of ether, the digestion to be continued during twenty-four hours, after which the ethereal extract was to be filtered and evaporated. PELOUZE followed the foregoing method in principle by employing the apparatus of ROBIQUET and BOUTRON, as used for the preparation of amygdalin. Fig. 341 represents this digester. It is an elongated glass vessel, A

Fig. 341.



having an orifice at the top, which is fitted with a ground-glass stopper, and contracting towards the other extremity, which fits tightly into the neck of a bottle or matrass, B, which receives the extract. Sometimes the lower bottle has a second tubular opening for the purpose of receiving a cork furnished with a tube, to which a connector, C, of caoutchouc is appended, the other end being attached to a similar tube fitted in cork which closes the top orifice. This adaptation causes the filtration to take place much more readily, whilst it prevents contact with any further quantity of air beyond what is contained in the apparatus. The further process is such as already detailed.—See Vol. I. page 581. By careful evaporation—the better if under the exhausted receiver—the tannic acid is obtained in the form of a spongy iridescent, uncrystallizable mass, having a light straw-yellow color. It may be washed with repeated quantities of ether to remove any remaining gallic acid, after which treatment it may be desiccated as previously stated. So prepared, tannic acid is in its purest known state; but as sometimes it results almost colorless, doubtless it is not free from impregnations arising from decomposed tannin—apothema—or some other matter.

Another modification of the method just detailed was introduced by DOMINÉ, and offers the advantage of yielding a larger product, while it admits also of being applied on the large scale for the purposes of the manufacturer. He places the powdered galls in a damp cellar for several days, during which they absorb moisture; the powder is next transferred to a wide-mouthed jar, and made into a paste with ether—specific gravity 0.75—after this the vessel is hermetically closed, and

the contents allowed to digest for twenty-four hours. At the expiration of this time the pasty contents are transferred to a strong linen bag and subjected to gradual pressure, when the ethereal extract of tannin, having a dark sirupy consistence, flows off into the receiver. This liquid must be evaporated to dryness at a gentle heat—100° to 110°—by which the tannic acid is left in the form of light-colored resin-like scales. The compressed residue is further treated with ether, to which six per cent. of water is added in the same manner as when preparing the first extract, and, on expelling the fluid by a gentle heat, a residue of tannin is obtained. It is, indeed, more impure than the product resulting from the method of PELOUZE, as it contains portions of chlorophyll, volatile oil, and gallic acid; still the tannin thus prepared answers very well for medicinal and other uses, for which it is applied in the arts.

Properties of Tannic Acid.—In its purity, tannic acid is colorless, inodorous, possesses a highly astringent taste, and is very soluble in water. It is, however, devoid of all bitterness, notwithstanding its astringency is so powerful. On testing the aqueous solution with litmus, the reaction evidences the acid nature of the tannin; and further, by treatment with an alkaline carbonate, carbonic acid is freely displaced, showing that a combination of the alkaline base and the tannin has taken place. With the oxides of the heavy metals it in a great measure combines, giving rise to precipitates which are the tannates of the respective bases, and generally possess a color more or less remarkable. Thus an infusion of nut-galls reacts in the following manner:—

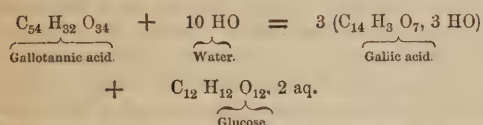
With a *neutral* solution of salts of

	Precipitates given.	
	Brande.	Dumas.
Protoxide of manganese,.....	Dirty-yellow.	—
“ iron,.....	Purple-tint.	—
Sesquioxide of iron,.....	Black.	Blue-black.
Oxide of zinc,.....	Dirty-yellow.	—
“ tin,.....	Straw-yellow.	Yellowish.
Binoxide,.....	Fawn-yellow.	Yellowish.
Oxide of cadmium,.....	—	—
“ copper—protochloride,.....	Yellow-brown.	Grey.
“ —protonitrate,.....	Green.	Grey.
Oxide of lead,.....	Dingy-yellow.	White.
Teroxide of antimony—from emetic tartar,.....	Straw-yellow.	White.
Teroxide of bismuth,.....	Yellow.	Orange.
Oxide of cobalt,.....	—	Yellowish-white.
Salts of cerium,.....	—	Yellowish.
“ titanium,.....	—	Blood-color.
“ tellurium,.....	—	Isabelle-yellow.
“ chromium,.....	—	Brown.
“ tantalum,.....	—	Orange.
“ molybdenum,.....	—	Brown.
“ uranium,.....	—	Brownish-red.
“ silver,.....	—	Pale-yellow.
“ platinum,.....	—	Greenish-shade.
“ gold,.....	—	Brown.
“ osmium,.....	—	Bluish-purple.

In making the foregoing experiments, it is necessary to employ neutral solutions of the salts, otherwise any excess of the acid may not only alter the shade of the precipitate, but prevent it altogether. This is especially the case with salts of iron and of titanium. When a solution of tannic acid is added to another of protosulphate of iron, according to DUMAS, no precipitate occurs; but if one of the sesquisulphate be substituted, there is an abundant deposit of a blue-black color.

By exposing an aqueous solution of tannic acid to the air, at a moderately elevated degree of heat, oxygen is freely absorbed, and an equal volume of carbonic acid is disengaged. Upon examination, the matter in solution will be found to be wholly transformed into two other substances, gallic and ellagic acids, the former of which is in excess, and is dissolved in the liquid, whilst the latter remains insoluble in the form of a yellowish powder.

This transformation takes place in the aqueous extract of gall-nuts much more readily than in one of pure tannin; this is particularly the case if the marcs or insoluble residue of the galls be left in contact with the liquid, as it induces a fermentative action, which brings about the transformation the more readily. When boiled with sulphuric or hydrochloric acid, gallic acid is also formed, together with grape sugar, which, as STRECKER states, remains in the mother liquid after the newly-formed acid is removed by crystallization. The change here induced may be represented thus, according to MILLER :—



A concentrated solution of caustic potassa at the boiling point has also the effect of transforming tannic into gallic acid; and if air or oxygen be admitted, of converting the latter into an ulmin-like substance. Hydrochloric, nitric, phosphoric, and arsenic acids, occasion in strong solutions of tannic acid white precipitates, which are, as stated by BERZELIUS, compounds of the tannin with those acids respectively. All these precipitates are, however, readily decomposed, and their tannin changed into gallic acid, by seething them with dilute sulphuric acid or with an excess of alkali. If a cold aqueous solution of tannin be mixed with another of gelatin, isinglass, bone-size, or glue in excess, an opaque white precipitate is obtained of tanno-gelatin, that is soluble by the aid of heat in the supernatant fluid. When, however, the conditions are reversed, and an excess of tannin is taken, it happens that instead of dissolving, the precipitate agglutinates, and forms a membranous matter of a greyish hue, that possesses considerable elasticity, and thus approximates to caoutchouc. The solutions filtered from these bodies strongly tinge those of the sesquisalts of iron. It appears that tannin solutions react in a similar way with protein compounds in general.

It was thought for a long time that the insolubility of the tanno-gelatin offered a means for insuring the purity of tannic acid, and of detecting the absence or presence of gallic acid in the sources affording tannin; but this insolubility, excepting in water alone, does not answer the purpose. PELOUZE employed a piece of skin, cleaned in the ordinary way from hair and epidermis; this was immersed for some hours in the extract, and the whole agitated occasionally, and finally the liquid filtered. When pure tannic acid was operated upon, the whole combined with the integument, so that the fluid had no astringent taste, nor did it color a solution of a sesquisalt of iron; but if gallic acid had been mixed with it, the bluish-black tint would present itself in the latter case.

Freshly precipitated alumina, agitated with a solution of tannin, absorbs the latter rapidly, and forms with it an insoluble composition; gallic acid behaves in a similar manner. At the temperature of an oil bath, tannic acid is decomposed, water and carbonic acid being formed; but when the heat is increased, other

products are generated, and nothing remains but charcoal, which, if heated on platinum wire, burns, leaving no residue. Strong ether dissolves tannin, and forms a sirupy liquid, which does not combine with fresh ether. Alcohol behaves with tannin in the same way, the solvent power of the spirit decreasing in reference to it as it approaches purity or dehydration.

From the analysis of BERZELIUS, it appeared that tannin was composed centesimally as follows :—

	Berzelius.	Pelouze.
Carbon,	52.69	51.40
Hydrogen,	3.86	3.51
Oxygen,	43.45	45.09
	100.00	100.00

These numbers nearly correspond with the formulæ, $\text{C}_{18} \text{H}_8 \text{O}_{12} = \text{C}_{18} \text{H}_8 \text{O}_9, 3 \text{HO}$; but STRECKER in his later researches gives the equation for gallo-tannic acid thus, $\text{C}_{54} \text{H}_{82} \text{O}_{34}$, showing that it contains less oxygen and hydrogen than is indicated above.

Varieties of Tannin.—As already stated, recent investigations have a tendency to the conclusion that tannin from the various vegetal products manifests such difference in its reactions with several substances, as to justify the recognition of many varieties of this compound, though classed under the above generic name. The impurity of this body was long considered to affect its behavior with reagents so as to vary the reaction; but, latterly, STENHOUSE and others have arrived at other conclusions, and regard the tannins from the different sources, and which give unlike reactions with reagents, as distinct chemical bodies. Doubtless, the other extractive matters in the solutions of the tannin modify to a great extent the color of the precipitate or other characteristics, from those afforded by the pure tannin, but all the difference cannot be attributed to this cause. With gelatin many of the tannins give well-marked indications, which would go far to show the dissimilarity in the nature of the tannin; yet it is upon their behavior with a solution of sesquisalt of iron that the discrimination is based. To ascertain this point, STENHOUSE prepared a reagent which affords indications only with the variety of tannin contained in galls and with gallic acid, and which consists in the production of pyrogallie acid when the body to be tested is submitted to the destructive distillation. In this way he observed that many varieties, which comported themselves exactly similar with sulphate of iron and in their general reactions, are by no means identical. Taking the behavior with solutions of sesquisalts of iron as the criterion, the following varieties are detected :—

1. *Tannin which forms a bluish-black precipitate in solutions of a sesquisalt of iron:*—Tannin from nut-galls, oak, poplar, beech, hazel, chestnut, maple, cherry, apricot, plum, elder, and other barks; sumach and logwood; from the roots of *lithrum salicaria*, *iris pseudacorus*, *geum urbanum*; *polygonum bistortum*—bistort; *alchemilla vulgaris*—ladies' mantle; from the leaves of the *arbutus uva ursi*—bearberry; *amothera biennis*, *geranium pratense*; from the husks of the *caesalpinia coriaria*; from lentils, *et cetera*.

2. *Tannin which forms a green precipitate in solu-*

tions of sesquisalts of iron:—Tannin from catechu—juice of the *mimosa catechu*; gum-kino—juice of the *coccoloba wifera*; most of the cinchona barks; horse-chestnut bark; the roots of the *rumez aquaticus*—water-dock; *tormentilla erecta*—septfoil; *krameria triandria*—ratany; *polypodium flex mas*—male fern; tea and badian; a species of anise; the leaves of *salvia officinalis*—sage; and of *arnica montana*—leopard's bane, and in date-stones.—*Morfit*.

Artificial Tannin.—Besides the foregoing, chemists distinguish other varieties of tannin which result from the chemical action of several powerful agents upon many substances; as, for instance, from the action of nitric acid upon charcoal and indigo, and likewise from the effects of sulphuric acid upon resins and camphor. The first notice of artificial tannin was published by HATCHETT in the Transactions of the Royal Society in 1801: he discovered it whilst making experiments upon the slow carbonization of plants. This tannin is different, however, from other varieties of this substance at present known. When one part of charcoal, reduced to an impalpable powder, is digested with five parts of nitric acid of spec. grav. 1.40, and ten of water at a moderate heat, the fluid being added portionwise to the charcoal, the latter after a time disappears, and a transparent deep-brown liquor remains, which, on evaporation, leaves the artificial tannin slightly impregnated with acid. By repeated solutions in water, and evaporations, this impurity may be removed. From the above materials about 1.2 of artificial tannin is obtained.

Artificial tannin prepared in this way is a brown, inodorous substance, having a vitreous fracture, and very soluble in water. THOMSON states that alcohol of spec. grav. 0.80 dissolves it, and so far it manifests a difference of behavior from natural tannin. The aqueous solution of this substance precipitates gelatin of a brown color, but the shade deepens as the liquids are more dense. This precipitate is a compound of tannin and gelatin, in the proportion of thirty-six parts of the former to sixty-four of the latter. It is insoluble both in hot and cold water. With the alkaline bases it combines, forming more highly-colored solutions, which, in the course of some time, get cloudy. The ammoniacal solution of artificial tannin, on being evaporated to dryness and redissolved, will not precipitate with gelatin till after the alkali which it retained is neutralized with an acid. The alkaline earths precipitate it, but the precipitates are slightly soluble in water; the heavy oxides throw it down in combination as a puce-colored substance. On treating the precipitate with nitric acid, the artificial tannin dissolves without change, whereas the natural product is altered by this agent. Heated alone in a retort, it yields water and nitric acid, ammonia, carbonic acid, and another gaseous substance, probably nitrogen. According to CHEVREUL, this variety of tannin is a compound of nitrous or nitric acid with a carbonaceous matter.

A second kind of tannin is produced when indigo, or similar compounds rich in carbon, are treated with nitric acid, as in the foregoing method. A very bitter, orange-colored residue is obtained, which is soluble in water,

precipitates gelatin and metallic bases, and affords, when decomposed, nitrous or nitric acid. If sulphuric acid be made to react upon resin or camphor till these dissolve, and heat be applied till the liquor blackens, and then cold water added, a black powder falls which, when treated with alcohol and the spiritous extract evaporated, yields a residue which is a third kind of tannin compound. This variety precipitates gelatin and some of the bases. CHEVREUL considers that this compound contains sulphide of hydrogen.

Uses of Tannin.—The range of the application of tannic acid is not very extensive. It will be already understood to be of primary importance in the manufacture of leather; but, besides this application, it serves another purpose in wine-growing countries, namely, of precipitating the *glaiadine* from the fermented *must*, especially of white wines. The removal of this principle is of very great importance to the vintner, for if it be suffered to remain, it is apt to induce a secondary viscous fermentation, which would destroy the wine. Tannic acid seems to be the best antidote in this instance, since it coagulates the *glaiadine*, and forms a tannate with it. Tannic acid is also extensively employed as a medicine on account of its powerful astringent properties, which are readily explained by what has been said regarding its action on albumen, fibrin, and gelatin. Its effects are to check hæmorrhages, profuse secretions, and to constrict relaxed fibres; and for either purpose it may be administered either internally or externally. When taken into the system, it would appear that it is capable of being converted into gallic acid, pyrogallie acid, and a humus-like substance, all of which may be detected in the urine; but this change does not seem to have been effected till the tannin has exhibited its peculiar astringent action. In the laboratory, tannic acid is occasionally employed as a test.

GALLIC ACID.—The tendency of tannic to be transformed into gallic acid has been already mentioned; but it may be well to show more in detail the circumstances under which this change is effected, and to point out the properties of gallic acid generally, as also with regard to the operations of the tanner. Its name has been derived, as is evident, from galls, on account of those excrescences containing it ready-formed; it likewise exists in the cypress-nut, *arnica* flowers, white hellebore, meadow saffron—*colchicum autumnale*—and in a number of astringent barks, together with tannic acid, but in small quantities. Its most prolific source is tannic acid, which, by oxidation, yields it abundantly. The conditions affecting the change, such as exposure of the solution of tannin to air and at an increased temperature, have been already mentioned, as likewise the decomposition of the same body by the mineral acids. All the methods recommended for the production of gallic acid from tannin, are based upon these properties of the latter. Thus BRACONNOT prepares it from powdered nut-galls, by drenching this substance with water and maintaining a temperature of 70° to 75°. After a while a quiet action succeeds, and when this subsides the pasty mass is to be expressed and afterwards heated with boiling water, which dissolves out the gallic acid, and yields it upon

evaporation in impure crystals. These, by re-solution in water and filtration of the liquid through animal charcoal, afford a menstruum which gives the gallic acid in a state of purity when concentrated. WITHELL prepares it by treating thirteen drachms of dry tannin with two fluid ounces of sulphuric acid of 1.84°, diluted with four times its volume of water and the application of a boiling heat. Gallic acid in crystals is deposited to the amount of eighty per cent. of the tannin employed.

It would appear from various researches, that the change of tannin to gallic acid, on exposing the extract containing the former to air and moisture, is due to a fermentative process, which is considerably expedited if the vegetal matter in the bark or gall, or whatever else the source may be, is permitted to remain in contact with the liquid. Such is the case, especially, with extract of gall-nuts; and it might be inferred that the tannin from all other sources, and which is capable of being transformed into gallic acid by oxidation in the above manner, is similarly affected. M. LAROCHE, has shown by comparative experiments the effect of the marcs of gall-nuts, after the extraction of the tannin with ether in the ordinary way, in operating this change. By inclosing an aqueous solution of tannin and a portion of this residue in a bottle or flask, and allowing it to remain for some time, he found that the tannin was entirely converted into gallic acid, whilst a strong extract of tannin, freely exposed to the air at the same time, retained nearly the whole of its tannin unaltered. Hence, doubtless, the insoluble matter in galls in the presence of moisture, is capable of acting on tannin as a ferment, and that the change of tannin into its derivative is the result of a fermentation. It is well known that fermentation by contact of yeast, blood, and albumen, effects the same transformation of the astringent extract as the residue of the galls which have been digested in ether, and also that the latter will excite the vinous fermentation in solutions of grape-sugar, and, therefore, these reactions may be taken as mutually corroborative. Further, the gallic fermentation may be intercepted by antiseptics, like the vinous. Protochloride of mercury—corrosive sublimate—completely prevents the decomposition; and pyroligneous acid, or carbonic acid, as shown by the investigation of CALVERT, on account of some empyreumatic matter which it contains, likewise considerably retards the fermentation.

It has been shown, that sulphuric and hydrochloric acids at a boiling heat rapidly change tannin into gallic acid, and without the intervention of air; but if the mixture be kept at a common temperature, M. ANTOINE has shown by his researches that the decomposition of the tannin is retarded by a small portion of those acids. On the contrary, tartaric, malic, and vegetal acids in general, expedite the decomposition of the tannin. The rapidity with which sumac ferments, may be referred to the quantity of malic acid in the leaves.—Parnell.

Properties of Gallic Acid.—When pure, this acid crystallizes in long silky needles, which are unalterable in the air; its taste is acrid and styptic. BRACONNOT states that it dissolves in a hundred parts of cold, and in about three parts of hot water; four or five

parts of alcohol in the cold dissolve it, but one part of the hot spirit will take it up. It is soluble in ether, but in less quantity. The aqueous and spirituous solutions, but the former more readily, undergo decomposition, so that the surface of the liquid becomes mouldy, and a brownish matter is produced, which DÖBEREINER considered ulmin. Added to a solution of gelatin, no precipitation occurs—a behavior which at once distinguishes gallic from tannic acid, and which indicates that it is unavailable in converting skin into leather. This being so, and, as has been already pointed out, tannin being readily convertible into this body, it becomes of the utmost importance to the tanner to guard against this transformation, which, in the usual way of tanning, is so apt to take place. The researches of LAROCQUE have shown that, in regard of the tannin from galls, the decomposition is completely and readily effected, provided the insoluble residuary matter be allowed to remain in contact with the liquor containing the tannic acid, and it is equally well known that the tannin from sumac is liable to decomposition, as well when it remains in contact with the insoluble portion of this body, as when it is separated from it; but independently of the action of the residue, the malic acid here plays an important part. Though the evidence proving that the insoluble portion of the barks, *et cetera*, employed in tanning, when allowed to remain in the tan-liquor, does operate in the rapid conversion of tannin into gallic acid, thereby rendering the former valuable body useless, is not definite,—still, knowing that in the waste tan-liquor, a large quantity of gallic acid is found, it may be safely stated that its production is from the tanning, and also is owing more to the effects of the insoluble matter of the source of the tannin, than to any oxidation which might take place during the tanning processes. Even those kinds of tannin which are incapable of producing gallic acid by decomposition are subject to a metamorphosis which destroys the tanning agent, and this fermenting action is more readily produced when the insoluble matter is left in contact, than if the liquor were retained by itself. The only benefit which the tanner derives from gallic acid is, that it aids in swelling the hides, and thus facilitates the absorption of the tannin; but when it is considered that a dilute solution of sulphuric or vegetal acids effect the same thing quite as well, it will be evident that he who relies on the swelling by gallic acid, and sacrifices a corresponding portion of tannin in its production, suffers a considerable loss, and is not fit to compete with those who can obviate such a sacrifice.

At 410° to 420°, according to the observation of PELOUZE, gallic acid is entirely volatilized, producing a sublimate of beautiful white crystals and pure carbonic acid; if the heat be urged to 464° or 482°, instead of the foregoing change, another takes place, in which pure carbonic acid is likewise developed. But in addition to this a quantity of water is produced, and which runs along the sides of the retort, in the bottom of which remains a considerable mass of brilliant-black insoluble matter, which at first sight might be taken for charcoal. It is, however, a true acid, and is called by PELOUZE, meta-gallic acid.

According to the above-named chemist, crystallized gallic acid is composed of—

	Centesimally.
Carbon,	50.10
Hydrogen,	3.64
Oxygen,	46.26
	100.00

numbers which agree with the formula, $C_7 H_3 O_5$, HO; STRECKER, however, regards it as a tribasic acid, thus $C_{14} H_6 O_{10}$, $2HO=3 HO$, $C_{14} H_3 O_7$, 2 aq.—and capable of forming salts which correspond with the general formula, MO , $2 HO$, $C_{14} H_3 O_7$; 2 MO , HO , $C_{14} H_3 O_7$, and 3 MO , $C_{14} H_3 O_7$; MO being here the representative of a metallic oxide.

As pyrogallic acid, $C_7 H_3 O_5$ or $C_{14} H_6 O_{10}$, meta-gallic acid, $C_7 H_2 O_5$ or $C_{14} H_4 O_{10}$, ellagic acid, $C_{14} H_2 O_7$, HO , and other derivatives from gallic acid and, therefore, remotely from tannic acid, are of no importance in the making of leather, they will not be further dwelt upon. Ellagic acid is said, however, to be the chief agent that gives the bloom to the tanned hide.

SUBSTANCES USED IN TANNING.—Those which are available for the purposes of tanning, embrace a wide range if the juices, barks, leaves, roots, fruit, and

excrescences of trees, and also vegetals which contain tannin of one kind or other, be taken into account. In looking over the researches and labors of chemists, many hundred substances which yield tannin have been discovered; but practice, or the trade, recognizes only a few of these, probably owing to the quantity which can be annually produced, their yield of tannin, or because they offer some advantage either in making a better leather, or in the time required to effect the operation. The tannin and other distinct principles in vegetal growth of every kind, are derived from the sap or soluble matters, imbibed by the rootlets from the soil in which the plant exists, and the gases absorbed by the foliage. In many plants which elaborate tannin, it is met with in small proportions, owing perhaps to its being only a secondary, and not a primary secretion. It is found in some vegetals equally in all parts, whilst in others certain parts are richer in this substance, the remaining exhibiting only slight indications of its presence. The particular portions of plants that yield the greatest amount of tannin are, therefore, preferred in making leather.

The following is a list of the materials which contain tannin in the largest quantities, and which may be employed in the manufacture of leather.

INSPISSATED AND PREPARED EXTRACTS,	{ Kino, Catechu, <i>Terra japonica</i> , or Cutch.
VEGETAL EXCRESCENCES,	Galls.
	Of the different kinds of willow.
	Of the <i>quercus robur</i> —common oak; <i>quercus cerris</i> —Turkey oak; <i>quercus ilex</i> —evergreen oak—and other varieties.
	Of the <i>erica vulgaris</i> , or common heath, and of other varieties of the same plant.
TREE LEAVES,	Of the <i>cyndra scolymus</i> —garden artichoke.
	Of the sloe-tree— <i>prunus spinosa</i> .
	Of the <i>conium maculata</i> —spotted hemlock.
	Of the <i>arbutus uva ursi</i> —bear-berry.
	Of the <i>thea Chinensis</i> —the leaves of the several varieties of green and black teas yield tannin—and of the <i>rhus glabrum</i> , known as <i>sumac</i> .
FLOWERS AND TREE TOPS, FRUITS,	These are hardly ever employed, although many afford extracts which precipitate gelatin and salts of iron.
	Of the grape.
	Of the <i>hydro-sapathum</i> and wild cornel.
SEEDS AND BULBS,	The hulls of the fruit of the <i>casalpina coriaria</i> , known under the title of divi-divi, or leby-diby.
	The bulbs of the <i>scuilla maritima</i> .
	The dried acorn hulls of the prickly-cupped oak— <i>quercus agrifolia</i> .
WOODS,	All woods or trees, the barks of which yield tannin, also afford more or less of this substance; they are, however, scarcely ever employed.
	Of the dentillaria, or lead-wort— <i>plumbago Europaea</i> .
	Of the male fern— <i>aspidium filix mas</i> .
ROOTS,	Ratany— <i>krameria triandria</i> —root.
	Of leopard's bane— <i>arnica montana</i> .
	Of statice, or marsh rosemary.
	Common bark, of which there are several varieties; birch, chestnut, and horse-chestnut barks; sassafras, or the bark of the root of the <i>laurus sassafras</i> ; larch, hazel, beech, Lombardy poplar, blackthorn, pomegranate, ash, elm, cork-tree, cinchona, willow, sycamore, tulip-tree, wattle and oak barks; besides these, however, there are other barks—such as that of the sumac shrub, winter's bark, <i>et cetera</i> —that afford tannin in available quantities.
BARKS,	

It will not be uninteresting to state briefly some of the properties of the substances mentioned in the foregoing table, with respect to their uses for tanning purposes.

KINO.—Of the inspissated extracts which are found in the market, kino or gum-kino, is the richest in tannin, containing, as it does, according to VAUQUELIN'S analysis, seventy-five per cent. of this compound. Nevertheless, it has not hitherto come into use for tanning purposes, but is solely devoted to medical uses. For its more general properties, refer to page 316, Vol. II.

CATECHU.—Catechu is another of the same class as the preceding, and forms a most useful article for the tanner. There are several varieties which are distinguished by various names, such as cutch, terra japonica, and gambir. Formerly, this extract, from its brownish-red color, was supposed to be a kind of earth, hence the title *terra* given to it. Catechu is extracted from the acacia catechu, a tree which grows to the height of twenty or thirty feet, and abounds in the forests from latitude 26° to 30° , known as the Bornese territory on the Malabar coast, and called Cancan. The heart and bark of the wood are boiled in water, and the solution

evaporated, which leaves the astringent extract known as Cancan catechu. According to NEES VON ESENBECK, most of the catechu exported from Bombay is prepared from the acacia catechu, whilst that brought from Bengal, is derived from the *uncaria gambir*, a shrub cultivated in the countries lying on both sides of the shores of Malacca. It is obtained by boiling the wood, bark, and leaves of this shrub together with the inspissated juice in water, and evaporating, then adding a little sago to give it consistency; it is finally exsiccated in the sun, and then cut into square or circular cakes to suit the purchaser. Bombay catechu, which is the richest in tannin, is of a dark brownish-red hue, both externally and internally, and possesses a specific gravity of 1.38. DAVY examined the Cancan catechu, and found it to be 1.39; he also found in two hundred parts of this, as well as of the Bengal catechu, and known by the title *Pegu*, from the province of Bengal where it is prepared, the following constituents:—

	Cancan or Bombay catechu.	Pegu or Bengal catechu.
Tannin,.....	109	97
Extractive,.....	68	73
Mucilage,.....	13	16
Earthy residue,.....	10	14
	200	200

The genuine catechu, of whatever variety, contains, on an average, about half its weight of tannin, and its efficacy in making skin into leather, has been estimated as being five times greater than the best oak bark; but this seems exaggerated. Besides the real tannin, the extractive matter contained in it is another definite substance, which is called *catechin* or *catechuic acid*, and which, doubtless, plays a part in the process of tanning. To it is ascribed the property of coloring the leather so deeply. The latter body differs from the tannin in being insoluble in cold water, although a solution of the tannin of catechu takes up a small quantity of it. The varieties of catechu of commerce are:—

1. *Cake catechu*, from its being in circular cakes. Their color varies from a light-brown to a black, and their weight from several ounces to two pounds.

2. *Pegu catechu*.—As already stated, this variety obtains its name from the province where it is prepared. It is generally imported in masses of a hundred pounds weight, but as seen in the shops, it presents the appearance of angular irregular fragments in double layers, with leaves between. It has a compact shining fracture, and a deep-brown color.

3. *Bengal catechu* is manufactured in rectangular cakes, but in the course of transit they get reduced to fragments. Externally, it has a rusty brown color, and internally, the shade varies from a brownish-grey to dark-brown.

4. *Bombay catechu*.—This variety occurs in globular lumps of the size of an orange flattened, and two pieces generally adhering together. In color it resembles that brought from Bengal.

5. *Gambir*.—It is stated by M'CULLOCH that no less than four thousand six hundred tons of catechu, under the name of *gambir*, is produced annually by the Chinese settlers in Rhio. It takes its name from the shrub which is its source, the *uncaria* or *nuclea*

gambir. It has a deep yellow or reddish-brown color on the outside, but within it is paler, and presents a dull earthy fracture. It comes to these countries in solids of about a cubic inch. ESENBECK, who examined this variety, states that it yields from thirty-six to forty per cent. of tannin. Boiling water entirely dissolves it.

6. *Arecha catechu*.—The nuts of an Indian palm known by this title, afford this kind of astringent substance. These fruits are macerated with water, and the decoction evaporated, when a better sort of catechu results, known by the term *kassu*, and the semi-exhausted residue upon further treating it with water, affords a solid extract, which is distinguished as *coury*. The former is of a black color, and intermixed with husks, and the latter of a yellowish-brown, with an earthy fracture. The *coury* is, of course, inferior to extract known as *kassu*.

With regard to the application of catechu to the manufacture of leather, the natives of India have long practised it; but its introduction into the trade of this country for a similar purpose, is of modern date. Its richness in the tanning agent causes it to be very rapid in producing a gelatino-tannate of the substance of the skin, or, in other words, of making leather. The qualities of the article manufactured from it, are not, however, so satisfactory as the rapidity of its effects, either to the tanner or the public: for the leather is very permeable to water, light and spongy, hard, and of a dark-reddish fawn color. The characteristic deposit from oak bark and a few other tanning agents, known as *bloom*, is not produced by catechu, and this want is a material objection to its use, as the existence of *bloom* upon leather is considered as a kind of guarantee of its goodness. One pound of catechu, of first-rate quality, is capable of producing one pound of leather, and, consequently, in tanning power is equivalent to five of oak bark, or thereabouts, as already stated.

Besides the inspissated juices just mentioned, there is another which, though not yet introduced into the European trade, has, nevertheless, been employed by the North-western Indians for tanning purposes. This is gum-butea, the account of which will be found at page 315, Vol. II.

GALLS.—There is no other natural product that affords so much tannin as those round, hard, woody excrescences known as galls. Formerly it was supposed that these were a kind of fruit; but naturalists and physiologists have ascertained that this is not the case, but that they are excrescences or tumors which form on the branches of different trees and vegetables, owing to the puncture of certain insects, for the purpose of depositing their eggs. The tree which affords those galls that are commonly known as *nut-galls*, is a stunted species of oak—*quercus infectoria*—which is very general throughout Asia Minor. It grows to the height of four or six feet, has a crooked stem, and yields an acorn two or three times larger than its cup. The gall-flies, which occasion the gall, belong to the genus *cynips*, and, from different accounts, there are several species; that which is concerned in producing the officinal galls, is the *cynips gallæ tinctoriæ*. The female insect of this variety, by means of an appropriate apparatus, per-

forates the cortical part of the plant, and in the wound deposits her eggs, together with an acrid liquor. In two or three days the part is, as it were, inflamed, and a swelling appears, and continues to increase till it results in a gall. The eggs which are inclosed in this excrescence are hatched, and in due time the young larvæ appear, and develop themselves, being supported by the juices of the plant till they become a perfect insect, when they perforate the gall and escape. When this happens, the excrescence loses much of its astringent principle, and becomes lighter; but if gathered or harvested before the entombed insect is completely developed, the nuts are not only heavier, but are richer in tannin, and command a better price in the market. Galls gathered before the escape of the insect, have a black or bluish shade, but when the insect has left, their color is paler, and they generally attain to a larger size. To prevent this occurrence, great care is taken to harvest the galls before the insect attains its full growth, and eats its way through, leaving them, however, on the trees till they have acquired their greatest weight. In some parts the governor, or *aga* of the district, levies a tax on the produce; and being thus interested in the success of the crop, he causes the cultivators to traverse frequently the hills and mountains

to report upon the advanced state of the galls, and wherever the proper growth has been attained, they are immediately collected. The selections thus made are known in the market as *green-galls*, and come to these countries from Aleppo, Smyrna, and the interior of Asia Minor. Those which escape harvesting before the entombed insect has attained its full growth or emerged, are known as *white-galls*, and are imported from the same place. Another kind of gall, produced upon the oaks growing in many departments in France, are nearly equal in size to the Asiatic green-galls, but they are rounder, and possess a smooth and in some instances a polished surface. They have a brownish color, and rank in their content of tannin intermediate between the green and white Aleppo galls. A variety originating from the puncture of an insect allied to the *aphis* on the branches and shoots of the *distylium racemosum* comes from Japan. They are of an irregular shape, having in some instances both ends small, whilst the middle is much thicker, but more generally the stem end is the least and the more swollen part is near the other. Hence they are called commercially apple-galls.

Annexed are the analyses of samples of Aleppo and Chinese galls by two distinguished authorities:—

	Aleppo galls.		Chinese galls.	
	By Guibourt.	By Davy.	By Bley.	
Tannin,.....	65.0	26.0	69.00	
Gallic acid,.....	2.0	6.2	4.00	
Ellagic acid,.....	2.0	—		
Brown extractive,.....	2.5	—		Fat
Starch,.....	2.0	—		albumen
Gum,.....	2.5	2.4		and resin.
Sugar,.....	1.3	—		Cellular
Chlorophyl and volatile oil,.....	0.7	—		matter.
Woody fibre,.....	10.5	65.4	—	
Water,.....	11.5	—	8.00	
	100.0	100.0	100.00	

LEAVES.—Of the foliage of trees containing tannin, very few, if any, are now employed in the manufacture of leather. The leaves of the heath were once extensively used in this country; but this material has long been abandoned, preference being given to oak barks and other substances of native and foreign growth.

The leaves of the sloe-tree—*prunus spinosa*—were likewise used to some extent in London for tanning calf skins, by employing a decoction prepared by boiling the leaves in barley water. So also it is stated in the *Bibliothèque Physico Economique* for 1789, that garden artichoke was resorted to for preparing calf and goatskins for bookbinders' use, and that the operation was as successful as if nut-galls or willow bark had been the tanning agent.

The various species of tea yield variable but large quantities of tannin, amounting from thirteen per cent., according to MULDER—to thirty-five and even forty per cent., according to FRANCK. The value of this article, however, as a luxury and dietary, precludes its employment in the production of leather.

Sumac.—In its purity it consists of the powdered leaves of a shrub that grows extensively in the south of Europe, in the United States, and in Asia to which it is indigenous. It seems that there are several species

such as the *rhus cotinus*—wild olive—*rhus glabrum* or *coriaria*, which is the best and most esteemed for the preparation of the finer kinds of leather. Italy, Sicily, Portugal, Spain, and France produce considerable quantities of sumac, varying in quality, and distinguished from one another by the habits of the tree, the color, and other properties. The sumac obtained from the *rhus cotinus* is for the most part employed in dyeing, and the product of the *rhus coriaria* is that which is converted to the uses of the tanner, especially in the preparation of morocco and similar leather. The latter shrub which grows wild in Portugal, Spain, and other countries named above, rises to the height of four to eight, and in some cases to twelve feet; its stem is crooked and covered with a reddish-grey bark; the leaves present a green on the upper and a whitish color on the under surface during spring and summer, but they assume a reddish hue in autumn. It flowers in July, the blossom being greenish-red, and yields a cluster of small crimson berries on ripening. Regarding the effect of sumac as a tanning agent, it is stated that it deprives the skin of much of its softness and elasticity, but it offers one great advantage of not coloring it during the process, and is on this account preferred in France and other places, notwithstanding its cost being

much greater than other tanning agents, by the fabricators of morocco and glazed leather. It is utilized in the ordinary way of tanning mixed with bark or other matter, and affords good results.

Of the species of sumac in the market, the Sicilian is accounted the best. There are two kinds, one of which, the Alcamo, is the most esteemed. It is a very fine light-green powder, containing very little woody matter, having an agreeable odor analogous to that of the violet, and a strong astringent taste; it contains very little coloring matter, though it gives a yellowish green solution when macerated with water. The second variety inclines to a reddish yellow, has a feebler odor, with a less astringent taste than the foregoing variety. On this account it is not much employed in tanning, though extensively used in dyeing; see vol. i. pp. 579, 629. Sicilian sumac is generally packed in bales weighing about one hundred and a half.

Spanish sumac is various in quality, being less carefully prepared, and, consequently, more or less mixed with woody matter. The best sort comes from Priego, and is grown in the neighborhood of Malaga. It is, like the Sicilian, finely ground, and affords a color of equal or greater brightness; its odor reminds one of the tea plant. With water it gives a dark and more reddish solution than the foregoing. It is usually packed in bales of one hundredweight. The other sorts, the Molina and Valladolid sumac, are next in quality to the foregoing; they are very similar.

Portuguese or Porto sumac is almost similar to the Priego, but is generally dirtier, and contains more mineral salts.

Italian sumac has a dark-green color, is free from woody matter, but feels granular in the hand, and has an odor like that of the bark, which possesses similar qualities as the leaves.

French sumac is similar to the preceding. Three sorts are collected, the Fauvis is almost equal to the Sicilian when well purified, and comes from Brignolles, near Marseilles. If less care be taken in its manufacture, it approaches more to the quality of Malaga sumac. It frequently goes under both these names. A second sort, Donzere, and a third, Pudis, are commonly used in the tanneries. A fourth variety, called *redou* or *redoul*, obtained from the *coriaria myrtifolia*, cultivated in Languedoc, is of a greyish-green color.

The operations involved in the preparation of sumac, consist in collecting the branches of the shrub whilst in full foliage, drying them in the sun, and then separating the leaves by threshing, or other means. Subsequently the detached leaves are ground under vertical mill-stones, and packed in bales for the market. In some cases, the peduncles and more tender branches are ground with the leaves; but as these contain a good deal of tanning material, they do not so much injure the quality.

FLOWERS AND FRUITS—Valonia.—Hitherto flowers and flower-tops, though containing tannin, have not been used in the preparation of leather on the large scale. The same might be said of fruits, with the exception of the acorn-cups of the *quercus agilops*—prickly-cupped oak,—a tree which grows in abun-

dance in the Morea and the adjacent countries. In commerce, they pass under the title *valonia*, and are imported from Turkey, Greece, Italy, and India. When the fruit is gathered, it is conveyed to the nearest port to be shipped; there it is stored in a warehouse during several months, being laid out in beds of three to five feet in thickness. A slight heating or fermentation sets in during the above period, and as the moisture escapes, the long spreading scales, which hitherto confined the acorn become contracted, and allow the latter to fall out of the cup. After being well dried the whole is picked, and the acorns which contain no tannin and the damaged cups are separated from those of the latter that are dry and good. The cup of this acorn, so long as kept dry, retains a bright drab color; but when exposed to moisture, it loses this appearance and turns black, losing by the change its tanning properties. Doubtless, to the long exposure of the upper cups to the disengaged vapor from the bed, is owing their being invariably more or less damaged. Ordinary or common *valonia*, the cups of which average about two inches diameter, differs from that kind known as *camata*, or *comatena valonia*, which are only about the size of a large cherry. The latter is said to be the fruit of a smaller species of *quercus* than that which affords the common *valonia*. It is in greater demand for silk-dyeing than for tanning.

Leather prepared with *valonia* is said to be harder and less permeable to water than that made with oak-bark; and, besides, it presents the advantage of readily depositing a rich bloom upon the leather, a characteristic much sought by the traders in this article. Not less than from ten to twelve thousand tons of this tanning agent are annually imported into Great Britain and Ireland, and it is stated that two pounds of good average quality are sufficient for making one pound of leather. The duty, which up to 1842 was twenty shillings per ton, was then reduced to five shillings, and entirely removed in 1845. Its price varies from ten to twenty pounds per ton, according to the stock and seasons.

Myrobalans, the dried fruit of various species of *terminalia*, is extensively employed in tanning and dyeing factories. There are several kinds, all of which come, however, from the East Indies, by Calcutta and other ports. This sort of fruit when ripe is pear-shaped, deeply wrinkled, of brownish-yellow hue, and weighing from seventy to one hundred grains. The whole of the astringent matter which it yields is contained in the husk, which is easily separated from the inclosed nut by bruising the whole; besides the tannin, a yellow coloring matter with mucilage and other principles is extracted. The tannin from this source differs but slightly, according to STENHOUSE, from that found in nut-galls.

Divi-divi is an article which has acquired, within a comparatively modern date, an interest with tanners and commercial men. It may be classed with the foregoing, since it consists of the dried pods of a leguminous shrub—*caesalpina coriaria*—which is indigenous to South America, and grows to the height of twenty and even thirty feet. The pods are about three inches

long, of a dark brown color, and curled up as if they had been submitted to a high temperature during desiccation. The whole of the tannin is concentrated in the rind of the pod, immediately beneath the epidermis, and has consequently a very astringent taste, but the inner portion that incloses the seed is very insipid. Besides tannin, it yields coloring matter, and a mucilaginous substance which interferes with its application in dyeing and printing. The leather prepared with divi-divi is very porous, and tinged brown or brownish-red, according to the density of the ooze, time allowed, and state of exposure to the air. Its formation is attributed to a fermentative change induced by some of the extracted matters; this change occurs as well in cold as in warm weather, but more frequently in the latter. During the reaction, a reddish matter deposits upon the leather in course of preparation, and on the sides of the pit. By preventing oxidation of some of the principles present, through the exclusion of atmospheric air, none of the forementioned substance appears, and the leather retains the natural color. A solution, or extract of divi-divi, readily affords a deposit of bloom to leather. STENHOUSE has shown that the tanning matter of divi-divi, though similar to that contained in galls, inasmuch as it exerts a like reaction on solutions of sesquisalts of iron, is, nevertheless, different from the latter, since it produces no pyrogallie acid when submitted to dry distillation.

WOOD.—This material has not been converted to any useful end so far as it immediately concerns tanning, notwithstanding, that tannin, as before stated, exists to some extent in many species.

ROOTS.—Several substances of this nature may be advantageously applied in tanning. The root of the common avens, *geum urbanum*, contains, as shown by TROMSDORFF's analysis, forty-one per cent of tannin. This plant is perennial, and is indigenous to Europe; it grows wild generally in damp and shady places. The root is about a quarter of an inch in thickness, has long descending fibres, and appears in alternated layers of red and white, the former predominating. It should be gathered in spring, and dried cautiously at an incipient heat. It has a slightly bitter and astringent taste, and, in the dry state, an odor not unlike cloves.

Ratany root is another substance very rich in tannin. MORFIT describes this shrub—*krameria triandria*—as being indigenous to Peru, growing in mountainous districts, and flowering at all seasons. As found in commerce, it is in pieces of irregular shape and size, some not thicker than a pipe-stem, and others an inch in diameter, and two or three feet long. Occasionally, several of the stems issue from one head. The bark is of a dark yellow or brown color, readily separable from the wood, and has an astringent, nauseous, and slightly bitter taste. The woody part has less taste, and a color approaching to red. Water at 212° dissolves the valuable principles, and the decoction, which has a deep-brown color, is abundantly precipitated by the mineral acids. The alkalies only change its color to that of urine. Sulphate of iron produces a black, and acids a fawn-colored precipitate. Gelatin proves the presence of tannin. The following

analyses by GMELIN and PESCHIER indicate the composition centesimally:—

	Ratany root.	
	Gmelin.	Peschier.
Tannin,	38.3	42.6
Gallic acid,	—	0.3
Sweet matter,	6.7	—
Nitrogenous matter,	2.5	—
Mucilage,	8.3	—
Lignin,	43.3	—
Krameric acid,	—	0.4
Gum—extractive and coloring matter,	—	56.0
Loss, .....	.9	—
	100.0	100.0

TOURNAL has drawn attention to a perennial plant growing wild in the south of France, the dentillaria or leadwort—*plumbago Europæa*—on account of its contents of tannin. The same chemist has made reference to the *statice* or marsh rosemary, and suggested its being employed as a substitute for oak bark. The Kalmucs, it is stated, use a decoction of this plant and sour milk, for tanning the skins of sheep and goats so as to be available for clothing.

BARKS.—This species of tanning material is by far more generally preferred in tanneries than any other, and that which ranks of highest importance for the purpose is oak bark. There are several kinds of this substance, varying more or less in their amount of tannic acid; these, however, come under two classes—the evergreen and deciduous oak barks. Like most of those substances already described, the virtues of the oak and other barks are not disseminated equally in the several parts; indeed, in the rind of the common oak of these countries, there are portions in which no tanning or other valuable secretion is found. In examining the exterior covering of trees generally, a very great analogy will be observed between it and the skin of animals. For instance, the *epidermis* or outer thin, dry, and occasionally transparent layer of matter, has its analogue in that of the skin; and, like the latter, it is thrown off as the tree grows old and increases in size, owing to the formation of internal layers of other matter, which cause the epidermis to fracture and ultimately to fall off. The matter beneath the epidermis is a layer of cellular substance, which partakes more or less of the vitality of the tree. It is generally the seat of the green color, and, like the *rete mucosum* of animals, is being constantly dried up into the epidermis exteriorly, whilst the secretion of herbaceous matter from the interior maintains it in the normal state. Beneath this is found the *cortical* tissue, of which, as the tree grows older, the woody matter is formed. In it are found all the valuable secretions of the tree, such as gum, sugar, resin, oil, and the other matters which are so generally applied in medicine and the arts. It is constituted of a number of elongated cells, divided into layers by a variety of longitudinal woody fibres. This is more particularly the case with the inner portion of this layer, and which is called the *liber* from its organized appearance. It immediately overlays the real ligneous matter, or wood of the tree. In its general construction it resembles in a measure the last-mentioned, only that there are more longitudinal

fibres, forming as it were leaves or laminæ, being reticulated and bound together by cellular substance. These layers may be separated by macerating the *liber* in water, which removes the cellulose, so that they appear like the pages of a book, and hence the term *liber* applied to it. It is this portion that is annually converted into wood, and which gives to the transverse section of the heart of the tree the annular appearance it presents, and which is generally termed the *grain*. Each of these rings represents a year's growth of woody fibre.

As regards tannin, the parts of the *cortex*, or true bark, in which it is mostly contained, are the exterior layers of the portion known as the *liber*, and the interior of the cortical tissue—the inside portions of the former, and the most exterior of the latter, yielding very little of this principle. The same observation is true of other matters, such as quinine and the like. The various dyes are seated frequently in the exterior portion of the cortical tissue. The sap always ascends through the cellulose of the real bark; and as this fluid is the source from which tannin is secreted, it is evident that there will be more of it in the bark, when the flow is greater than at other periods. Experiments have proved this to be the case as regards oak, and the same observation applies to the barks of other trees, such as the willow, elm, pine, birch, beech, *et cetera*, with equal force.

It may be well to state here, as briefly as possible, the nature and peculiarities of the more important barks referred to at page 500, with the view of showing their adaptability for tanning. In this digest, considerable information has been obtained from Professor MORFIT'S very copious work on tanning and currying leather. The bark of the cinnamon-tree, though yielding tannin, has not yet been employed for the manufacture of leather. Larch and birch barks are resorted to in a very limited way, being in Great Britain and Ireland applied only for tanning bazils and other sheep-skin leather. In the larch-tree bark the tannin amounts to two per cent.; but in that of birch, DAVY found 6.75-parts centesimally. Birch bark is very much employed in Russia for making the fancy red-colored leather, known in that country as *jucten*, and other kinds, and the peculiar resisting powers, as well as its odor, are attributed to the assimilation of the oil which this bark contains. The American variety of the chestnut-tree bark yields four per cent. of tanning material, and the leather prepared from it is said to be more flexible than that made with oak bark. The bark of the Spanish chestnut contains, according to DAVY, four per cent. of tannin. In the United States, the bark of the hemlock spruce, a species of fir—*abies canadensis*—is much used for tanning as a substitute for oak bark. MORFIT states that this tree, which grows to the height of seventy to eighty feet, constitutes three-fourths of the evergreen woods in Nova Scotia, New Brunswick, Maine, Vermont, and part of New Hampshire; it is less common further South, though found in the middle and Southern states on the Alleghanies. The bark of this tree is grey when young, but grows lighter when old, and is generally covered with moss. In June the barking is effected, and before

being ground half of the epidermis is shaved off. Leather made with this bark is reddish, and is judged inferior to that yielded by oak bark; however, the two barks worked together are supposed to afford a better product than oak tan produces by itself. DAVY found in the bark of the beech about three per cent. of tannin. Some varieties are employed by the tanner when oak bark happens to be scarce, but the leather from it is white and inferior. The same chemist obtained from the bark of the Lombardy poplar, 3.12 per cent.; from ash bark, 3.32; from elm bark, 2.7; from the white or European willow, 2.295; and from the Leicester willow, 6.86 per cent. of tanning principle. Lombardy poplar bark makes a light-brown colored leather, which acquires during the tanning a fragrant odor, somewhat resembling that which is given by birch bark. Elm bark is not much used in these countries for making leather, but it is utilized in this way in Norway, and the remarkable beauty of the glove leather of that country is attributed to the mode of tanning, which is done with elm bark. Willow bark also is restricted to the tanners of Northern Europe, although it is worked up occasionally with oak bark in British and other tan-yards. The Danish and Schoonian leather, much in request for the manufacture of gloves, owing to its peculiar and agreeable smell, is prepared with the bark of the white willow; in Russia, the tanner uses this material occasionally, but impregnates the leather subsequently with the empyreumatic oil of birch bark. The barks of all the cinchona species afford considerable quantities of tannin; still these are more valuable in pharmacy, owing to the alkaloids they yield, and, therefore, they are not resorted to for leather-making. Several other trees afford tannin, when their barks are submitted to the usual process, but they are rarely turned to any account.

Oak Bark.—The bark of the oak, has been for a long period extensively employed in tanning skins, and if other materials have been used, it still happens that, in Great Britain and Ireland at least, these have not been resorted to by preference, but rather from the scarcity of the staple article, oak bark, which seems to part with the tannin under those circumstances which best avail for its combination with the tissue of the skin, and thus for converting the latter into an article of prime quality. There are several varieties of oak, known as well in Europe as in America, all of which secrete tannin in their bark; but those which are valuable to the tanner are the different varieties of *quercus robur*, *quercus coccifera*, and sometimes the *quercus suber*, indigenous to Europe; and the *quercus falcata*, *quercus rubra*, *quercus tinctoria*, and *quercus prinus monticola*, indigenous to the American soil. The bark of the *quercus robur*—which term is applied to designate a group of closely allied species or varieties, and of which the *quercus pedunculata*, and *quercus sessiliflora*, form the two principal—is generally preferred by the tanner, with the exception of Norway and the North of Russia and some districts in France. In Norway, as already remarked, the birch and willow are resorted to, and in Russia and France the bark of other species of oak, the *quercus glomerata*, and *quercus coccifera*, are occasionally substituted. The latter variety,

known also as the kermes oak, is a tortuous branching shrub inhabiting the South of France, Portugal, and Spain. It grows to the height of three to four feet in close clumps, the roots interlacing one another, so that the soil, which might otherwise be washed away by the heavy rains, is retained. The bark of the root of this shrub, which is sometimes called coppice oak, is of a yellowish brown hue, and very rich in tannin. It is much in quest in France for tanning sole leather of a superior quality.

Barking of Trees.—In the foregoing pages are given the varied natural products which have been more or less employed, or offer advantages for tanning. The bark of the oak is, however, the most extensively consumed, and, therefore, much care is paid to its collection and harvesting. For a long time it was supposed that the rind of old oaks was more valuable for tanning than the product from younger wood; but experience is rectifying, or has done so, this mistake, for tanners have by a long course of working ascertained with certainty, what, through the labors of Sir HUMPHREY DAVY and others, has long been on record, that the bark of young trees is richer in tanning principle, than that of old ones; and, not only does the bark of the former offer this advantage, but the leather prepared with it is softer and whiter than what old bark produces, owing to the amount of coloring and extractive matter which they yield. Doubtless, the best age at which the trees should be barked, is from eighteen to twenty-five, or thirty years; but owing to the importance of the timber for building and other purposes, rarely are trees of this age felled in England or European countries. In France, however, they harvest the bark of oak of this age, but the wood is not turned to further use, excepting for the manufacture of charcoal, owing to the variety being unadapted for the builder. In France, too, the advantage may be gained of collecting the bark in spring, at a time when the sap is in full flow, and when there is most tannin contained in it; but in other countries, where the bark of the tree constitutes only an inferior secondary product compared with the wood, this season is not chosen, in consequence of the timber being cut when the sap is in active circulation and thus liable to decay. In England, Holland, and America, the period for stripping the bark is about June; but it varies according to the mildness of the winter and the spring. The operation of barking, is performed by cutting two circular bands round the trunk, at a distance of two, three, or more feet, then a longitudinal strip from one band to the other, loosening the bark at the upper, and stripping it off in bands towards the lower end. When stripped, the pieces are spread out to dry in beds, a shady site being preferred, care being taken to turn them occasionally, so as to prevent the beds heating. If the harvesting of the bark is not strictly attended to, considerable injury is sustained, not only in the loss of tannin, but more so in the kind of leather it affords in the pits. For the most part, or indeed in all cases, the bark should rest on hurdles elevated more or less from the ground in an inclined state, and the fragments ought never to be heaped together more than from twelve to eighteen inches in thickness. Provision ought to be made to protect the bark from the rain, and the whole

should be turned at least once a week till quite dry. After this it is usually stacked in larger rectangular heaps, and protected by thatch, if not by a roof, from rain or wet.

Quality of Barks.—It is important, that in regard to this article of so much value to the tanner, he should have some means of ascertaining its quality. By physical characters, the man of practice and experience will often form a good opinion in this respect, so as to decide between a good and bad quality of the same kind of bark; but this will not enable him to tell what amount of tannin it contains. Thus, if the bark has a whitish color exteriorly, and a reddish interiorly, and combines with these a dry, fragile, and clean fracture, and an astringent taste, the bark has been well harvested, and other properties being taken for granted, it is of good quality. So also when the epidermis and liber are thick, dry, and ligneous, with large crevices and a blackish aspect, it is deemed of an inferior quality, for the former characteristics indicate age, and the latter, that it has undergone a heating or fermenting change. There are other indications also from which persons acquainted with tanning materials form a judgment as to its goodness; it happens, however, that there are exceptions, so that an article presenting one or more of these appearances, may be of a first-rate quality, and make a good leather; but, under any circumstance, they will not lead the purchaser to the knowledge of the per centage of real tannin they yield. To attain to this end, a determination of the tannin must be made by chemical means, and even then the results are often only approximative.

Estimation of Tannin in Barks, et cetera.—Several methods have been devised for estimating the amount of tannin in barks and other products which are used in tanning, most of which are founded on the behavior of tannic acid with gelatin, and similar bodies; but mention will be made here only of those of DAVY, STEPHENS, and latterly, WARINGTON. The process of DAVY consists in treating three hundred and sixty grains of the powdered bark with a pint of boiling water, the vessel being frequently agitated during the digestion, which ought to last twenty-four hours. After filtering off the extract, it should be mixed with an equal volume of solution of jelly or isinglass, prepared by dissolving sixty grains of either of those substances in a pint of hot water. The precipitate of tanno-gelatin is then collected on a tared filter, exsiccated and weighed, and four-tenths of the entire taken as the proportion of tannin contained in it. Modern research has shown, however, that it is almost impossible to separate the precipitate by filtration from the liquid, so that at best this method is tedious; but it is inaccurate, inasmuch as the first portions which fall contain about fifty per cent. of tannin, which diminishes towards the end of the saturation. Sulphate of quinine, acidulated with a few drops of sulphuric acid, may be employed for precipitating the tannin from its solutions completely, and the deposit, unlike the gelatin compound, is constant in its composition. The tanner, however, in his yard, bases his operations on the indications of what is called the *barkometer*—an instrument like a hydrometer—and

according to the extent to which it sinks in the extract, so is the strength of the *ooze*, or tan-liquor estimated.

STEPHENS, to avoid the error to which DAVY's method is liable, proposed to estimate the tan by combining it directly with the cortical tissue, as in tanning, and determine the amount of the acquired weight. For this purpose, strips of the best ox hides, shaved as thinly as possible, are washed in water, thoroughly dried and weighed, then soaked in water a second time till they become soft and porous, and immersed in the extract of the sample of tan under examination, at a temperature of 90°. In the course of eight or ten hours, the whole of the tannin will have combined with the skin, so that after this period, by abstracting the strips, drying and weighing, noting the increase as the amount of tannin in the sample operated upon, the per centage in the bark may be calculated. This mode is likewise tedious, and fails to give satisfactory results.

WARINGTON proposes to estimate the tannin, not only in barks, but in all other astringent substances volumetrically, by determining what volume of a standard solution of gelatin is required to precipitate the tannin from the extract prepared from the sample submitted to examination. In preparing the test solution, the above chemist recommends the long staple

isinglass, as that is the most constant in its quality, and the least liable to undergo change. The solution is made of such a density, that a degree on the burette will represent one-tenth or one-fourth of a grain of tannin. Besides the preparation of the test liquor, the only other novelty in the operation, is the method employed for filtering off portions of the menstruum in order to determine whether the whole of the tannin be precipitated. As the passing of the liquor through bibulous paper, would not afford a clear filtrate, a piece of glass tubing, a foot in length, and half an inch in internal diameter, was selected; into the lower extremity a piece of wet sponge was introduced, and when it was desired to abstract a portion of clear liquid from the assay, in order to test if further precipitation took place, the sponge end of the tube was submerged, and the fluid filtered by ascending through the sponge. Part of the clear menstruum thus obtained, was transferred to a test tube, and a drop of the test solution added, till the point of saturation had been accurately arrived at. By this method, which is as applicable to the substances rich in tannin as to bark, accuracy and expedition are secured.

The annexed table, from MORFIT, indicates the per centage of tannic acid contained in the various substances specified:—

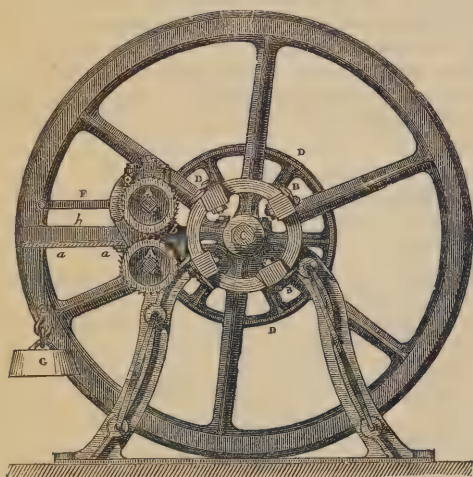
TABLE OF THE AVERAGE QUANTITY OF TANNIN IN DIFFERENT SUBSTANCES.

Substance.	Per centage of tannin	Authority.
Catechu—Bombay,.....	55.0	Davy.
“ —Bengal,.....	44.0	“
Ratany root,.....	42.6	Peschier.
“	38.3	C. G. Gmelin.
Kino—tannin and extractive,.....	75.0	Vauquelin.
Butea gum,.....	73.2	E. Solly.
Nut-galls—Aleppo,.....	65.0	Guibort.
“ —Chinese,.....	69.0	Bley.
“ —Istrian,.....	24.0	Roder.
Old oak—white inner bark,.....	21.0	Cadet de Gassincourt.
“	14.2	Davy.
Young oak—“	15.2	“
“ —colored or middle bark,.....	4.0	“
“ —entire bark,.....	6.0	Davy and Geiger.
“ —spring-cut bark,.....	22.0	“
Oak kermes—bark of the root,.....	8.9	“
Terra japonica, or gambir,.....	40.0	Esenbeck.
Avens root— <i>geum urbanum</i> ,.....	41.0	Tromsdorff.
Squill—bulb,.....	24.0	Vogel.
Statice of South Carolina,.....	12.4	Parrish.
Birch bark,.....	1.6	Davy.
“	1.4	Biggers.
Beech bark,.....	2.0	Davy.
Larch bark,.....	1.6	“
Hazel bark,.....	3.0	“
Chestnut, American rose,.....	8.0	Cadet de Gassincourt.
“ Carolina,.....	6.0	“
“ French,.....	4.0	Julia de Fontenelle.
“ Spanish—white inner bark,.....	1.3	Davy.
“ —colored, or middle bark,.....	0.3	“
“ —entire bark,.....	0.5	“
“ horse,.....	2.0	Julia de Fontenelle.
Lombardy poplar,.....	3.5	“
Blackthorn,.....	3.3	Davy.
Ash bark,.....	3.3	“
Sassafras—bark of the root,.....	58.0	Reinsch.
Elm bark,.....	2.9	Davy.
Sumac, Sicily,.....	16.2	“
“ Malaga,.....	16.4	“
“	10.4	Franck.
“ Carolina,.....	5.	Cadet de Gassincourt.
“ Virginia,.....	10.0	“
Willow, Leicester—white inner bark,.....	16.0	Davy.
“ —colored, or middle bark,.....	3.0	“
“ —entire bark,.....	6.8	“
“ —bark of the trunk,.....	1.4	Biggers.

Substance.	Per centage of tannin.	Authority.
Willow, weeping,	16.0	Cadet de Gassincourt.
Sycamore bark,	16.0	" "
" "	1.4	Biggers.
Elder,	2.3	Davy.
Plum-tree,	1.6	Biggers.
Cherry-tree,	24.0	Cadet de Gassincourt.
" Cornish,	19.0	" "
Tormentil root,	46.0	" "
Cornus sanguinea of Canada,	44.0	" "
Alder bark,	36.0	" "
Apricot,	32.0	" "
Pomegranate,	32.0	" "
Bohemian olive,	14.0	" "
Tan shrub with myrtle leaves, bark of,	13.0	" "
Service-tree bare—June berry,	18.0	" "
Cloves,	15.0	Davy.
Winter's bark,	9.0	Henry.

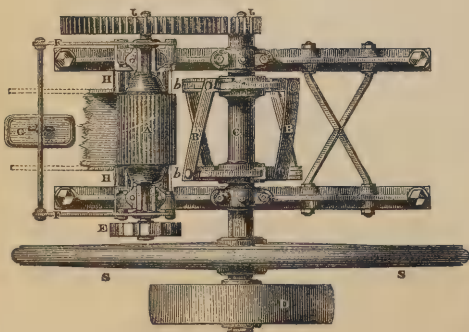
To render any of the foregoing materials suitable for the present operations of the tanner, it is necessary to bring them into a minute state of division, in order that by the treatment to which they are subjected, they may the more quickly yield up their tannin.

Fig. 342.



With the exception of the inspissated juices, this condition is gained by grinding or cutting machines which reduce the roots, branches, or barks, to a fine powder.

Fig. 343.

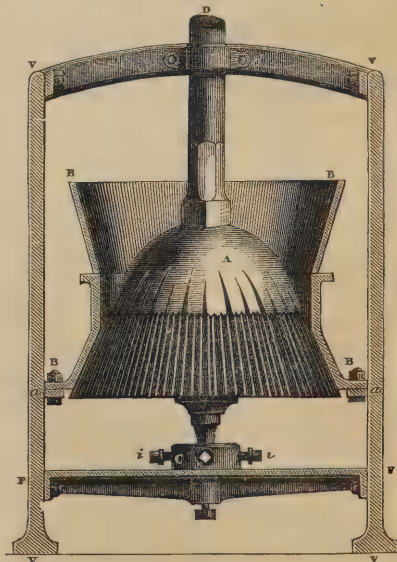


Numerous kinds of mechanical adaptations have been introduced into this department, varying in simplicity from the old head-stone rollers, to very intricate ar-

rangements. It would require too much space to give even a curt description of these; suffice it then that the principles on which they are constructed may be inferred from the machines described here :—

FARCOT'S bark-cutting machine, extensively used in France, is shown in elevated section and plan in Figs. 342 and 343, in which AA' are two fluted cylinders, which supply the bark previously spread upon the table, *a*, having a raised ledge, *h*, to the cutting apparatus. This is composed of two parallel circles, fixed upon a common axis, *c*, having steel plates or knives, *BB*, screwed upon them, and which are disposed in the form of a helice or spiral. On one end of the axis, *c*, is the fly-wheel, *s*, and drum, *D*, which receives the movement or power by a strap that connects it with the main shaft of the engine; the other end has a pinion, *i*, which gears into a toothed wheel, *J*, on the axis of the

Fig. 344.



fluted cylinder, *A*, and by means of another smaller one acting upon *E*, on the axis of *A*, the motion is likewise transmitted to the latter. By the levers, *FF*, and a weight, *G*, the two cylinders, *AA'*, are regulated to any required proximity. Inside the fluted cylinders is a longitudinal piece of steel, *C*, which delivers the bark to the revolving knives, and at the

same time acts by its sharp edge as a shears towards the cutting knives. The cylinder which carries the cutting knives makes about one hundred and thirty revolutions per minute, as also the feeding cylinders; and the quantity of bark cut averages one thousand six hundred pounds per hour.

The chopped bark is then passed to a mill for reducing it still further, and which is shown in Fig. 344. This machine is on the principle of WELDON's bark-grinding mill, introduced so far back as 1797. In this figure, A is a conical drum of iron on the end of the shaft, D, which forms its axis, inclosed in the cast-iron hopper, B B, where the coarse bark is deposited. This hopper is firmly secured by screws to a flange, which runs all round the framework, *vv*, as shown at *aa*. In the top of the exterior is a cross beam secured by screws, and having a socket in the middle part through which the axis of the drum passes. The lower part of this shaft rests and turns upon a bed, C, upon the stage, T, and regulated so as to have the cone, A, in position, by the side and bottom screws, *a'a'* and *b*. The inner face of the hopper, B, which is in close contact with the revolving cone, is, like the latter, serrated or grooved, so that the bark passing down is more minutely sundered. Fig. 345 shows the position of the two cutting surfaces with respect to one another.

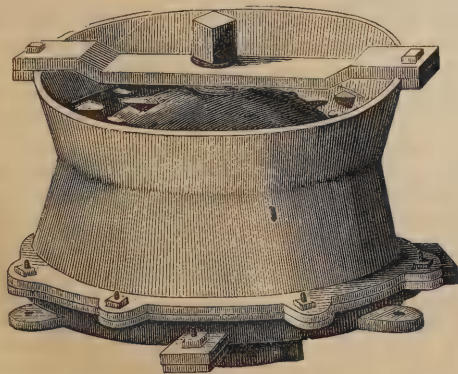
Fig. 345.



The central drum makes twenty-five revolutions per minute, and in the course of twenty-four hours grinds about eight thousand six hundred pounds of bark. The cutting machine already described is capable of supplying three grinding mills.

Another grinding mill, very much used in America, where it is known as WILTZE's or CATSKILL's, is shown in Fig. 346. This in principle is the same as WELDON's, only that instead of grooves an arrangement of sharp-edged teeth, both in the inclosed bell and hopper, is employed. As the bell turns by the power exercised upon the shaft, the teeth in the former,

Fig. 346.



revolving, also react on the principle of the shears with those in the interior of the case, and the bark is very finely and rapidly reduced. Before the matter is submitted to this machine, it is broken by passing it into another hopper adjacent to the former, in which there

is a sharp-toothed hoop or curb, and which divides the bark into pieces. It is moved at the rate of thirty to forty revolutions per minute, whilst the grinding machine may travel at the rate of one hundred and fifty. With this speed, communicated by a ten horsepower engine, it will grind from one to two cords per hour. The bark is cut short, without being reduced to flour, and thus it is more readily exhausted; there is also the additional advantage that, should the bark be moist, it does not become clogged like others.

THE SKINS OR HIDES.—The next object of attention in the preparation of leather, is the hides or skins of the animals. Three classes are specified in commerce; the term *hide* is applied to the skin of the larger and full-grown beasts; *kips* are the skins of the younger animals of the same class; and *skin* indicates the hides of the sheep, goat, kid, and the like. The term *kip* is qualified by the size of the skins. Generally speaking, the skins which are converted into leather, are those of oxen, cows, and calves, of the sheep, the goat and their young, of the horse, the pig, the dog, and a few others; but by far the most extensively worked, as well as the more important, are ox, cow, and horse hides, kips, calf, and seal skins. Considerable difference is observed in the thickness and quality of the skins of various animals, even of those of the same class, owing to circumstances connected with the food, age, variety of breed, the state of health, and even the period of the year when they are slaughtered. Thus, large oxen are well known to afford hides which are tanned into thicker and heavier leather than bulls or cows, especially if the latter be old, and have had several calves. Bull hides are coarser grained, and thinner in the back than those of oxen and heifers, or young cows, but much denser in the neck, and parts of the belly. It would also appear that when cows have repeatedly calved, the skin becomes distended and thinner, and does not, therefore, afford as heavy a sole leather as that of younger beasts. Again, hides of animals dying in a state of disease, are found to be much inferior to those of healthy ones of the same class, although the apparent difference is not very marked before tanning. No very definite *criteria* are known, to guide the purchaser in distinguishing the quality of hides and skins. If the hide be thin, flabby, soft, and will not bear handling, then such a one will not make good leather; but should it present the opposite qualities, it may be confidently expected to be a good article. It has been remarked of sheep, that the finer-wooled variety have inferior skins; also that the skin gains in thickness and quality, considerably, in the course of a few days after shearing.

Ox Hides.—Under this head may be enumerated the skins of *oxen, cows, buffaloes, and calves*. In Great Britain and Ireland, the market draws, in the first place, upon the home produce; these are usually vended in the *green* or fresh state. They are obtained from the extensive *abattoirs* generally found in large towns, and local butchers throughout the country. But besides these, considerable numbers are imported from other countries, especially from South America, the East and West Indies, and the Cape of Good Hope. The trade carried on between Great Britain and the South American

ports in hides, though averaging a million annually, is only a fraction of what sprung up of late years between that country and other European nations, such as France, Belgium, Austria, and Greece. The animals which roam along the Pampas and Llanos, or great plains, in herds of vast numbers, are, in addition to those owned by the extensive cattle owners or *hateros*, the stock whence this vast quantity is annually derived. They are imported in the dry state, and salted, and produce a very good sole leather. It should be remarked, however, that the hides from beasts inhabiting the extreme Southern latitudes, are not suited for tanning so well as those from the temperate and Northern parts of the globe. The *green* or fresh hides of the home market always rate higher than other sorts, owing, perhaps, to the fact that they do not require so much labor as the imported dry kinds; still, in consequence of the amount of water they contain, they prove to be much dearer than the others; for allowing that for the production of one hundred pounds of leather, seventy-five pounds of dry hide are requisite, the equivalent of this of salted hides, would average a hundred and fifty pounds, and a hundred and eighty-five of green or market hides. Heavy hides are converted into sole, belt, and harness leather, also for carriage coverings, and the smaller and lighter kinds are made into leather much used for *skirtings*, and for enamelling. That which is used for ladies' shoes, and for bridle-leather, undergoes a bleaching process, termed *fair finish*. Hides from the West coast of Africa, make good upper leather, but are much employed in their raw state for trunk covering.

Calves' skins and kips of home produce are of very superior quality, and produce a leather, when made with good oak bark, very extensively worked into uppers of shoes and boot fronts. In France, where the calf-skin leather has been reputed for its excellence, they are taken off the animals when five or six months old. Kips are imported from the East Indies, Buenos Ayres, and Monte Video; those from the former place are dried and salted, or merely exsiccated, and from the latter places, they come simply salted. The countries adjoining the Baltic, more especially St. Petersburg, send here a good many; but owing to the animals being slaughtered when young, they are, properly speaking, skins. Many of them, however, as well as some imported from other countries, belonged to small, but full-grown animals, and are, properly speaking, hides. The lesser and inferior kinds of kips and calf-skins are tanned for bookbinders' use, for gloves, and the manufacture of ladies' boots and shoes. Buffalo hides imported from the East Indies, are tanned like ox hides, but they make an inferior quality of sole leather. The American Indians prepare these into robes, the hair being retained on them. When tanned in a particular way with oil, they constitute what is termed *buff belt-leather*, which is superior to the similar article made of cow-hides.

Horse Hides.—The skins of these most useful animals are much inferior to those of oxen in thickness, texture, and strength, and, consequently, they are never prepared with the view of making *sole* leather, though the better quality is used when tanned for uppers. The chief

consumption is, however, as cordovan, or enamelled leather, the hides being split by machinery to reduce them to the adapted thinness. Horse hides are likewise made into tawed, white, or alum leather, and are in this state used as aprons for certain classes of mechanics, and as thongs for the manufacture of the commoner kinds of whips, and for sewing common harness. A considerable number of horse hides is annually imported from South America, sometimes as many as one hundred and ninety or two hundred thousand. The imported hides are much superior to those which find their way to the home market, on account of the latter belonging generally to old and worn-out animals, while the former have been flayed from the captured wild horses of the pampas, lying between the chains of the Andes. Ass and mule hides, tanned and so prepared serve for the manufacture of scabbards; the leather is called *shagreen* or *shagri*.

Sheep Skins.—The home supply is very extensive; and although they are capable of making only a spongy weak leather, the uses to which they are devoted are various, and their manufacture gives employment to numerous hands. Tanned with bark they constitute bazils, and are used for making slippers, and as bellows-leather; but when prepared with alum and salt, or with oil, white leather, much employed for aprons and by druggists, chamois leather result. A good many are split, the upper or grain side being tanned with sumac and dyed, then worked up as *skiver*, *roan*, and *morocco*, into pocket-books, hat-linings, and the under portion being made into white leather, and used very much by the chemist; but it is much the more general practice to reserve lamb skins for the latter purpose. Sheep skins are sometimes tanned with the wool adhering to them, and made into mats. The principal seats for the dressing and dyeing of sheep skins in England, are Bermondsey, Leeds, and Manchester; from these places they are exported to various parts of Germany, South America, and the United States; but the exports to the latter country are only partially prepared and salted. A large number of the skins of a particular breed of sheep is imported into Great Britain, and a similar variety is brought into this country, and likewise into France, from Asia Minor. In the latter country a considerable trade rises from the preparation of lamb skins for ladies'-glove leather, for linings of morning gowns, for slippers, and for winter gloves. In the hides from Asia Minor the wool is kept for the purpose of retaining the warmth. Considerable difference may be observed in the quality of lamb skins; those from the animals killed shortly after being born are possessed of a very fine grain, and take a very uniform dye; the same qualities are, in a great measure, retained by the skins till a month old, but from this period they begin to deteriorate. In the Southern parts of France and in Italy great numbers of lambs are killed, averaging four weeks old, and the leather prepared and employed as a substitute for kid leather. Not less than one million four hundred thousand of these skins are annually imported to Great Britain for the use of the glover.

Goat Skins.—A very large trade is carried on in Great Britain and Ireland in goat skins, and the tanned

and prepared leather they yield. In the latter country a number of native skins is used, but the British market is supplied almost entirely by imported goods, more especially from Switzerland and the valley of the Rhine, from Magadore, the Cape, and the East Indies. Those from Switzerland—Swiss skins—are more esteemed, because they possess a close, fine, and equal grain, which enables the dyer to give them a brilliant and permanent hue; the leather is also stronger, and wears better than any other manufactured from goat skins. On an average about one hundred thousand are imported annually, and fabricated into morocco for the demands of the various branches of trade. Mogadore skins are made into a kind of black morocco leather, which still goes by the title of Spanish leather or cordovan, in consequence of the first supplies of this article being obtained from Spain and the Cordova, where the Moors originally brought the manufacture to great perfection. The sound skins which arrive from the Cape of Good Hope are much larger, and superior in strength and thickness, to any other variety. East India skins are small and light, and are generally converted into leather chiefly used for ladies' shoes and upholstery. Those from Mexico, known in the American market as *Tampico* skins, bear a very high character. Compared with sheep skins, those of goats are much superior in texture, strength, and durability. Goat skins are occasionally prepared so as to imitate chamois leather, and applied to most purposes to which the latter is adapted, and likewise with the hair on, and used for matting. Kid skins, manufactured into leather, are most extensively consumed by the glover, also for shoes, binding leather, and the like. Great numbers are produced in Ireland, the South of France, Switzerland, Italy, and other European countries. Those of France have the greatest repute; the Irish skins are likewise highly esteemed. After the animal begins to feed upon herbage, the skin invariably loses in delicacy of texture, and, therefore, becomes unsuited for the finest gloves.

Deer Skins.—A considerable number of these skins is manufactured into chamois leather, particularly in the United States, and also into glove leather. The preparation of this kind of leather in Great Britain and Ireland is very limited.

Hog or Pig Skins.—In Scotland, the swine are skinned; the skins are tanned, and constitute a very porous, light, but nevertheless very tough and durable leather. It is largely used by harness-makers and for saddle seats. The practice of skinning pigs is followed on the Continent, where the hide is dressed with the hair on, and used to cover portmanteaus, knapsacks, *et cetera*.

Seal Skins.—Of these a great quantity is imported yearly into Great Britain, and manufactured into upper and varnished leather. They are obtained from the animals captured along the shores of North America, from Newfoundland to the Arctic ocean, for their oil. A large portion of the supply comes from the coast of Norway. The skin of the seal is light, but of a close texture, and, when properly tanned, yields a leather which has greater strength, in proportion to its weight, than any other variety. Seal skin is usually made into

black enamelled leather for ladies' shoes, the stronger sorts being employed for the upper part of hunting and riding boots, and knapsacks. Many skins are merely dressed and converted into materials for caps and fur clothing.

Porpoise Skins.—The skins of the white porpoise have been tanned in Canada, and the leather is said to be soft, strong, and possessed of a beautiful finish.

Hippopotamus Hides.—About one hundred of these skins are annually imported from the South of Africa, and are tanned with oak. The hide, originally of great thickness, assumes the appearance of boards after being tanned. The only use which appears to be made of them, are implements used for beetling in washing and bleaching cotton and linen goods.

PREPARATION OF THE HIDES.—The tanner, previous to submitting the hides, skins, or kips, to the true tanning process, is under the necessity of subjecting them to one or more preliminary operations, with the view of removing dirt, particles of flesh, and in most cases the hair and epidermis; and the manner in which these are effected is of great importance, as much of the success of the subsequent process, and, consequently, of the quality of the leather, depends upon it.

Cleansing.—The hides which have been recently taken from the carcass of the animal require but very little labor to purify them from any filth which may remain attached to them, unless, indeed, as is said to be sometimes the case, they are wantonly saturated with such matters in order that they may weigh heavier. Sometimes, however, such *green* or *fresh* hides, as they are called, when they cannot be immediately disposed of to the tanner, or when the latter does not intend to submit them at once to the processes by which they may be made into leather, are salted to prevent putrefaction. When the hide has to remain for a period of a week, four or five pounds of coarse salt are used to preserve it; if a month, double this quantity is deemed requisite. Foreign hides—such as those from South America—receive more than the above quantity; in some instances as much as twenty pounds of salt per hide are used, according to their size and the season, but the average for foreign hides is about fifteen. All these matters must be separated by steeping and washing; and hence one of the absolute requirements of a tannery is a profusion of water. Green hides are steeped in water during a period of one to twelve hours, according to the quantity of blood and dirt they hold, at the end of which time they must be thoroughly rinsed before removal. In many cases much greater pains must be taken, such as repeated scrapings of the hide with a blunt tool on the beam or support, trappings in the water buckings, *et cetera*. If a current of water is available, much labor is spared by fastening the hides to a rack fixed in the face of the stream, for the friction of the water will detach the impurities without the aid of much mechanical labor. When dried hides, or such as are salted and dried, are treated, the difficulties are much greater, since a longer period and more time is required to soften and bring them into the condition of fresh ones. With these the soakings, trappings with the feet, handlings—that is, the removal from the water

or steep—and scrapings are multiplied before they attain the softness and purity of clean fresh ones. In large establishments the mechanical labor required is executed by a kind of mill, similar to that for fulling cloth, wherein the hides are exposed to the continued action of two heavy stocks, which squeeze out the slimy matter and dirt that might induce a putrefactive fermentation. The immersion and handling even in this case require to be alternated with the action of the machine; and it is necessary to remark that where vats or tanks are used, the water should be frequently renewed, otherwise, if the contents happen to get stale or overcharged with the slimy extract from the hides, and the time of submersion be prolonged, there is danger of putrefaction, and, therefore, of injury to the skins. Where only water is employed for the above purpose, it is necessary to keep in view the quality of this liquid, irrespective of the change which it undergoes by saturation with the nitrogenous matters, dirt, *et cetera*, from the hides. When very calcareous, its cleansing qualities are less effective than when the water is *soft*; but, independently of this, it is believed that *hard* water affects the hides in another way, by which their softness and porosity are injured, owing to the fatty and other matters which may be in an incipient state of decomposition, forming combinations with the earthy bases which fix themselves in the skin.

In many parts of France and Belgium, they employ a weak solution of lime to assist in cleansing and freshening the hides, with the view, at the same time, of rendering the succeeding operations of depilation and tanning more easy and efficacious.

Depilation.—After the thorough softening and cleansing of the hides, they are next submitted to a further immersion in baths or tanks with compounds which effect the solution of the cellular matter in which the hair is rooted, or are otherwise exposed to the action of agents which operate towards the same end. A variety of methods are practised by tanners for the solution or softening of the matter which binds the epidermis and hair to the true cutis, or that portion of the skin that enters into the formation of leather, with the view to their removal. The most important of these are the *liming* process, the *sweating* or *fermentative process*, the *rhusma* and gas lime processes; and latterly, in America, the *cold sweating* mode has been introduced with success.

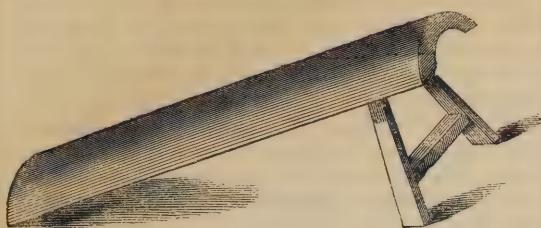
By Liming.—Of these processes the *liming* is by far the oldest, and is still very extensively adopted, but with greater caution than in former times. In its action it is not so quick as certain other agents, necessitates much future labor, and frequently is the cause of injury to the leather; still, probably from its cheapness and the effect of custom, it is more resorted to than any other. Generally speaking, it is now used in the form of a semi-liquid or milk, formed by agitating a certain quantity of it with a given body of water—about eight bushels to one hundred and fifty gallons. The liming is carried on in a series of pits or tanks, sunk in the floor of the liming house; these are built of bricks or masonry, and well cemented, and have an outlet at the bottom for the purpose of drawing off the fluid contents when necessary. Their dimensions

vary according to the requirements of the establishment, and the number of skins to be operated upon at once. In some parts, as in France and Belgium, well bound wooden tubs are preferred. The number of these varies from five to twelve, and the solution in them is so arranged, that there is a regular increasing gradation of density from the first to the last, even where the larger number is taken advantage of. The first of these, called usually the *dead vat*, contains very little caustic lime, and this is the one to which the hides after washing are exposed, in commencing the operation. Here they remain for one, two, or three days, according to circumstances, and during this period they receive a handling at regular intervals, some twice, and others three times a-day. This handling merely consists in taking the skins out of the pit or tub, and laying them on a plank or inclined board near the tank, and introducing them again. Before the re-introduction, the contents of the tank are well agitated, with a view to distribute any undissolved quick-lime through the liquid, so that there be no partial or undue effect exercised on the skins. The workmen likewise contrive to spread out the latter in the vat as much as possible, and so every part has the same exposure to the lime. In the dead vat, however, there is left very little if any quick-lime undissolved. After spending the allotted time in the first vat, they are transferred to the second, which contains a stronger liquid, or more lime, and left in this, with occasional overhauling, for a few days, after which they are put into the third, and so on till the hides ultimately arrive at the last vat, which contains the fresh lime. In operating in this rotation the dead vat of one batch of hides becomes the *live* one of the next, and so on in succession. The time which skins take for thorough liming, varies according to their weight and texture. Thus the lighter skins, as of the sheep, are sufficiently acted upon in three to five days, but ox hides, kips, and calf-skins, require two to three weeks, according to the season. Formerly the process of depilation extended over a period of three to fifteen months, and even eighteen, the hides being steeped in the weak lime vats a considerable part of this time, but such procedure is now entirely relinquished. In many parts of the Continent, however, the operations preparatory and conducive to the depilation last two and three months; but in these cases the skins are partly swelled, so that, for this special treatment, they do not require so much attention in the succeeding stages. The quantity of lime which is used by the different tanners is somewhat various, and dependent upon the size of the hides, but the average is from eighteen to twenty-four gallons of freshly-burned fat lime—three to four cubic feet measure—for a hundred hides of average size. The lime is permitted to slack in the strong or live vat, and afterwards stirred about with a wooden spatula, to distribute it equally in the liquid.

When the epidermis is sufficiently softened it is detached, together with the hair on the *beam*. This is an arched wooden or stone bench—Fig. 347—upon which the hide is laid, with the flesh side inwards, and the hair removed by the *scraping knife*, shown in Fig. 348. After the separation of the hair and epi-

dermis, the loose fragments of skin are pared off, as likewise the flesh and fatty matters adhering to the

Fig. 347.



reverse side—such fleshings being economized in the preparation of glue. The implement used for the latter purpose is a long, straight knife, having a sharp edge.

Fig. 348.



Fig. 349. After the last operation, it is necessary to submit the hides to thorough rinsing in the stream or vats, in order to remove all uncleanness, lime, et

Fig. 349.



cetera, as much as possible. It often happens that the hides present inequalities as to thickness and the like, and to reduce them to average homogeneity, they are treated with the smoothing or polishing stone, represented in Fig. 350. This tool is of sandstone, interiorly moulded, so as to lie parallel upon the beam, fixed to a piece of wood, and furnished with handles,

Fig. 350.



with which the hide is rubbed, to bring the part to an equal thickness as nearly as possible. This operation is not so much practised by English as by continental tanners. By repeated scrapings in this way with the knives and stone, alternated with steepings and washings, the dirt, hair, fleshy parts, and lime are removed as effectually as possible, previous to the true tanning operation. In the large English tanneries the scraping and fleshing of the hides are executed by mechanical contrivances, and so the manual labour is greatly diminished. Machines for this and other purposes have been constructed by several, among others by POOLE, PLANT, and WOODWORTH.

Bating.—With respect to the removal of lime from the skin, it has been found that no amount of scraping and rinsing is capable of making a perfect separation, a portion of the earth being retained in the pores of the skin, combined with, perhaps, some of the decomposing tissue, and with the grease and fat of the hide, as a lime soap. These combinations, if not altered and

removed, obstruct the union of the tannic acid with the gelatinous fibre of the skin, and not only this, but they communicate a rigidity to the leather which excludes it from such applications as require a soft, tough, and pliable material. Several plans are employed to remedy this defect. The old method is that which is known as the *bate*, or *grainer*, that is, a menstruum prepared by macerating the excrements of pigeons, pen-fowls, and of dogs, in water, and immersing the scraped and clean skins in it for a certain period, when, it is stated, the lime is separated by a chemical decomposition that takes place and renders it soluble. The proportions employed are from ten to twelve gallons of the fresh dung to one hundred, or less if they be large skins; and the time of steeping stretches over ten days in ordinary weather, but less time is required if the liquid be warmer. In this treatment, likewise, the repeated handling and scraping on the beam are resorted to. Investigation has shown that the above matters contain an ammoniacal chloride that parts with its chlorine on coming in contact with the lime, and so gives rise to a soluble combination of this base—chloride of calcium—that may be readily abstracted by water. That this disgusting method should still continue to be so extensively practised is disgraceful to modern science. It is stated, that in London alone not less than five thousand pounds are annually expended in collecting and purchasing the above materials, for the sole use of the tanners of the capital and its suburbs.

Although this method of *bating* the hides is tolerably effective, yet it is well known to be attended with serious disadvantages, not the least of which is the putrefaction of the *bate* that is going on during the steeping, and which injures the hides by acting upon the tissue of the skin, reducing its weight in the first instance, and in the second, rendering it incapable of yielding the quality of leather it would doubtless produce, did the above change not occur. Taking the hint from the action of the alkaline chloride in this case, some tanners have attempted to prevent the putrefaction induced by the bating with excrements by avoiding its use altogether, using hydrochloric acid in a diluted state as a substitute. The innovation has not yet become very general in England, although many tanners, especially in Paris, are reported to have practised it successfully, the object of the expulsion of the lime being satisfactorily gained by it, and in addition to this, the swelling of the hides also. Sulphuric acid has likewise been proposed as a substitute for the *bate*, but the effect of this is not so powerful as that of the acid already mentioned, since it constitutes with the lime a very insoluble compound. The acid is, however, almost always resorted to for *raising* or swelling the skins, preparatory to submitting them to the tan-pits. MACBRIDE in 1774 was the first who showed that it possessed this property. TURNBULL introduced the use of saccharine liquids for removing the last portions of lime from the hides, as well as for softening the hair and cuticle. Four or five pounds of coarse sugar or treacle dissolved in sixty to seventy gallons of water, constitute the bath. The sugar in this process forms a soluble saccharate of lime, which is removed by

soaking and rinsings. A new process, in connection with others, for the purpose of facilitating tanning and improving the leather, was patented in 1841 by WARINGTON. It consists in employing carbonate of ammonia instead of the usual bate for the graining of the skins; but although this salt converts the lime into a neutral compound, it does not remove it, and consequently, the flexibility and softness of the skin must suffer.

Depilation by Acids.—Besides these methods, by which the influence of the lime on the skin is counteracted, others are employed which dispense with it in the first instance. Acid liquors have long been known to operate upon the roots of the hair and epidermis, so as to detach them from the skin. The Calmuck-Tartars employed a bath of sour-milk for this purpose, and in Paris the same agent is adopted at the present time. Another menstruum, obtained by the fermentation of barley or rye meal, was once very extensively used as a steep for the hides for separating the hair. Here, together with the fermentation, the active body was acetic acid resulting from the latter. This, in common with other acids, such as sulphuric, hydrochloric, oxalic, *et cetera*, operate so as to soften the epidermis and hair, to an extent sufficient to enable the scraping process to cleanse the skin from them. Tanners urge, however, that by their use the skins are swelled to such an undue extent, as almost to render it impossible to prepare good compact leather from them. The weak vegetal acids, however, are not excluded from practice, more especially in France, Belgium, and parts of Germany. Many of the Paris tanners submit the hides, after they have been soaked in water, washed, and fleshed, to a number of acid vats, in a way analogous to the liming. Generally, the series of baths consists of five, which from the first to the last increase in power and efficacy; the first is usually intended to cleanse the hides, the second to soften the hair and epidermis for the depilation, and the other three to swell and give body to the skins. This operation, which is called the *white dressing*, requires a period of five weeks in the summer, and six in the winter season. The quantity of farinaceous matter which is taken varies at different establishments; in some cases one hundred and forty-five pounds of barley-meal, and in others, one hundred and fifty or sixty are employed. The dressing is generally made by leavening one-tenth or one-fifteenth of the bulk till it becomes sufficiently sour; it is then softened with hot water, and after the whole has become a thick homogeneous fluid, free from lumps, it is added to the remaining quantity of the meal in the vat, and tepid water in sufficient quantity poured in to fill the vessel. In some cases yeast is added to quicken the fermentation. Eight or nine hides are worked in each vat, and as in the lime process, the weak or first vat passes in succession from one to the other in rotation. The final vat is composed with sixty pounds of meal leavened and thinned with water, and left to develop acetic acid for fifteen days. In all of these operations the handling and working the hides on the beam at regular intervals are indispensable.

By Sweating.—The depilation is effected at the pre-

sent day by many English and continental tanners, more especially the latter, by what is known as the *sweating process*. Various means are adopted, but the principle common to all is the softening of the epidermis, by fermentation, or putrefaction. In Paris and other parts of France, one-half the hide is sprinkled with some chloride of sodium, and the other half lapped over it, with the view of arresting the effect of the putrefaction which succeeds from injuring the tissue of the skin. Several hides are then piled one upon another in a pit or other convenient place, and left till an incipient odor of ammonia is observed. This is a sign that putrefaction has commenced, and, therefore, that the hides are approaching to a state in which they readily part with the hair. As the fermentation thus excited would be very deleterious to the leather-making portion of the hide, too great caution cannot be exercised in order to arrest the action as soon as the hair is softened. With this view, the hides should be examined once or twice a day, refolded and piled again, till it is discovered that the hair will readily yield. The same result is attained, without the precaution of adding salt, in Germany and some parts of Great Britain, by simply piling the hides upon one another in a pit. The moisture and circulation of the air acting upon the nitrogenous matters—blood, sweat, and other impurities—readily augment the heat of the whole mass; and incipient putrefaction, recognizable by the evolution of ammonia, follows. It is necessary to examine the hides frequently, lest the action should prove injurious. In many instances they are piled between layers of stable dung in a heap, and the whole covered with the same material, till the hair becomes detached, care being taken, however, to examine the hides every twenty-four hours or less.

Steam and heated vapors have also been tried as agents for removing the hair from the skin. M. DELLUT was the first to suggest the use of steam, and his method was carried into effect in several French tanneries. The hides are suspended in an airtight chamber of suitable dimensions, and which is furnished with a perforated, false, or second flooring. Steam is introduced beneath the perforated flooring, and ascends among the hides, through the small orifices, so as to keep the interior of the chamber at 68° to 80°, but not beyond this; for, in the event of the temperature becoming elevated, the gelatinous matter of the skins would more or less enter into solution with the condensed steam on them, and consequently, would afford a less weighty leather. When due attention has been paid to the operation, the hair and epidermis becomes sufficiently softened in twenty-four hours to be removed with the hairing knife. Compared with the putrefactive sweating process, this method is a decided improvement, as the liability to injury is very much diminished.

By Cold Sweating.—In America, especially in New York, New Hampshire, and in many parts of the Northern division of Pennsylvania, a process is in general use, called the *cold sweating*, by which the hair can be removed, and a yield of leather estimated at seventy to eighty per cent. acquired; whilst, by other means employed, such as by steam and lime depilation, not more than thirty to forty per cent. of the dry hides are retained

as leather. Besides this very material gain, another advantage follows, namely, that the laborious cleansing and fulling required in the other modes, is unnecessary; and consequently, the hides retain their natural density, a condition which very much improves the quality of the leather. The operations by which this is effected, are thus stated in a foreign journal:—

First, a vault should be prepared for the reception of the hides; this, for convenience sake, should be twelve feet long, the same in depth, and ten feet wide. The walls may be of stone, brick, or a planked frame. There should be one alley or vestibule for entrance, not less than six feet long, having a door at each end, the outer being made double and filled in with tan, to prevent the communication of warm dry air from without. A ventiduct made of plank, ten or twelve inches square, should extend from the bottom of the vault to the distance of three or four rods, and should be fixed not less than three or four feet below the surface of the ground. This channel serves both as a drain for discharging the water of the vault, and for admitting cold damp air to supply the place of that which has become rarified, so that a current is thus kept up through the ventilator at the top of the vault. The ridge of the roof may be on a level with the ground, and on it, extending its whole length, are set up edgewise two planks two inches apart. The space between these is to be left open, but the remainder of the roof may be covered with earth to the depth of a yard. Such covering is intended to preserve a low temperature in the pit, so that the hides may unhair without tainting. Spring water should be conducted, either in pipes or logs, around the angles formed by the ceiling with the walls of the vault; and from these conduits the fluid should be allowed to flow in minute jets, so as to form a spray, or else to raise a mist or vapor, so as to saturate the atmosphere of the vault with watery vapor. This arrangement keeps the temperature of the vault much under that of spring water itself, which usually stands at 50°, owing to the heat rendered latent by the evaporation. Three bars furnished with iron hooks, at intervals of three inches, are laid longitudinally and equidistant near the ceiling, and upon them the hides are suspended. Before hanging up the hides, they are soaked as for breaking, and then suspended from the butts in a way that they remain fully open. In the course of a few days, when the hair begins to loosen on the upper parts, they are taken down, and the middle bar being raised, they are again suspended by the other end, and left so till the hair easily separates. The hides should not be broken till they are ready to unhair. In a good vault, where the heat is maintained between 44° and 56°, above which it should never be allowed to rise, and where there is a free circulation of damp air, the hides generally require from six to twelve days. If the temperature falls below 44°, the ventilator should be partially closed; but if it rises above 56°, cold damp air must be forced in, or a larger volume of spring water thrown into the pit.

MORFIT states, that the hides carried carefully through this process are, when received by the tanner from the beamsman's hands, free from all extraneous matter, and retain all their gelatin, albumen, and fibrin

in an unimpaired state; and that it is not a fermentative change that produces the unhairing, because there is no ammonia generated. The effect is owing to the softening action of the absorbed vapor upon the epidermis, in conjunction with a swelling or distention of the roots of the hair, and tissue of the skin immediately underlaying them. Should these advantages be found, upon trial, attendant upon this simple and quite feasible method, it would undoubtedly be for the interest of tanners to adopt it, as not only does it require less labor, but the requirements in the shape of pits and water are still less than for the systems practised on this side the Atlantic, leaving the consideration of the great gain in the amount of leather out of the question; and which, of course, is its most powerful recommendation.

By Rhysma.—WARINGTON recommends a solution of carbonate of soda for unhairing the hides, but the effect is not so rapid as when the alkali is in the caustic state. The same chemist, in attempting to depilate hides by the use of *rhysma*, the long-known mixture of caustic lime and orpiment, or tersulphide of arsenic, discovered that the active agent was sulphide of calcium, formed by the decomposition of the arsenical compound in the presence of that base, and that *the arsenic* was without effect in the operation. He therefore tried the action of sulphide of calcium *per se*, and found that it acted so promptly, that only from twenty-four to thirty-six hours were required to soften the epidermis, and loosen the hair.

RAISING OR SWELLING.—After the removal of the hair and epidermis, and the bating, in case of hides intended as upper or pliable leather, it is necessary, to submit the *pell*, as the depurated unhaird skin is commonly called, to a further operation, in order to distend its cellular organs, with the view of enabling it the more readily to combine with the tannin. In England, sulphuric acid, in the ratio of one part of acid to a thousand of water, is the agent usually employed for this purpose; but in some cases immersion for a limited period in the spent tan-liquor, wherein a certain quantity of gallic and other acids have been developed, is substituted, and even this treatment is abandoned by many, a weak tanning liquor being preferred. This is especially the case in France, where a prejudice exists against the use of sulphuric acid, founded on the opinion that it destroys many of the good qualities of the leather. When sulphuric acid is used, the swelling or raising is sufficiently executed by twenty-four hours' immersion in the bath. When kips and skins are under operation, the raising is done partly during the liming and partly by the *bating*, to which they are afterwards submitted. Allusion has already been made to the mode practised with excrements; but besides this, the same end—the removal of any residuary lime—is attained by the employment of barley meal, made into a sour liquor. For one hundred pounds of dry skin, fifty pounds of coarsely-ground barley meal, and five or six pounds of soured dough are taken, the whole being intimately distributed in the water. Lactic fermentation follows, and the acids generated form soluble salts with the lime in the skins, when the latter are immersed in the liquor, and the succeeding washing removes them. This bath is termed

the *white* bate, to distinguish it from the *red* bate, or the aqueous washings of old used bark or tan. With this reddish brown liquid a number of vats are filled, the solution in the first being diluted so as to give them a gradation of strength. Before submitting the washed and unhaired skins to the series, they are steeped for a few days in summer, but a longer time—four or five days—in winter, in clean water, which is renewed every day, whilst the skins are left to drain for two or three hours. After this they are submitted to the first and weakest vat of the red bate, and after spending some time in it, they are transferred to the next, and so on, till they come to the last. During these operations the practice is to handle the skins morning and evening, leaving them to drain about three hours, whilst they are passing through the weak baths; but once a-day when they arrive at the stronger ones. Sometimes, in this way of working, the final bath are a solution of fresh tan, more or less concentrated, according to the views of the tanner. When the baths are rather concentrated, the period occupied in swelling by this method varies from a fortnight to three weeks.

The finishing of the *raising* is effected occasionally with strong tan-juice, which has been mixed by agitation with about four pounds of sulphuric acid. Eight or ten hides being submitted to this bath, they are taken out the first day twice, and permitted to soak or drain for two hours, the second day once, the same time being allowed for draining. In the morning of the third day they are transferred to another, composed of the densest tan-liquor, mixed with the same quantity of sulphuric acid as the foregoing. Whilst here, the hides are handled once a day, being allowed to drain at each handling one hour. About three days suffice to give them the necessary finish.

The red bate is regarded as being by far the best means in use, notwithstanding it is much slower in its effects than some of the others adopted in practice. This may arise from the fact, that the combination of the gelatinous tissue of the skin with the tannin is slowly going on from the immersion in the first vat of the series, at the same time that the lime is being removed, and, consequently, that the finished leather is more compact, and tougher, than if the swelling were made with acids in a shorter time.

THE TANNING.—The many improvements in reference to the combination of tannin with the gelatinous tissue of the skin, that have been put in practice within the last fifty years, seem almost to exhaust the subject. Hydrostatical pressure, the laws of exosmosis and endosmosis, exhaustion, or the vacuum principle, combined with mechanical action, have been successively tried, and the result is, that the time required for the operation, which formerly extended over two years, and sometimes longer, is now diminished in some cases to as many weeks. Unfortunately, it appears that, as the period occupied in the tanning is diminished, so also is the quality of the leather deteriorated, for although by the modern accelerated processes, a large amount of tanning agent is rapidly taken up by the skin, its union with the gelatinous matter is far from being complete, and the pressure or exhaustion applied to bring about

the rapid combination has the bad effect of leaving the leather porous, and without compactness or body. Hence, when a good article is required, such as shall combine density with closeness of grain and thorough homogeneous tanning, that which has been manufactured in a manner somewhat resembling the old system is still preferred.

This system consisted in spreading a layer of waste tan in the bottom of the pit, and over it another of fresh tan to the depth of an inch; upon the latter the hides was spread out evenly, and over it another stratum of tan. This alternate arrangement of tan and hides was continued till the pit was filled, when another layer of tan, six inches thick, was placed upon the whole, and well-trodden to compress the mass; the final covering was termed the *hat*. After a period of four months, when the bark was considered to be exhausted of its tannin, the contents of the pit were removed, the partially-tanned hides stretched, and again replaced with a supply of fresh tan in the same order as before, left for another interval of several months, then taken out, again stretched, and so on till they were deemed sufficiently tanned; the bloom being ultimately given with a concentrated extract of the bark. No moisture was allowed to enter the pit, except what was retained and absorbed hygroscopically by the bark; and as the tanning agent can come in contact with the skin only in a state of solution, it is evident that in the absence of sufficient liquid to bring it to this state, the method must have been slow and tedious.

Subsequently the plan was adopted of filling the pit with tepid water, the hides and bark being arranged as above stated, and new materials substituted for those exhausted every three or four months, till the tanning was nearly completed, the finish being given with a strong solution of tan liquor. Even by this course, which was a great improvement on the former, the hides took a period of eighteen months and longer to convert them into good leather. Another innovation followed; it consisted in filling the pit with tan-liquor or infusion of the bark, instead of water, the hides and bark being disposed as formerly. This mode is still much followed by Irish tanners, but is now deemed obsolete by most of the leather manufacturers of this and other countries. Leather can, however, be made by this method, unsurpassed by any other in quality.

It is rarely that ground tan is now used, the time of tanning being reduced, and leather of average excellence obtained by employing a solution or extract, termed *ooze*, instead. In the slow process of working, very little difference exists between the course followed by the various tanners; and where a difference is found, it is more in the manner of making the *ooze*, than in the succeeding manipulations. The adoption of solutions of tan has been gaining ground regularly from the time of SEGUIN, who first recommended it, and there is no doubt that it is much more effectual, as evidenced by the abridgement of the tanning period, than even the most finely powdered bark. There are several methods of preparing the *ooze*; cold water being employed by some; hot by others; while many extract the strength of the material by boiling; and, latterly,

the spent or weak liquor from the pits has been resorted to for this purpose. When cold water is preferred, the better way is to have a gallery of vats, in which the ground tan is exposed to the solvent action of the water. That which receives the water direct from the reservoir contains the almost exhausted tan, and, consequently, as the liquid passes from one vat to another, it meets with a richer material, and takes up more and more tannin, until, as it passes off from the last filled with the fresh bark, it possesses a high degree of concentration.

The same plan may be followed when hot water is used, in which case branch steam-pipes are laid to each vat for the purpose of heating its contents. By this means the extract is obtained of any degree of concentration, according to the quantity of water employed, and the time of digestion allowed. Sumach, divi-divi, and valonia, may be exhausted in the same way; but kino, and the several varieties of catechu, should be macerated by repeated agitation in the water. Divi-divi extracts should be made as much as possible in close vessels out of contact with air; and the tanning, also, when this substance is used, ought to be performed with as little exposure as possible, with the view of preventing the coloration of the leather.

Latterly, hydrostatic pressure has been resorted to for abstracting the virtues from barks and similar substances. A well-bound vessel is taken, and a perforated false-bottom inserted a short distance above the real one, and from the space between the two, an outlet pipe draws off the contents. It must be fitted with a strong and water-tight cover, supplied with two trap-doors, through which the bark may be inserted and removed, but capable of being perfectly secured. When filled with the bark, water is introduced through a pipe, which may be twenty or thirty feet high. By keeping the latter always filled, considerable pressure is exerted upon the contents of the tub, and by this means the tannin is more readily dissolved. The liquor is drawn off from time to time through a pipe, according as it filters through the mass.

Whatever be the means adopted for making the ooze, the next operation is the immersion of the skins in it, in order to convert them into leather. This is done by filling a number of pits sunk in the floor of the tan-yard, and introducing into them the swelled or partly-raised skins, beginning with those pits which contain a weak infusion, and after proper intervals, passing the skins forward into those which contain stronger solutions. In the construction of these pits, the practice is to excavate the earth to the depth of nine or ten feet, and to cover the bottom with a bed of retentive clay. The pipes for conveying the ooze, waste, tan liquor, *et cetera*, are then laid, and the intermediate spaces filled in with well-compressed clay. Instead of boards, bricks are sometimes used, and the inner surface is well secured with hydraulic cement. A composition of asphalte, made of the usual components, only substituting clay for chalk, would answer the purpose admirably. Such pits as contain the weak infusion of the tanning agents are called *handlers*, and those employed for finishing the process, and, therefore, having a stronger liquor, are known as *layers* or *bloomers*. In the weak handlers, the hides are taken

out twice a day, placed double one over another in a heap, and again introduced into the same or the next pit. After their removal to stronger pits, the handling, as the operation is called, is performed only once a day, and after they arrive at the layer-pits, they are taken out only once in the week, and finally once a month. The object of these handlings is to equalize and quicken the combination of the tannin with the skin; for during the time that the hides lie upon one another on the ledge over the pit, their weight forces the absorbed liquid out of their pores, so that they are more free to imbibe the juice on their re-introduction to it than before. Some are of opinion, however, that during the one or two hours they remain exposed, they contract some injury, and that the quality of the leather is much improved by transferring them at once into other pits; but, as will appear further on, a directly opposite view is often held. It is a common practice with many to introduce some powdered tan into the last pits or bloomers, between the hides, more especially when it is desired to produce a superior leather in point of quality and color. On the other hand, several manufacturers continue to use the powdered tan with the ooze throughout. To avoid the repeated handling of the hides, and the alleged injury from exposure, some tanners submit the hides to the tan-liquor in a vertical instead of a horizontal position. This method has the advantage of exposing every part of the skin to contact with the juice; but if care be not taken to alter the position at proper intervals, the lower part is liable to be better tanned than the upper, owing to the bottom of the pit containing the richer ooze. This, however, is very easily obviated by reversing the hides. Patents upon this principle were taken by Mr. KEASLEY in 1845, and by Mr. BARRETT in 1850.

The quantity of tan required varies with the weight and quality of the hides. Generally, heavy hides take about double their weight of good oak bark to tan them; but those which are lighter and of less body are perfectly tanned with a less quantity, from 1.6 to 1.8 of their weight. When sumac, valonia, divi-divi, or catechu is the tanning agent, a much less proportion suffices, since these materials, as already stated, are greatly richer in tannin than oak bark. With oak tan, the period required for tanning good sole leather averages ten months; about eight months when valonia is used; and six if *terra japonica* or catechu be employed.

The method of tanning introduced by M. OGÉREAU of Paris, is similar to the old system still followed in many parts of Ireland and Scotland, namely, the stratification of the pit with alternate layers of tan and hide; only that, in the French method, the pit is furnished with a false or hurdle bottom, through which the liquor in the vat filters, and collects in the space below. Once a day or oftener, as the case may be, the filtered juice is raised by a pump to the top of the vat, from which it gradually descends through the materials, to be again successively raised to the surface. By this means the tan juice in the pit is kept in circulation, and brought into close contact with the hides. At the end of a month the contents become exhausted, and fresh materials are introduced, the circulation being kept up as before. It is said that by this method the time occupied

in the tanning does not extend beyond four months, and that the leather is of first quality.

NOSSETER, in 1844, patented a method by which the pressure of the overlaying hides in the pit, which prevents free contact with the tanning liquor, is counteracted, and the conversion of the hides into leather much accelerated. This method consists in constructing within the tan-pit a frame with ledges, which support other frames on which the skins are placed when introduced into the pit. Even when fixed as closely as possible together, as many skins cannot be introduced as in the old way; but taking into consideration the limited time in which the operations are finished, the patentee states that, in the end, a larger number can be tanned by this method within a given time than by the ordinary arrangement. After all the frames and hides are placed, the pit is filled with ooze, and after it has become exhausted, the spent liquor is pumped out and fresh supplied, and this is repeated till the leather is formed. Another improvement embraced in this patent consists in depriving the hides of the old tan-liquor previous to immersing them in the new, by submitting them in numbers at a time to the action of a screw-press, so constructed that the hides do not require to be folded, but are laid flat on the table or press-board.

The plan adopted by BERENGER and STERLINGUE for tanning hides in a reasonably short time, without the aid of machinery, is the following:—A row of pits is formed, each furnished with a hollow vertical wooden cylinder, connected with the next pit of the series by a pipe fixed at a depth of six inches from the surface, and communicating with the space between the perforated and true bottom, by means of a punctured pipe. By this arrangement, the liquid in each pit may be made to pass over to the next in the series, and so to the end, without the least disturbance of the contents. Thus, if water from the supply pipe be conveyed into the first vertical cylinder in the series, the liquid flows down through the false bottom into the intervening space, causing the fluid already there to ascend through the body of the vat, and to flow over by the connecting pipe into the cylinder of No. 2 pit, where it displaces an equal volume of liquor in like manner. In working on this principle, a series of eight pits is preferred; No. 1 is filled with tan and hides in the old manner, and as much water as it will retain added. After twenty-one days, No. 2 is filled in the same way; but instead of employing water, as much strong ooze as is required to wet the materials is poured into the first pit, and this drives before it the weak liquor, which ascending by the pipe from the false bottom into the cylinder, flows over by the connecting pipe into, and moistens the contents of, No. 2, with the weak tan liquor of the first pit. After the lapse of another period, a third is charged with tan and skins, and after this a quantity of strong ooze, equal in bulk to what is necessary to moisten the contents of the new materials like the others, is poured into No. 1, when the liquor previously contained in it will flow over from the cylinder to No. 2, the liquid contents of which are in like manner transferred to No. 3. In this way the work progresses till the eight pits are filled. The connecting pipe of No. 1 is then closed, and the ooze in it pumped out, and the remaining

materials removed, when the leather will be found thoroughly tanned. A fresh supply of hides and tan are then put into this pit, which now becomes the last or eighth of the series, that which before was No. 2 becoming No. 1, and receiving the strong ooze. By this means the hides are tanned without once removing them from the pits till they are finished, and likewise with a great saving of labor. If the strong infusion be added at intervals of fifteen days, the time required does not extend beyond four months, but it may be prolonged at will, by allowing a period of twenty or thirty days to elapse between the addition of fresh ooze, or the filling of a new pit. The ooze used in the foregoing operation is prepared in a series of vats similarly constructed, or they may be placed one above another, so that the liquid in the higher may flow into the next beneath, as in the lixiviation of soda or of kelp—see IODINE—only that each is furnished with a coil of steam-piping, for the purpose of heating and concentrating the liquors, with a view to the removal of gallic acid and other substances. The liquor emptied from the tan vat is mixed with the ground bark or other material in the first of these, and after a while, the solution is drawn off to the lower one, where it becomes further enriched. In this way the liquid may be brought to any degree of density necessary for the operation, and much of the extractive and gallic acid may be removed.

Another patent process by CAGSWELL, recommends the process of filtration, as a means of causing the tannin of the ooze to unite with the matter of the hide in a shorter time than is ordinarily required. The prepared hides are to be laid in sawdust, in such a way as to form a kind of basin, and into this the rich ooze is poured. Gradually it finds a passage through the cells of the skin, and passing out at the other side, runs through the sawdust into a tank beneath or adjacent to the floor, but whilst going through the hide, the tannin is retained. By keeping the hollow of the hide filled with fresh ooze, the gelatino-fibrous tissue in a very short time becomes saturated with tan. There are some drawbacks, however, to this method; for instance, the porosity of the hide is very unequal, and as the filtration is greater where most porous, these parts are liable to be overtanned, when the others may not be sufficiently so. Again, the edges are never finished in this operation, and consequently, the hides, after the body has been made into leather, must be subjected to ooze in the pit. The great space, too, necessary to carry on an extensive trade by this means, is not among the least objections to it.

Besides the preceding methods in which the tanning agent is left free to react upon the skins, several others have been patented in which mechanical force, in concert with other means, has been employed to effect the tanning in a shorter time. The simplest of these are such as merely cause the agitation of the hides and tan-liquor in the vat, so as to effect a more thorough and rapid contact of the combining substances. Of several on this principle, that of Mr. SQUIRE of Warrington, patented in 1845, will be sufficient to illustrate the method pursued. A cylindrical drum or barrel is divided internally into four compartments by bars, space being left for the liquid of one part to flow into

the next as required. The hides are introduced into these divisions by doors which are well secured, and the tan-liquor, which may be that of divi-divi, catechu, or any other, in quantity sufficient to fill the cylinder to more than three-fourths. All the openings are then perfectly secured, and motion is given to the apparatus by means of a winch fixed upon its axis, or a strap passing over a drum, and connected with the engine shaft. The rotation is slow, but sufficient to keep the hides and fluid contents in motion. In the course of a very short time the hides are well tanned by this method, and the air being excluded during almost the whole period, the leather retains a good appearance, even when divi-divi and catechu are the agents employed.

Some erect a roller over the mouth of the pit, and string the hides together by stitching in the form of an endless web or belt, which is wound in several coils loosely round the roller, and then placed so as to be partly submerged in the ooze of the pit. By turning the cylinder, the immersed portion becomes saturated with the liquid; and as it rises again on the roller, the weight of the suspended hides exercises a force by which considerable quantities of the liquor are squeezed out, and the hides descend at the other side in a condition to absorb fresh liquor. This alternate absorption and expression of the liquor is very conducive to rapid tanning; but the time is still further abridged by a process patented in 1837 by COX and HERAPATH, which consists in passing the hides between two rollers fixed longitudinally over the pit. In order to avoid injury to the hides from contact with the metallic surface of the rollers, and to allow the solution to pass away more readily, the lower cylinder is covered with horse-hair cloth, and the upper one with folds of flannel. Both rollers revolve, and the upper one may be weighted to any degree, so that the hides passing between them lose all absorbed water and re-enter the same pit, or another containing a stronger ooze, in a condition to imbibe the solution very readily. It is stated that sole leather may be thoroughly tanned by this method in one to two months, and kips for upper leather in three or four weeks. It should be remarked, however, that although with care an average quality of leather may be prepared in this manner, yet, if too much pressure be exerted, the process of tanning will be rather retarded than otherwise, because the elasticity of the tissue will be destroyed.

Tanning by Hydrostatic Pressure.—SPILSBURY, in 1831, was the first to introduce the method of permeating the hides by hydrostatic pressure. His mode consists in securing any holes or damaged parts in the hide, and then to stretch it on a suitable frame, having iron hooks for fastening the edges of the skin all round. Upon the frame so furnished another is laid, and screwed tightly, so as to allow no room even for water to percolate between the two frames. Another hide is then fixed upon the second frame, and its edges secured in the same manner by a third frame, the whole three being bolted firmly together by means of clamps. In this way a kind of water-tight compartment is formed between the two hides. The frames are then placed upright, and the interval between the

hides is filled with ooze. As the skins form the side walls, it is evident that their whole surface will be exposed simultaneously to the liquor, and as the latter by the force of its own weight penetrates them, the tannin enters into combination, and they are gradually converted into leather. An arrangement of pipes and stopcocks permits the confined air to escape in the first instance, and afterwards the spent liquor, after it has percolated through the hides. Of course the rapidity of the tanning by this, as by other processes, depends more or less upon the thickness of the hides, the strength of the ooze, and the amount of pressure exerted.

DRAKE, instead of using frames, directs that the hides should first be submitted to an incipient tanning, and then sewed together in pairs, so as to form a kind of sack. A small aperture is left at the shoulder or neck part for the introduction of a funnel for filling the sewed hide with the tanning juice; and to prevent the distension to which the hides would be liable on being filled, he places each pair in an upright frame of suitable size. The bag being filled with the ooze, the liquid percolates through the pores of the skins, being deprived of the tannin in its passage, and trickles down into a receptacle beneath the frame, whence, if rich in tannin, it is pumped back into the bag in order to be again exuded. Towards the close of the operation, when the skins become firm and hard, so that the confined fluid exudes very slowly, the atmosphere of the room is heated to about 150°, with the view of promoting the permeation of the ooze, and the process is continued till the hides give indications of being thoroughly saturated with tannic acid, which is known by their beginning to darken in places, and by the passing through of the ooze without losing strength. The contents of the bag are then withdrawn, the stitchings cut open, and the leather subjected to the finishing processes, which will be presently described.

By the improved methods of CHAPLIN and COX, the hides are sewed up into bags, leaving a small aperture for the introduction of a branch pipe from the main, connecting them with a tank which holds *hot ooze*. On turning a tap, the ooze flows into the bags by means of the branch pipes; and provided the connection and sewing be secure, the pressure exerted may be varied at pleasure, according to the height and quantity of liquor in the vat. As the hides are necessarily extended more or less under the force so exerted, frames answering to the size of the bags are used to keep them from bursting or being too much expanded. The plan of encasing the sewed hides in canvas or flannel, has been patented as an improvement on the practice of placing them in frames or boxes of wood.

PEACHY, POOLE, and others employ force pumps and other similar means to cause the tan-liquor to penetrate the hide, but the principle of hydrostatic pressure is still retained.

All these methods by infiltration are subject to the disadvantage arising from the unequal permeability of the hides at different parts, and from the weakening of their structure consequent on the prolonged distension.

By Exhaustion of Air.—KNOWLIS and DUESBURY, to avoid the evils which hydrostatic pressure occasioned, had recourse to infiltration produced by the

exhaustion or rarefaction of the air in the vat, in order to tan the hides more regularly. For this purpose the hides are suspended within an air-tight vessel from cross beams furnished with hooks. To economise room, they are arranged as closely as possible without touching, and weighted beneath to keep them extended. The top of the vessel is movable, and the pipes for exhausting the air by the pump, or for forcing air into the apparatus, are fixed at the sides near the top. When ooze has been introduced till the hides are covered, and the lid is firmly screwed down, the air is exhausted, and the contents left to their natural reactions for twenty-four hours or more. The air is then admitted, and the ooze drawn off. During three hours the hides are now left in the vessel in contact with the air, till in fact they become saturated with it, and when this period has elapsed, the tan liquid is again introduced, and the exhaustion renewed. In this way, the alternate filling of the vat with liquor, exhaustion, and exposure to air, are continued till the leather is fully formed, taking the precaution to employ stronger ooze as the operation proceeds.

By endosmosis.—The process patented by TURNBULL in 1845 embraces a combination of the exosmotic and endosmotic principles. The hides, sewed into bags, are filled with the ground tanning material and water, or a weak ooze, and the bags are then immersed in a vat filled with a strong extract of catechu, freed as much as possible from catechuic acid by solution in cold water and filtration. The inequality of density between the weaker liquid within the bags, and the stronger solution contained in the vats, causes a motion by which the exterior penetrates, and the interior solution exudes, both parting with tannin to the gelatino-fibrous tissue, and causing its saturation in a very short time without the intervention of any mechanical force. To expedite the operation, the liquid in the vats is rendered denser by dissolving in it salts or sugar in the proportion of fourteen pounds to one hundred gallons. During the tanning, it is necessary to keep the bags filled by occasional additions of water or weak ooze, and likewise to maintain the density of the liquor in which they are immersed, as this causes the endosmosis or infiltration, and consequently the exosmosis or exudation, to be more rapid.

By acupuncture.—SCHNYDER, some few years ago, obtained a patent for a quick process of tanning, effected by exposing a more extended surface of hide to the tan-liquor than is ordinarily done. His method is to puncture the hides with steel points either by hand or machinery, with an instrument having from one to three hundred points to the square inch, and afterwards to expose the skins so indented to the action of the tan-juice, with or without pressure, as may be most convenient. Either the flesh or hair side may be operated upon with the steel points; and, notwithstanding that such perforations permit the liquor to enter into the interior portions of the skin, still, as the tanning approaches completion, they close up, and the leather is as capable of resisting moisture as that made from hides which have not been subjected to the same operation.

According to MORFIT, this method is more worthy

of attention than most others, owing to the combination being so readily effected between the skin and tan that the ooze has not time to acidify before it becomes exhausted, and so the relaxation and expansion of the fibres, the enlargement of the grain, and consequent brittleness of the leather which acids produce, are obviated. Also, because by this method the formation of leather takes place in the heart of the hide as readily as at the surface, the overtanning of the latter, by which it becomes rigid and brittle under the old system of prolonged exposure in the tan vat, is done away with.

Mineral Tanning.—It has been shown in the introductory portion of this article that gelatin, fibrin, and albumen, are capable of combining with and precipitating metallic oxides and basic salts from their solutions. On this reaction have been founded certain processes for converting skins into what may be called a *mineral leather*, by impregnating them with suitable metallic bases. This is easily effected by merely placing the raised and depilated hide in contact with solutions of such bases, when the affinity of the gelatino-fibrous tissue for the mineral compounds results in their combination. Alum has long been known as a compound capable of rendering light skins imputrescible—in fact, of converting them into leather; but this agent has not been used for making ox or such hides into sole or upper leather till lately. The first to draw attention to the manufacture of leather suitable for all ordinary purposes, without the aid of tannin—considered as a branch of trade—were D'ARCET and ASHTON; but their attempts, although they suggested the idea, left very much to their successors to accomplish.

BORDIER, in 1842, obtained a patent for an improvement in this department, which deserves more attention than the methods of his predecessors. On this system the hides are to be washed, depilated, and raised by any effectual method, and then exposed to the mineral constituent, which consists of a subsulphate of sesquioxide of iron, prepared by digesting twenty-two pounds of protosulphate of iron—copperas—in a mixture of two parts and a quarter of nitric acid, specific gravity 1.33, and three pounds one ounce of sulphuric acid, of 1.848 density. A stone-ware jar may be employed for this purpose, the contents to be heated with steam, and stirred repeatedly. As soon as the red fumes of peroxide of nitrogen— NO_2 —cease to be evolved, the vessel is to be removed from the heat, and the mixture kept agitated, till, as it cools, it forms a kind of paste. After settling for twenty-four hours, it is to be diluted with water, and some further portion of sesquioxide of iron added. It is again left for several days, with occasional stirring, for the purpose of allowing the sulphuric acid to take up the sesquioxide of iron and retain it in solution. The cleaned skins are then immersed in the bath, and stirred about or handled occasionally, as when working in the tan-pit, till they are made into leather. With light skins this happens in three days or thereabouts, and in six to eight days with thick skins intended for sole leather. During this immersion a combination of a basic salt—a subsulphate of the sesquioxide of iron—takes place, and an acid

salt with uncombined sesquioxide remains in the bath. There is little doubt that the acid liberated in consequence of the union of the base with the skin must have an injurious effect upon the leather, as is the case when tan is used; and if this be so, a method of working in which the uncombined acid might be neutralized as soon as disengaged from the iron base, would be preferable.

CAVALIN's mode is to impregnate the cleansed, depilated, and partially-drained hides, with a solution made of ten pounds of bichromate of potassa and twenty of alum, in one hundred and eighty pounds of water. For this end they are immersed during four days, being handled once in the twenty-four hours, and rubbed, if necessary. Much of the success of the finishing process depends on the thorough manner in which this first saturation is performed, and therefore the strength or density of the bath is kept up by the addition of more of the above salts, in proportion as the hides absorb what has been already dissolved. For the second step in the process, the vat is filled with a solution of copperas—protosulphate of iron—using one pound of this salt for every gallon of water. The hides saturated with the aluminochromic solution are immersed in this bath in such a way as not to touch one another, nor the walls of the vat. At an interval of twelve hours they are drawn out, allowed to drain for a short time, and again plunged into the bath; the alternate draining and immersion being thus continued till the leather is formed. It is necessary to maintain the strength of the bath, as the iron enters into combination, by adding more of the salt. In this operation the iron base is peroxidised in the hide by means of the chromic acid, which is itself reduced to the state of sesquioxide, and remains, with the iron and a portion of the alumina base, firmly united with the tissue. The time extends over from five to six days for upper leather, eight or ten for Swedish sole leather, and thirteen to nineteen for thick *butts*. After the finishing of the operation, the hides are drained, and then thoroughly soaked in water to remove everything that has not entered into combination. Upper leather prepared by this method is said to be soft and pliant; and the thick sole leather is alleged to have a body and imperviousness that render it equal for wear to the best tanned leather. The same inventor recommends another method of making leather of skins, by first submitting them to a dyeing process, employing a strong dye beck, in which four ounces of alum are added to the gallon of liquor. Frequent immersion in this solution reduced to the proper strength—as determined by a preliminary test with a bit of prepared skin—is necessary, till the materials assume a light-green yellow color on the grain, and yellow-green on the flesh side; after this they are drained and finished in a bath made by dissolving ten pounds of bichromate of potassa in eighteen gallons of water.

FINISHING PROCESSES.—Such are the principal methods followed in the tanning of hides, but after this operation has been performed, the hides are not in a fit condition for the market; they have still to be submitted to several additional processes. When

thoroughly tanned, the hides are taken out of the layers or bloomers, and washed slightly, or brushed with water to remove all extraneous matters, without, however, detaching the bloom which is so much prized, and is regarded as a kind of guarantee for the quality of the leather. They are then hung up to dry in a spacious and well-ventilated apartment, from which the sun's rays are excluded. Much care is necessary in the drying: if conducted too rapidly, the hide is liable to crack on the grain side, owing to the rapid and unequal contraction of the inner and outer parts; on the other hand, it must not be so slow as to allow the leather to get mouldy. In winter, a medium temperature is maintained in the drying-room, or loft, by means of steam-pipes, judiciously placed so as to give out their caloric to the air of the place. When partially dried, the leather intended for soles and other similar uses where great impermeability is required, is submitted to a process for condensing it, and destroying in a great measure the porosity which it retains after the tanning has been executed. Formerly, this was done by hammering the leather on a smooth table with heavy mallets or hammers, almost in the same way as the shoemaker hammers his leather upon the lapstone; but subsequently machinery was substituted. In many concerns, the compression is effected by means of rollers of brass surmounted by a carriage, loaded with ten to thirteen hundredweight.

STERLINGUE was the first to introduce a hammer moved by machinery for condensing the leather, but in his invention numerous requisites were found wanting, so that it was often necessary to finish the leather by hand with the hammer or mallet. In 1840, DEBERGUE patented another apparatus, in which a roller attached to a weighted lever, with other regulating mechanism, was the compressing agent. The hide or side of leather being placed upon a strong table faced with brass, and having either a plane or concave surface, was submitted to the action of the roller. COX and WILTSE have lately introduced machines which are analogous in their action to the preceding, but are simpler in their construction. Another machine was introduced by M.M. IRAN and SCellos in 1852, of which report speaks favorably; but as the object of all these machines, of which there is a great variety, is simply uniform compression, either by beating or rolling; and as the details of their construction would too much extend this article, the Editor forbears to enlarge upon a subject purely mechanical.

After the rolling or hammering, as the case may be, the sides of leather are hung up again to dry, and left with occasional changes of position, till all the moisture is removed as far as possible. After this, the sides are in some instances stored by laying them one above another, and weighted; their position being changed from time to time before they are sent to the market. This storage is supposed by many to improve the quality and color of the leather, but others regard it as unnecessary trouble.

CURRYING.—Such are the processes through which heavy or sole leather passes. With upper leather, or that prepared from lighter skins, a different course is pursued—the rolling or hammering being dispensed

with, and another set of operations termed *currying* being practised. In some cases, the finishing of the leather to suit the shoemaker, coach, and harness manufacturer, becomes a distinct and independent branch of business from that of the tanner; but in many establishments, the two are carried on together, so that the finished leather issues from the tannery.

To curry leather, so as to confer qualities which adapt it for the boot and shoe maker, the carriage and harness maker, and other particular applications, requires its subjection to various processes, which, independently of the tanning, according as they are well or imperfectly accomplished, affect in a great measure the suitability and lasting qualities of the leather. From the difference of treatment which becomes necessary to confer these qualities, result the numerous designations by which the finished material is known. Thus, a distinction is made between smooth or sleek leather, tallowed, oiled, and waxed leather, with several other varieties. In the variety and quality of their curried leather, the manufacturers of Great Britain are far behind their French brethren. The heavy upper and harness leather produced by the British currier cannot be excelled; but when a light article is required for summer wear, and which should retain its suppleness, the inferiority of the British leather, compared to the French, becomes apparent to the wearer after a very short time.

The role of operations required for this finishing may be enumerated—the dipping or soaking, the beating, stretching, oiling, tallowing, waxing, dyeing, and polishing.

Soaking and Beating.—As the tanned hides or skins come from the tanner they are dry and hard, but before they can be submitted to any of the finishing operations of the currier, they must be rendered soft and pliable. This is done by soaking them in water, or sprinkling them with that liquid, and allowing them to rest till they become sufficiently moist. When this happens, the side is placed upon a rectangular hurdle of basket-work, and trodden with the feet—the operator wearing heavy wide shoes for the purpose—or else beaten with an instrument called a *mace*. The working is continued carefully so as not to tear or injure the leather, till it becomes sufficiently soft and pliant, and when this is effected, it is placed upon the horse, and worked with the *cleaner*. There are various kinds of this tool, but, in all cases, the sharp edge of the instrument is so formed as to prevent it entering too far into the leather. By its use, the inequalities and overtanned parts on the flesh side are shaved off, and an uniformity of thickness and regularity of surface produced.

Stretching.—By the preceding treatment, the grain of the leather is brought out, but the desired equality is not attained till after it has undergone the *stretching* and *pommeling*. The former is executed by means of tools of steel, copper, or brass, or of hard stone or glass, the latter materials being resorted to when a better and smoother surface is desired. After the shaving on the horse or beam with the knife, the skin is further soaked in cold water and scoured, then placed with the flesh side under upon a smooth stone

or mahogany; and the workman, grasping the wooden handle of the stretcher in both hands, holds the tool almost perpendicular to the side of leather, and forcibly scrapes the surface, especially where there appears to be inequalities. By continuing this action, usually from the tail to the head part, over the entire surface, and using water freely in sprinkling, the whole is brought to an equal thickness at the same time that it is stretched, and the *bloom* of the leather more developed; density and smoothness are also acquired.

Pommeling.—The partially prepared hide is now submitted to the last operation called *pommeling* or boarding. The pommel is of hard wood, having a smooth and fluted or channeled side, the former being next the hand, and the latter for acting on the leather. Fig. 351 shows this instrument with the strop intended to confine the hand of the workman, so as to give him greater power for applying it. According to the fineness of grain required, so do the grooves in the pommeler or crippling board become finer and sharper.

Fig. 351.



Usually the grooved side of this instrument forms an arc of a circle, and the surface next the hand being straight, forms as it were the chord of that arc. This construction allows of considerable body in the middle part, whilst at the extremities it is thin. In using it the workman doubles the hide with the grain side in contact, and strongly rubs it on the flesh side, applying the force outwards, and then reversing it. This mode of working is ordinarily termed the *graining*, to distinguish it from the *bruising*, which takes place when the operation is performed on the grain side of the leather. In many instances the hides are again damped, and worked under the *slicker* or *stretcher*, and then dried and placed one upon another, and weighted for some time in order to complete the process; or they may be whitened by rubbing the flesh side with a sharp knife on the horse, after the action of the *grainer*, in which state, provided the leather be treated with oil or tallow before the last workings, it is known as *finished russet*. Leather prepared in this fashion is called *stretched leather*, but it may be made into *sleek* or *grain leather* by a few further operations, and a very slight modification of those described.

Grained Leather.—To render the hides—which are in most cases cut in two and pared—pliant and even in body, they are drawn over a flame from straw or such material, the flesh side being that so exposed. Fatty matters, which vary with the choice of the currier, though tallow or mutton suet is preferred, dissolved if required by heat, are then laid on the flesh side in a coating, by means of a brush or mop, to the extent of three to four and a half pounds for cow hides, and one for thick calf skins. After this *dubbing*, as it is called, the hides or skins are doubled up, the hair side being inwards, and remain so for some hours, or in some instances one or two days; they are then refolded, and put into a tub containing water, where they soak for eight or ten hours, being worked during this time

more or less, so as to detach the fatty matter on the surface of the leather. When the whole of the pieces assume a uniformly white appearance, they are taken from the soak, and beaten with a *mace*, afterwards worked by the pommel till the grain is brought out, then cleaned with the sharp knife on the horse or beam, and finally, any creases removed by working and polishing them with the brass and glass slicker. This being done, the leather is slightly sprinkled with water, and, if necessary, cleaned and then hung up to dry. When it is required to color the product, the latter operation is not carried too far, so as not to necessitate its moistening again. The operator now rubs on the hair side, by means of a brush, a solution consisting of a sesquiacetate of iron, prepared by digesting scrap-iron in sour lies or beer, or of logwood, nut-galls, gum, and copperas.

Several coatings with such a composition are applied, the leather being partially dried after each, folded up, and worked under the stretching and polishing iron in order to give the finish. Before being sent out, however, it is rubbed over once or oftener on the grain side with a piece of woollen stuff dipped in sour beer or barberry juice, worked by the pommel and slicker, and finally, exsiccated. This kind of leather is much used by the saddler, trunk, harness, and coach makers. Of course, very many modifications in the order of application and execution of the foregoing treatment of the hides are practised by different parties, but the preceding general view of the operations will indicate the nature of the business.

Oil Leather.—Calf and cow leathers are curried in oil very extensively. The preliminary dipping, treading or working, *et cetera*, are applied, in order to give the substance more suppleness. Fish oil is recommended, but the French prefer the material usually employed for scouring skins that are intended for chamois leather, and which consists of fish oil and potassa. It is thicker than the ordinary oil, and becomes more rapidly absorbed; besides it gives greater pliancy and softness, and less is required than of the fish oil alone. Neat's-foot oil is likewise used, and it is said to add materially to the good qualities of the leather, but a proportion of fish oil must be mixed with it. When applying the dressing or oily matter, the skins should be slightly moist, so that, as they dry, the oleaginous portion may be gradually and thoroughly absorbed. Should they be too dry, the oil would be soaked too quickly, yet not properly combined so as to render it sufficiently resisting to water or moisture; on the other hand, excess of moisture must be guarded against, as in this instance too much oil would be expended, and the time would be prolonged in proportion. A coating of oil is uniformly spread over the grain and flesh sides, after which the hides are hung up to dry, the direct rays of the sun or too violent a draught being guarded against. In summer time the drying is effected in twelve hours, though in winter it sometimes requires three or four days. When dry, they are again full, and a further coating of fish oil mixed with the fatty scourings already mentioned, only in smaller quantity than in the previous case, laid on, and the process is repeated after the drying of the leather as before. Finally, the grain side is cleaned by rubbing it well

with a brush and a weak potassa lie. The coloring of the grain or flesh side, as the case may be, follows these operations, and is effected by employing the dye already alluded to. After receiving one coat, the leather is pommeled crosswise; another layer of blacking applied; dried and pommeled, or stretched, according as it is deemed necessary; rubbed over with a cork pommel to give a smooth surface, and finished by giving a light coating of oil on the hair side.

Varnished Leather.—During the last few years a considerable quantity of a light glazed or varnished leather, intended for the manufacture of patent boots and shoes, has been introduced into the market. The French are celebrated for the beauty and superior quality of their manufactured product. This kind of leather is simply tanned kips, calf-skins, or split ox-hides of superior quality, well curried, and then passed through two other operations—one intended to render the leather impermeable to the varnish, and the other the laying on of the varnish. In currying leather intended for this manufacture, it is necessary that the fatty or oleaginous matter be laid on as thinly and evenly as possible, in order to insure the uniformity of the article after being prepared.

Such curried skins are taken and rubbed over, either on the flesh or grain side, with a coating of boiled linseed oil mixed intimately with ochre, ground chalk, or some such substance, and dried; the coatings are renewed after each desiccation till it has received three, after which the surface is well rubbed over with a pumice-stone tool till it appears even, and the fatty and other matter is compressed into the pores of the leather. When this is done, other layers of a thinner material than the above, but of the same nature, are applied, and after drying, rubbed into the skin as before; by which means the adjacent part of the skin becomes thoroughly saturated with the fat, and an even surface is given to it. After this part of the work is executed, the prepared surface is coated over two or three times with a composition made with boiled linseed oil, but without mineral matters; subsequently adding lamp-black and as much turpentine as will make it flow freely. This is laid on evenly with a fine brush, and allowed to dry after each coat, till a sufficiently black and shining surface is given to it; for which purpose it is rubbed over with a piece of woollen stuff and the finest kind of pumice-powder or tripoli.

The leather is now ready to undergo the final operation or varnishing, which consists in laying on coats of a composition made of boiled linseed and copal varnish, with which any coloring matter intended to show on the leather is incorporated. Generally this is composed of twenty pounds of boiled linseed oil, such as is employed in the first operation, twenty of turpentine, ten of thick copal varnish, and one pound of asphalte, Prussian blue, or ivory black in the finest possible state of division. In making it, the oil and tinctorial matter in finest powder are incorporated, then the varnish is added, and finally the turpentine, the whole being so well stirred as to insure a homogeneous mixture. It is then set aside in a warm place for two or three weeks, after which it is ready for use. It is necessary that the utmost cleanliness in regard to the

manufacture be observed, and that no dust or other matters be allowed to float in the atmosphere, either of the apartment wherein the coatings are given, or in that of the drying chamber, as this would injure the smoothness and brilliancy of the article.

The number of varnish coatings applied varies, but five is the ordinary limit, the drying being effected after each in the chamber intended for the purpose, the temperature of which is kept at 160° and under. In this way a brilliant surface is given, and the leather has the property of resisting strains and of bending without the least crack or any injury to the even and perfect surface of the varnish.

It has been stated that the black varnish generally used for boot and shoe leather, is colored with lamp-black and Prussian blue, but the tint may be varied; thus for blue leather, Prussian blue or ultramarine mixed with a little Krem's white, and incorporated with the varnishes, answers well; lakes are used to give a red color; white lead for white; ochres for yellow, and so on, the shade being varied at will. An inferior quality of polished leather is made for belts and coach harness, by impregnating the skins with the linseed oil varnish, mixed at once with the lampblack and Prussian blue, copal varnish and turpentine. The linseed oil varnish is made by boiling, say, five gallons of this material with four pounds and a quarter of white lead and an equal weight of litharge, till the compound acquires the thickness of a dense sirup. For particular uses this is mixed with ochre, powdered chalk, or ground bones, as in the first operation for making a superior dress-boot leather.

NOSSITER of Birmingham obtained a patent for making sheep and goat skin leather into this article. He splits it by machinery and, on the new surface produced by the section, forms a grain by polishing with a slicker, and then lays on the varnish. It is said that by this means a better surface is obtained than when the outside, either on the hair or flesh side, is operated upon.

Split Leather.—With reference to the preceding patent it may be here stated, that a considerable number of hides are now split by machinery, generally after receiving a slight tanning, and the divided parts afterwards fully tanned and curried, so as to adapt them for the manufacture of light boots, shoes, and other applications. It is almost unnecessary to remark, that leather which has been subjected to this operation, is much weaker than that which is manufactured in the entire state. A large proportion of cheap and inferior articles are formed of split leathers. Ox hides, kips, and skins, so split and tanned, are chiefly used by shoe and boot makers for the inner soles, by trunk and portmanteau makers, and in carriage facturing; whilst the sheep and goat skins, similarly treated, are converted into the finer kinds of glove leather.

FANCY LEATHERS.—Besides the various kinds of leather already described, there are many others, included under the name of *fancy* leathers, which are extensively used, and are therefore manufactured on a large scale. Such are the well-known Russian leather, *morocco*, Hungarian, and chamois leathers, with a few others of lesser importance, but which, nevertheless, merit a short description.

Russian Leather.—This article, known as *juten*, has long been valued for its qualities of resisting moisture and the ravages of insects, as well as by the peculiar odor it possesses—qualities which render it of great importance to book-binders and others. RUSSIA was long the only country that produced it, but it has lately been manufactured in Paris. Its odor and particular qualities are attributed to the essential oil of birch bark, with which it is impregnated after the tanning with this material. In Russia it is manufactured from all kinds of skins, but in Paris, and wherever else the product is imitated, only sheep and goat skins are operated upon.

The method of preparing this article, is not very generally known out of the seats of the manufacture, but the following details from the memoir of COUNT DE KARTSOFF on the subject will give an insight into the process:—The dried skins are softened by soaking in water for five or six days in summer, and ten or twelve in winter; well cleaned and deprived of their hair by the use of milk-of-lime, prepared by disseminating one hundred and eighty-five pounds in a vat or tub eight feet in diameter, and seven feet three inches deep, nearly filled with water. During the steeping the skins are frequently examined, and as soon as the hair and epidermis are found to be detached, they are worked upon the beam with a dull knife, and afterwards with a sharper instrument, on the flesh side, to separate extraneous matter. When ox and cow hides are operated upon, the depilation is effected by piling them one upon another, sprinkling some common salt upon them to resist the injurious effects of over-fermentation, and after the proper time has been allowed, working on the beam as before. Bran-water baths are occasionally resorted to for the same purpose, but only when the more delicate skins are treated.

The usual steeping and beating, *et cetera*, are given after the depilation, with the view of removing the lime; and after this is done, the cleaned pelts are introduced into a vat like that described, containing a fermented menstruum of eleven hundred pounds of rye, and four hundred and fifty of oatmeal, six pounds of salt, and a sufficient quantity of leaven. They remain here for forty-eight hours or longer, according to circumstances, in which time they become *raised*. The tanning process is then commenced by steeping them for some time in a weak infusion of oak or willow bark by preference. After this the skins are placed in a tan-pit, interstratified with layers of coarse willow bark till it is full, and then charged with the liquor of the last steep, the whole being pressed by planks and stones. Fifteen to twenty-eight days are allowed to transpire before they are disturbed; at the end of this period the pit is emptied, fresh bark and solution substituted for the exhausted material, and the whole left as before. Three to six such changes and terms are required, according to thickness and weight of the skins, to finish the tanning; very thin skins get but two changes. Whilst tanning, the leather acquires rigidity, which is removed by immersion for a day or longer in a thin paste made of one hundred and thirty pounds of oatmeal, and nine or salt, macerated with warm water. This quantity should serve for one hundred and fifty skins of ordinary

size. When taken out of this steep, the leather is well cleaned, and allowed to drain. At this juncture the currying commences, which confers the particular virtues already mentioned. The leather still moist, but not over-saturated, is placed with the grain side downwards on a table, and crated with a mixture of oil obtained from *sea calves*, and that distilled from birch bark; the proportions are varied according to circumstances, but for the most part, one of birch oil to two parts of the other is the standard composition. This, in quantity of about nine ounces to each medium-sized skin, is laid on with the hand so carefully as to insure an even and entire coat. This done, the skins are stretched upon cords in an open shed, and left so till dried.

The Baskirs and Kirguises prepare their skins by smoking them, in lieu of tanning. The hair is detached by scraping them, while in the green state, with a broken sickle attached to a handle. When this is done, the skins are attached to cords placed parallel to one another in a pit, the depth and breadth of which depends upon the number of skins to be treated at once, and which is connected with another, at the distance of five feet, by a tunnel at the bottom. The pit containing the skins is well covered, and a fire of dry and decayed wood lighted in the other, which is likewise protected. As no immediate means of escape exists, the smoke passes over into the pit charged with the skins, by the tunnel or gutter at the bottom, and in the course of two or three weeks that they are exposed to its action, converts them into a leather which is said to possess a degree of impermeability superior to that of any tanned leather.

The method pursued in France for making Russian leather is as follows:—

The skins are deprived of hair by steeping in a lime vat, or in one containing a mixture of lime and potassa lie, but too weak to act upon the fibre, and scraping on the beam; they are then rinsed and fulled for a longer or shorter period, according to their body, and subsequently allowed to ferment in a steep, being first well washed in hot water. Eight days are allowed for this operation, at the end of which time they are taken out, again fulled and washed, and, if necessary, submitted a second time to the vat, in order to open all the pores. When this is properly done, they are taken out, well washed, placed on the beam, and worked with the flesher on both sides. After this a paste is made, sufficient for two hundred skins, of thirty-eight pounds of rye-flour. This is allowed to ferment, then diluted with a sufficient volume of water, and the skins are immersed in it during forty-eight hours; and at the end of this time they are transferred to smaller vats, and allowed to remain in them for fifteen days, when they are taken out and well washed in running water.

They are now fit for the tanning, which is done by putting them into vats filled with extract of willow bark—*salix cinerea* and *salix caprea*—of such a degree of heat as will not injure the animal fibre. Whilst in this solution—usually a week—the skins are handled twice daily, and pressed for half an hour each time; after this the decoction is renewed, and the same course followed as when in the first bath, the time in the second case being likewise a week. After this the

skins are taken out and dried in the ordinary way, when they are fit for currying with the empyreumatic oil which gives this kind of leather the virtues so much desired. In the execution of this part of the work, the ordinary course is followed, fish oil being first used, with the requisite shavings, stretchings, and pommellings, to render it pliable. The leather is then grained by passing it between rollers weighted to the proper degree by levers or some analogous means, and having on their surfaces raised threads parallel to, and intersecting one another, to give the intended grain. After this the skins are dried to the proper degree, and then oil of the birch, or *Russian* oil, is spread over on the flesh side. The color peculiar to this kind of leather is then laid on, and in this state the skins are repeatedly exposed to the rays of the sun, in order to make the color penetrate into the pores; they are then well pommelled and slicked with the *lunette* or circular knife on the beam, and finally worked with a hard brush on the hair side. The red color of Russian leather is produced with alum and a decoction of Brazil and sandal wood, and the black with a solution of sulphate of iron—copperas—and sandal-wood.

In impregnating with the oil, great care is necessary to have the absorption equal; at the same time, too much oil must not be employed, lest it might pass through and stain the grain side. This is especially to be guarded against when operating on small delicate skins; when it is desired to confer some of the properties of Russia leather upon undyed, or Morocco leathers, the quantity of birch oil necessary is very small.

The method of manufacturing the oil of birch in Russia is somewhat rude. The white membranous matter of the bark of the tree, deprived as much as possible of woody fibre, is introduced into an iron vessel of suitable dimensions till the latter is full, when the cover, of an exterior convex shape, is fixed on. From the middle of this lid an iron tube issues, and enters to about three-fourths of the depth of another iron receptacle placed over the former. The edges of both vessels are well bolted and screwed together, and the whole inverted, so that that charged with the bark is uppermost, and the empty one beneath. In order to condense the oil as much as possible, the empty receptacle is buried in the ground to keep it cool; the top one is then secured by a coating of cement made of clay and sand, and when dry, surrounded with a wooden fire till it is raised to a red heat, which is continued till the distillation is completed. When the two vessels are detached, the upper one is found to contain a light friable charcoal, and that serving as a condenser, a brown oily empyreumatic liquid, possessing a very strong odor, some tar, and pyroligneous acid. The product, being depurated from tar and acid, is retained in well-closed vessels for the use of the currier. In France, the bark is distilled in copper vessels, and the heavy oil condensed in a tube passing through water, or an ordinary worm. About six per cent. of the bark passes over, but the oil, which is highly colored, is not very abundant; by rectification, however, it can be obtained almost colorless, in which state it is better adapted for oiling fine white leather than the original product, as it does not leave any stains.

It appears from the experiments of CHEVREUL, PAYEN, and CHEVALIER, that the principle to which the above oil owes its odor and other qualities, is a white pulverulent substance soluble in alcohol, which they call *betulin*; it is volatilized by heat, and condenses into crystalline needles; thrown upon live coals, it gives off thick white vapors similar to those emitted by Russia leather under similar circumstances, but more agreeable.

Hungarian Leather.—By the method long known and practised in Hungary, and latterly in France and other countries, leather is prepared in a rapid way, and without the aid of tannin—mineral salts being substituted together with other agents. The substance most generally resorted to for combining with and preserving the tissue of the skin, in other words, for converting the latter into leather, is sub-chloride of aluminum, produced by the decomposition of ordinary alum by common salt. This preserves the skin; and another kind of tanning process, with oil or tallow, gives the leather suppleness, and prevents it from forming a hard body. In this manufacture, the influence of the season, air, or other agents which affect the labors of the ordinary tanner are not felt, in consequence of the brief time it occupies, and the nature of the process. The requirements for carrying on the business are fewer and more simple than those of the ordinary tanner. They consist of a shed erected on the banks of a stream, wherein the beams for pairing, fleshing, and unhairing are arranged, and the knives, scraping stones, and other tools kept. A boiler and furnace for preparing the alum liquor is fitted up in one corner, besides which are two larger tubs for immersing the skins, together with a number of smaller ones. The other division of the factory, where the oiling is done, consists of a room six and a half feet high, by sixteen and a half square, capable of being rendered perfectly tight. One corner of this chamber is occupied with the furnace, over which is placed a copper pan capable of containing one hundred and eighty pounds of tallow; the sides are occupied by tables, whereon the skins are greased; the centre has a stone slab three feet and a quarter square, and on this an iron grating is fixed, whereon charcoal is burned for the purpose of flaming or heating the hides, as will be mentioned afterwards. The upper part is furnished with poles for hanging the skins on.

In tanning or preparing Hungarian leather, the principal preliminary processes are analogous to those already described, only that instead of liming for the depilation, the hair is carefully shaved off—that is to say, the skins are well washed, cut in halves, shaved, and steeped for twenty-four hours in the running stream.

The greatest care must be exercised, and the most expert workmen employed for fleshing, paring, and shaving off the hair, lest the skin should be injured, and at best the operation is tedious, so much so, that one man can work no more than a dozen or fifteen skins in a day. The shaving and washing being completed, the hides are passed through the first alum bath, composed of six to seven pounds of alum, and three and a quarter to four and a half pounds of common salt dissolved in eight gallons of water, for every hide of seventy-five

to eighty-five pounds weight. After raising the temperature of this solution to about 120°, or a little higher, the hides or sides are arranged in parcels of three or four in each, and deposited in two large tubs already mentioned, the hair side being uppermost.

As much of the liquor as will cover them is now poured in, and a workman stamps or treads them out, passing backwards and forwards till the piece exposed to this treatment is sufficiently worked, after which it is rolled up, and the same operation proceeded with till every one of the parcel has received the proper treading. After this, the partly-spent alum liquor is returned to the boiler; and as soon as its temperature is raised, another quantity is ladled into the vat, and the pieces of skin tramped out as above. A third and fourth treading is given, using warm liquor each time, after which they are folded up and deposited in a series of small tubs, about two feet high and eight inches in diameter, and the spent alum menstruum poured over them. They remain in these tubs for eight days, or longer in winter, being handled every day, and the liquor freshened. At the end of this time the strips of skin are taken out and shaken, or stretched, to remove creases, and then treated a second time exactly as in the first aluming, save that they are left only twenty-four hours in the small tubs, in contact with the saline water. After taking them out, they are laid one upon another on an inclined plane, in order that as much of the alum liquor as possible may run back into the vat. When thoroughly drained, the ends are pierced at the corners, and wooden rods or laths thrust through; then one of these is laid on cross-beams, and the piece of hide distended permitted to be freely suspended. Here they remain for eighteen hours, and then they are taken down, laid on the floor, and the workman, by folding and stretching, removes the wrinkles and creases; this done, they are laid one upon another, and left so for two days, then hung up by the laths on the cross beams till thoroughly exsiccated.

The dried skins, before they are fit to receive the oil, must be softened by treading them upon an inclined plane, suspended, as shown in the figure annexed, by upright and cross pieces firmly bound together. The strip of skin is laid doubled on this plane, and a smooth stick placed in the fold, and the workman, laying hold of the cross handrail, tramps upon the skin, and, by a shuffling motion of his feet and body, causes every part of it to be pressed and smoothened by the roller. To render the process more effectual, he wears thick-soled shoes. He continues the work of tramping and shuffling the stick about in the fold of the skin, till the latter becomes as soft and pliant as it is possible to make it. Each strip or piece is thus worked, and subsequently exposed for a short time, to be dried if necessary. After this

Fig. 352.



desiccation, they are again slightly trodden in the same manner as before, to erase any contractions and wrinkles, *et cetera*.

They are now fit to be greased, and, therefore, are submitted to this operation. The boiler, which occupies one corner of the air-tight chamber wherein this work is done, is three-fourths filled with tallow, fish oil, or whatever else is used for saturating the skins, and the whole heated by a fire outside the walls of the apartment. When the temperature stands a little above the melting point, a short-handled mop or dauber is dipped into it, and the fat spread equally in this heated state over the flesh side, after which the strip is turned, and the hair side brushed over with what remains in the dauber. Those which are first greased are laid upon one another, flesh side upwards, successively, till the entire number have been treated. They are allowed to remain for a time, to enable them to absorb the fat as much as possible before *flaming* them. For this purpose, a fire of charcoal is lighted on a grate, constructed on bricks in the centre of the room, and whilst it is being lighted, the workmen, two in number, leave, closing the door tightly after them. As soon as the charcoal is thought to be incandescent, they open the door to allow the carbonic acid to escape, and then enter, and taking the top strip of the pile, each by one end, expose it, flesh side downwards, to the glowing fire, holding it at some distance, and at the same time stretch it in all directions. The first so treated is laid on an adjoining table, and the others as they have passed through the same operation are piled upon it, the whole being covered with cloth as a protection against cold draughts and the unequal effects of the fire. This treatment aids in the absorption of the oil, and the stretching given at the same time improves the product. After an interval of an hour, the hides or sides are deprived of the excess of fat by wiping them. They are then thrown across poles to dry, flesh side outwards. The last exposure gives them a consistency, owing to the combination of the fat with the tissue and the saline matter united to it. The direct rays of the sun and an increased heat are to be avoided in this final airing, as neither is conducive to the improvement of the article. After this airing the sides are weighed, stamped, or marked, and put up for the market.

Hungarian leather prepared in this way, without the intervention of acids or alkalies, fermentation, or other matters and processes that are known to be more or less injurious when making leather with tan, preserves all the tenacity and body of the skin, combined with strength and great suppleness; for which, and for its tractive power, it is much used by saddlers and harness-makers.

TAWED LEATHER.—In the preparation of this kind of leather, the conserving agent resorted to is a subsalt of alumina, just as in the manufacture of Hungarian leather. The skins most generally treated are those of sheep, lambs, and kids, together with a few other light varieties. Generally the preliminaries required are performed in the ordinary way, only the skins being more tender, demand greater vigilance to preserve them from injury. They are well soaked in running

water for the purpose of cleansing. If dry, as in many cases, this steeping must be assisted by working or *breaking* them upon the beam with the back of the fleshing knife on the inner side. After another rinsing, the skins are smeared with cream of lime, or a mixture of lime and orpiment, gas lime, *et cetera*, on the flesh side, and then laid together in pairs, the hair side being outwards. According to the efficacy of the depilating agent employed, the time of the slacking of the skins extends from twenty-four hours to several days. However, as soon as it is found that the hair yields, it is separated, not in the usual way, but by plucking it out by sharp pincers. This being done, the skins are smoothened by a roller or some such means; then re-immersed for a short time in a weak lime-vat, from which they are removed to another steep, and left to soak therein for ten to fifteen days, with occasional handlings or examinations. When taken from the last vat, they are ready to be submitted to the bran vat or ferment, similar to those already mentioned, the proportions being forty pounds of bran in twenty gallons of water. In this mixture the skins remain for a period of a fortnight or three weeks in winter, according to the lowness of the temperature; but in summer, when the weather is hot, two or three days suffice to raise them sufficiently.

In any case, as soon as the skins sink in the menstruum—an occurrence which may be hastened by stirring them frequently—the action of the steep is known to be completed, and the skins are taken out and submitted to the first alum or *white bath*. This is composed of a mixture of thirteen to twenty pounds of alum, and three to four and a half pounds of chloride of soda dissolved in boiling water, the solution being afterwards diluted so as to saturate one hundred sheep skins. In summer the proportion of salt is increased, in order to preserve the skins from any injury of a putrefactive nature. The working of the skins is done in parcels, as in the preparation of Hungarian leather, each parcel being passed successively through the bath; after which, the whole are immersed for ten minutes. In some tanneries, instead of simply steeping the skins in the latter bath, the alum liquor is introduced at the proper degree of warmth, together with the skins, into a cylindrical vessel with means for revolving attached, and worked for the necessary time. The intimate contact of the skins with the whole of the liquid in this case promotes, it is said, the combination of the basic aluminous salt with the tissue, much more completely than is done in the other mode. The skins intended to remain white are then put into a paste, made by adding to the alum bath from fifteen to twenty pounds of wheaten flour, with gradual stirring, and the yolks of fifty eggs well whisked, and the whole contents of the bath well blended by brisk stirring. The skins are passed singly through this menstruum, which is about the consistence of honey, and afterwards the whole hundred are immersed, and allowed to remain in it during the night. After this they are taken out, and suspended on poles to dry, and left exposed for this purpose from eight to fifteen days, according to the weather, being occasionally stretched both ways. When sufficiently dry,

they are worked upon the *softening iron*, by which process any unevennesses are removed, the whiteness is developed, and the whole uniformly stretched. They are next fixed on hooks, where the stretching goes on—more, however, in the breadth than in the length of the skin—being worked during the period of their thorough desiccation with the stretching iron. In some cases the dried skins are submitted to a polishing process, by rubbing them with pumice and giving the final gloss with a smooth flat-iron.

These operations suffice for the preparation of tawed leather, in which the alum salt serves as tan, and the albuminous matter impregnated with it in the farinaceous bath supplies the place of oil or fat in giving greater suppleness and impermeability to the preparation than it otherwise would possess. Skins are frequently tanned by this process, with the hair retained and dyed. All the operations necessary in this case are the same as have been just detailed, with the exception of those that aim at the removal or softening of the hair, which are carefully guarded against. When dyed rugs are prepared, the wool is colored, previous to the commencement of the tawing, by any of the ordinary methods.

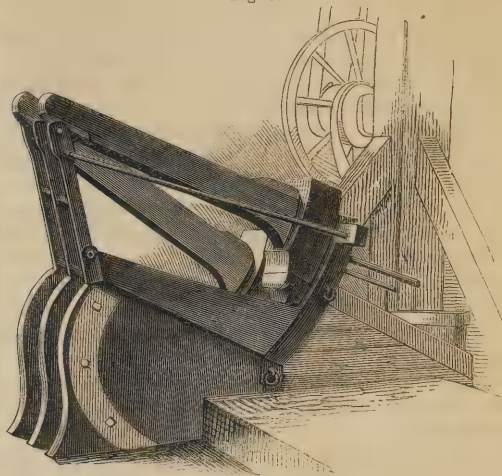
Tawed leather is occasionally colored. The tinctorial matter, whatever it may be, is laid on the grain side in a moistened state and while the skin is yet damp, and worked into it by means of a stretcher, after which treatment the polishing and smoothing take place.

OIL OR CHAMOIS LEATHER.—This article takes its name from the skins of the *chamois*; but, although the term is still retained, those of sheep, deer, lambs, and the thin portion of split hides and skins, are now converted into it. It is different from any of the varieties hitherto described, because neither tannin nor mineral matters enter into its formation; the conservation being entirely effected by means of oils and fats. Further, the finest, as well as the coarsest quality known as *wash-leather*, receive precisely the same treatment, and consequently the difference they present is owing to the circumstance, that the finest skins are chosen for the former, whilst the inferior ones are made into the latter. In the last, sixteenth, and earlier centuries, the trade in chamois leather was much more considerable than at present; because, in those periods, it was extensively used for clothing, particularly in the armies. It is now, however, abandoned for this purpose, in consequence of its permeability, owing to which it readily absorbed moisture, and parted with it but slowly; qualities which kept the wearer in continual danger of cold and rheumatic complaints.

In the manufacture of chamois leather the skins are prepared by passing through the lime vats, scraping on the horse, *et cetera*, in the ordinary way; and when these preliminaries are effected, and the lime removed in the lactic acid or bran vat, as much as possible, they are subjected to the *frizing* operation. This consists in rubbing them with pumice-stone, or the blunt end of a round knife, till the grain is entirely removed, the surface softened, and an equal thickness obtained throughout. After this the skins are squeezed or pressed, in order to remove as much water as possible.

With this view they are placed in the trough of a fulling mill, such as is represented in Fig. 353, after the large excess of water has been expressed, and are there subjected to the action of the wooden hammers till they become nearly dry. When this happens, they are

Fig. 353.



spread out on the table to receive the first charge of oil. That employed is usually cod oil, although any kind of animal oil is made to answer. When this has been sprinkled upon them, they are rolled up in bundles of four each, and then submitted to the action of the mill for a period varying from two to four hours, or until the oil has united or become absorbed in the pores of the skins. They are then taken out, unfolded, and exposed to dry for a short time; then a second oiling is given, followed by a fulling. It is necessary to repeat these operations several times, to insure the proper saturation of the skin fibre. However long the action of the fulling mill is continued, it is necessary to bring the aid of heat into requisition before the combination of the fatty matter with the skin is completed. Heat is applied generally by suspending the skins in a close chamber, furnished with steam pipes, or warmed with a stove to the proper degree. It is supposed that during this heating a fermentative change takes place, by which certain deleterious matters are destroyed, and the skin is afterwards better able to resist putrefaction, in addition to the more complete saturation of every part.

The greater dilution of the oil by the increased temperature of the stove-room causes part of it to exude on the surface, and this must be removed by immersing the skins in a wash or bath, made with soda or potassa in water, and of such density as will not dissolve the fibrous tissue. The skins are steeped for an hour, and handled in this bath, after which they are wrung at the peg and dried. To give the finish, the leather is worked with the stretcher on the table, then on the horse, and lastly, passed between rollers to give it the polish. The buff-color which generally, though not always, distinguishes chamois leather, is given by immersing the oiled skins in an infusion of oak bark,

and afterwards wringing, drying, *et cetera*. The tannin reacts here as a dye, and not as a tanning agent.

For supplanting the hand labor in *frizing* and other operations, NISBET has patented machinery by which rough bodies and knives, mounted on revolving cylinders, are made to rub against the skin. By this means a regularity in the thickness and texture of the skins is obtained, which could hardly be gained by hand unless more than ordinary attention were bestowed upon the work, while the time is curtailed to one-tenth of that required by the old method.

MOROCCO LEATHER.—*Maroquin*, French; *Saffian*, German.—Before the eighteenth century all morocco leather was imported from the Levant; but of the way in which it was prepared, nothing was publicly known till the account of GRANGER appeared in 1735. About the middle of the last century a manufactory was established at Paris, the first of its kind, in the Faubourg St. Antoine; this in a few years was followed by another; and from the impetus given by an increased demand, the trade continued to extend until, at the present time, there are several manufacturers of this article to be found in the different countries of Europe, and in the United States of America. Morocco is commonly known as a colored leather, having an indented or wrinkled fibrous appearance. The genuine or true variety is made from goat skins; but another kind, known as *imitation morocco*, is manufactured from sheep and lamb skins. As stated in the introduction, in connection with the subject of skins, the best kinds for this purpose come from Switzerland; but the English manufacturer draws upon other countries for his supply, such as Germany, Memel, Mogadore, East Indies, Cape of Good Hope, and several others. Compared with sheep skins, those of the goat have a closeness of fibre, a body, and strength that render them much superior in point of appearance and durability. In France, the Spanish goat skins are highly esteemed, and, consequently, a good many are imported from that country.

The skins usually come into the tannery in the dried state; and the operations required to render them as soft and pliable as fresh ones, and likewise to deprive them of epidermis, hair, and particles of flesh, are so similar to those already described in connection with the ordinary tanning processes, that a very brief account of the method of treatment will be sufficient. The dried skins are first immersed in water till they are sufficiently softened, and after this in a fermentable bath of a weak nature, such as has been used for a previous operation. Here the softening is considerably assisted; but it is necessary to watch its effects with much attention, lest it might be productive of injury to the skins. When it is thought they have acquired the proper degree of pliancy, they are worked on the flesh side with the disc or circular knife, to separate the fatty and fleshy matters, and likewise to remove the creases produced in the drying. This done, they are next submitted to the depilating agents, which consist of a number of solutions of lime, increasing in strength from the first to the last. Scarcely any difference exists between this part of the process and that which is followed in tanning upper-leather; but as the retention of lime or fatty matters is still more objectionable in skins

intended for morocco, owing to such matters being liable to produce spots or stains in the color applied at a future stage, greater attention and labor are required for their complete removal; hence after the unhairing, the fleshing, and paring of the head and leg parts, and the short steeping in lime-water which is usually given after this, the trimmed skins are introduced into a wooden cylinder moving upon an axis, and having interiorly a number of wooden pegs rounded at the end. This fulling machine is half filled with clean water, and, being charged with as many skins as it will conveniently hold, it is set in motion. By the action of the pegs and the movement of the skins and liquid, a considerable quantity of the lime is separated, the water of the cylinder being frequently renewed. To complete the depuration from lime, it is necessary to submit the skins to a bath of fermented bran or flour disseminated in water, or to one formed of dogs', pigeons', or pen-fowls' excrements, and called as usual the *bate* or *pure*. After being in one or other of these, as the case may be, from twelve to twenty-four hours, according to the strength and temperature, they are taken out and scraped on the beam on both the flesh and grain side, and examined for the purpose of rejecting those which are inferior or in any way damaged. In some instances, instead of the bran vat or *bate*, a solution of honey or a decoction of figs has been employed, together with a little salt, to steep the limed and unhaired skins in, on the principle of TURNBULL's patent, when the saccharine matter enters into a readily-soluble combination with the lime, and washes out with facility. In either case the more perfect skins which are set aside for the better quality of morocco, are prepared for the operation of dyeing, which with them generally takes place before the tanning, whilst the second and third qualities are colored after the tanning is executed.

Red Morocco.—The perfect skins are placed together two by two, so that the parts of one correspond with those of the other, the flesh side of each being inwards, and then sewed round the edges sufficiently close to retain the air, which is afterwards blown into them so as to swell them into a kind of bag. In this state, on being plunged into the mordanting liquor, only the surface destined to be dyed takes up the substance of the mordant, and consequently of the dye afterwards, and therefore no waste is incurred. The mordants are generally alum, chloride of tin, wine-stone, or such substances; but the tin-salt gives the finest shade of color. The mordant liquor of either of these, sufficiently diluted and warm, is put into a suitable vat or vessel, and the swollen skins immersed for a few minutes in it, then withdrawn and allowed to drain where the drippings may flow back to the vat. Afterwards they are worked on the beam with the view of giving them a grain, and expelling the excess of liquor more completely. This treatment prepares them for the dye, which is usually cochineal, as it gives the brightest color of any. For each dozen of skins from twelve ounces, or less, to sixteen is taken, according to the size. It is finely powdered, and suspended in water to which cream of tartar or some alum has been added. The whole is then boiled for

some time in a copper, filtered through a fine cloth, and divided into two equal portions to give two successive immersions. The skins sewed up thoroughly are placed in the tun with half of the dye liquor, and well agitated for about half an hour, after which time the liquor is replaced by the second portion, and the motion of the contents prolonged for a further half hour, when the dyeing will be completed. The skins are now taken out and submitted to the tanning operations, which are the same as will be presently described. Finally, the sewing is ripped; the skins—now tanned leather—well rinsed in fresh water, worked on the beam to render them supple and remove creases, dried, pommelled, slickered, and grained in the ordinary way. Sometimes the dye is brightened by passing a sponge saturated with a solution of carmine in ammonia over it, after the partial drying that follows the tanning and rinsing, *et cetera*. Also the skins are wetted with a decoction of saffron, in order to obtain a shade of color approaching to scarlet.

Morocco of other shades of Color.—Morocco leather of other colors is tanned previous to fixing the dye upon it. After the depilation and *bating*, or *branning*, as the case may be, the pelts are placed in a revolving cylinder with the tanning agent, which is always sumac, and a proper quantity of water slightly heated, and the agitation kept up for some time, by means of connecting or driving bands, and drums on the axis of the cylinder, and on the main or other shaft of the engine. The first tanning is given with sumac, partly or half reduced, and suspended in water, so as to form a thickish paste, and finished by substituting a new bath of fresh sumac; the motion of the cylinder being maintained whilst the skins and tanning agent are in contact. With this method, the formation of leather is very rapid, requiring only twenty-four hours. The tanned skins are now removed from the cylinder, rinsed, so as to clean them from the sumac, and exposed in the drying-room; and when the assimilated water is removed, they may be stored, or at once submitted to the process of dyeing, according to the requirements of the tanner. Another method is also much followed, as well with skins that have been dyed red as with those not so treated; it consists in employing a decoction, or *ooze* of sumac, and filling the skins with it, they being sewed two and two together for this purpose, having the flesh sides inwards, as already detailed. A quantity of powdered sumac is then introduced into each through the aperture, and afterwards a decoction of the tan; the opening is now secured, and the bags thus formed are deposited in a large tun, likewise containing a solution of sumac tan, as represented in Fig. 354, where they are floated and moved about, so as to expose every part of the skin to the action of the tanning agent. When the solution and tan in the leather bags are supposed to be exhausted, the bags are taken out and laid on the rack adjoining the tun, where they drain for some time; they are again filled with the strong solution, floated and moved about in the large tub as before, till the tannin has entered into combination. They are now removed from the tun, placed to drain, till the contained liquor is emptied into the tun, ripped, and cleaned from the

debris and impurities of the tanning material by thorough washing in cold water. Any wrinkles are removed by working on the beam before exposing them on the drying loft. During the desiccation, the skins shrivel so

Fig. 354.



much as to necessitate their immersion in water for some time, or the fulling of them in a machine such as is used for making chamois leather, tepid water being used. After fulling, several workings on the beam are given, as well on the hair as on the flesh side, in order to remove the excess of sumac. One of these workings consists in beating the tanned skin upon a table studded with round-headed pegs, with the view of breaking up the small fibres, which otherwise, by their contraction or expansion, would cause the articles made of this kind of leather to become deformed. They are placed one upon another, flesh side inwards, and stitched round, or indented with a blunt knife round the border, so as to keep them temporarily together, whilst they are being handled in the color-vat, and to prevent the dye being deposited on any other part than the grain side. For all the shades of color, with the exception of blue and black, a steep of Campeachy wood is employed, heated as hot as the hand can bear; this is put into a rectangular vessel, and the two skins laid into it carefully, and pressed and worked, so as to induce the penetration of the liquor, but not to remove them from one another. Several immersions are required with fresh coloring matter, till the proper tint is obtained. Much practice and attention are necessary to immerse and work the skins in the dye-vat, in order to stain them efficiently, and prevent the color running on both sides.

Black morocco is prepared by applying with a brush, on the grain side, a solution of sesquiacetate of iron. The azure tint is given by means of the cold indigo-vat, or with Prussian blue; violets and purples are produced by giving two coats of blue, and afterwards passing the skins through a bath of cochineal, the strength of which is regulated according to the shade required; yellows are obtained by working with quercitron root, finely ground and digested to abstract the color; this dye is very brilliant and stable. By modifying the work and multiplying the immersion and baths, any shade intermediate between those described can be obtained.

The dyed skins are now placed on the plate of the hydraulic press, and the excess of dye-stuff expressed, after which they are worked on the beam, to remove creases or wrinkles, and dried; first spontaneously in

a current of cold air, and afterwards in a heated atmosphere. Before being perfectly dry, however, they are worked with the knife, slicker, and pommel, as in the operation of currying, whereby they acquire suppleness and equality of substance throughout. They are then well polished, and the peculiar grain of morocco leather given. The latter is done sometimes by hand, but more generally by machinery.

Rollers, having raised parallel straight or diagonal threads, give the indented or wrinkled appearance, which distinguishes this kind of leather. When the skins are merely tanned, as when intended for the shoemaker, and then curried, the operations of the last process are such as are applied to delicate calf skins, only that as the goat skins are so much thinner, much greater care and delicacy of manipulation must be exercised in all cases.

SKIVER AND ROAN.—*Skiver* is a leather prepared from sheep skin and sumac, like imitation morocco, only the skins are split by machinery. In tanning the sections, however, the practice differs from that followed when preparing the morocco leather, inasmuch as the sewing of the skins into bags is omitted, the extreme thinness of that intended for skiver adapting it to combine with the tan more readily when spread out in the ooze. *Roan* is sheep skin tanned like morocco leather in all its details, but wanting the grain given to the latter by the grooved rollers in the finishing processes.

Before closing this article, it may be proper to give a short notice of two other materials, which, though not leather in the proper sense of the term, are nevertheless analogous to it; these are Parchment and Shagreen. Both are prepared from the same kinds of skin, but generally the stronger and coarser kinds are reserved for the latter.

PARCHMENT.—This article, undoubtedly of Eastern origin, is said to be the invention of EUMENES, king of Pergamus, in Asiatic Turkey, who reigned about 200 years before CHRIST. It was much used as a substitute for the papyrus, owing to its durability; and even at the present time it is the article in general use for valuable writings, such as deeds, wills, and the like. The fine parchment used for such purposes is manufactured from the skins of young calves, kids, still-born lambs, sheep, and goats; but when intended for coarser purposes, such as drum-heads and the like, those of older calves, wolves, asses, and *he-goats*, are taken. Soaking or fulling, liming till the hair is softened, scraping, fleshing, and washing, prepare the skins for the process of conversion into parchment, properly so called. It consists firstly in stretching the cleaned pelt upon a circular hoop, or more generally upon a stout rectangular frame, furnished with holes, pins, and screws, or skewers and cords, for exerting any required tension. This machine is usually fixed against the wall of the building, for the purpose of facilitating the scraping and rubbing of the drawn skin, after it has been sufficiently extended by the pins and skewers. The preliminary scraping effected with a double-edged semicircular knife, formerly referred to, removes adhering flesh and other extraneous matter. After the fleshing, the frame is turned, and the grain side carefully rubbed with the blunt edge of the knife, to

throw off the exudations of dirt and moisture. Then follows the *grinding*, which consists in sprinkling the flesh side with finely-powdered chalk, or slaked lime, and rubbing with a piece of pumice-stone, the face of which is previously flattened upon a sandstone. By this operation, a further portion of the assimilated moisture is taken up. A slight rubbing with the pumice-stone is then given on the grain, but no lime is used, and afterwards the drying is allowed to go on gradually out of the sun's rays. In cold weather, the freezing of the moisture in the skin would be injurious; and is, therefore, carefully guarded against by keeping the temperature of the room above 32°, or by protecting the skins with cloths. Towards the completion of the desiccation, the skewers are further tightened. Finally the white appearance given by the lime is removed by careful rubbing with the woolly side of a lamb skin. Should grease stains be now detected, it is necessary to immerse the skin anew in a lime-pit for eight or ten days, to remove them; this induces the formation of a lime soap with the fatty matter, and consequently the deletion of the spots. The pelt is again stretched on the *horse* or frame, and dried, and then transferred to the *scraper*, who mounts it upon a frame like the last, the tail end downwards, and stretches it with cords only, on a support of well-extended crude calf-skin. Here it is carefully pared with a larger and sharper knife, but similar to the one used for *fleshing*, to remove inequalities, and then scraped on the grain or outside, till a perfectly even, smooth surface is given. Whatever is wanting in this operation, is remedied by a further rubbing with a very fine-faced piece of pumice-stone on a cushioned support. Any defects in the skin, such as holes and the like, are removed by carefully paring round the edges of the injured part, and tastefully patching suitable pieces on with gum-water.

The green color of parchment is given by spreading with a brush a solution, made with thirty parts of crystallised acetate of copper and eight of bitartrate of potassa in five hundred of rain or distilled water, four parts of nitric acid being added to the mixture when cold. It is necessary to moisten the skin before applying this dye. Finally, the lustre is given by rubbing the surface with a solution of albumen or gum arabic.

SHAGREEN.—The article known under this title is very analogous in its nature to parchment, and consequently is not a true leather. Like parchment, it was originally an Eastern preparation, and is still principally obtained from Astracan and Asiatic Russia. From the accounts obtained of the manufacture, it appears that only the hides of horses, asses, and camels, are appropriated to its production, and of these only the small strip from the crupper along the chine to the neck is used.

The strips, cut out of the proper size, are steeped in water till the hair softens and gives readily, when it is removed by scraping; they are again steeped and worked by the *flesher*, till all matter extraneous to the skin is separated, and the skin itself is reduced to the proper thinness. They are now mounted on the *herse*, or horse, and stretched thoroughly, being occasionally moistened to favor the stretching.

As soon as this has been carried sufficiently far, the strips of skin are placed on the floor and covered on

the grain side with the seeds of the *alabuta* or goose-foot—*chenopodium album*. A covering of felt is then laid on, and the seeds are pressed into the skin by trampling on them, or by the use of mechanical pressure. The skins, still bound in the frames, are then dried, till the seeds begin to drop, when the latter are shaken off. At this stage the skins appear dry, horny, and deeply indented. They are next placed on a padded horse, and shaved till the indentations caused by the seeds become very shallow and of uniform depth, after which they are steeped in water and then in a hot alkaline lye, and piled one upon another whilst in a hot moist state. During the time they are so left, the compressed parts swell out, forming as it were embossed balls on the skin, and thus constitute the peculiar appearance of this preparation. Shagreen is dyed of various colors; red is obtained with a decoction of cochineal, in the same way as morocco; blue by the cold indigo vat; black, by steeping the skin, or brushing on the side intended for the dye, a solution of tannin, and afterwards one of sulphate of iron—copperas; and green, by moistening with a dense solution of chloride of ammonium—sal-ammoniac—and sprinkling the part so moistened with copper turnings and rolling up the strip, keeping the grain

side inwards. The ammoniacal salt dissolves a portion of the metal and forms a subsalt with it, which enters into combination with the skin, and gives a bright hue. To finish the article, the dyed strips are carefully greased and worked in hot water, then rubbed with blunt tools and dried.

Shagreen of an inferior quality has been made from sheep, goat, horse, and even fish skins; the treatment they receive is analagous to that already described, but for the most part, where the skin is weak, a slight tanning is allowed before shaving, and the skin is stretched more in the direction of its length than crosswise. The grain is given by pressing the prepared skin on warm copper plates, engraved so as to imitate the appearance of the genuine shagreen.

In preparing this account of the leather manufacture, much of the information, besides what has been derived from private sources, has been obtained from Doctor MORFIT's able work on Tanning, KNAPP's Technology, SCHUBART, DUMAS, PARNELL, SULLIVAN, the Catalogue of the Irish Industrial Exhibition, and other authorities.

STATISTICS.—The following table expresses the imported quantities of the principal tanning materials in 1849 in hundredweights:—

	Tanning bark, et cetera.	Terra Japonica.	Sumach.	Valonia.
Belgium,.....	141,392	—	140	—
Holland,.....	114,180	—	—	—
East Indian empire,.....	—	169,140	—	—
Naples and Sicily,.....	1,166	—	218,380	—
Turkey,.....	—	—	—	296,000
America,.....	42,318	—	—	—
Australian territories,.....	—	—	29,840	15,820
Morocco,.....	27,619	—	—	—
Norway,.....	12,784	—	—	—
Spain,.....	9,594	—	440	—
Tuscany,.....	9,931	—	20	4,320
Australia,.....	4,563	—	—	—
Syria,.....	—	—	—	4,280
Greece,.....	—	—	—	10,480
Miscellaneous,.....	5,035	—	2,980	2,520
Total,.....	368,582	169,140	251,800	333,420

MAGNESIA.—English and French; *Talkerde*, *Bittererde*—German.—This is one of the primitive earths, and was first discovered by Sir HUMPHREY DAVY to be the oxide of a metal which he designated magnesium, and which LIEBIG has proposed to prepare by calcining a mixture consisting of chloride of magnesium and chloride of ammonium. Very great precautions are requisite in this method, and especially the most complete desiccation. On the mixture being dried, the ammoniacal salt begins to volatilize; the mass is to be pulverized and reheated, in order to expel the last traces of moisture. The difficulties which this operation presents, and the errors to which it frequently gives rise, induced BUNSEN to seek for a less doubtful and convenient method of procuring this singular metal. Now, the chloride of magnesium is decomposed with the utmost facility by the galvanic current when it is liquefied by heat. A few elements of a Bunsen's battery suffice for obtaining in a short time several grammes of product.

Take a platinum crucible equally divided by a vertical diaphragm for half the height of the vessel; this diaphragm is necessary for the protection of the mag-

nesium, in proportion as it is released from the action of the chlorine, which is liberated at the positive pole of the battery. The crucible is closed with plugs of fire-clay, traversed by two charcoal stems constructed as for batteries. These stems form the poles; that which corresponds to the negative pole is hollowed with cavities or channels for the purpose of retaining the magnesium, which, if this precaution were omitted, would float on the bath of fused chloride of magnesium, in which it would be burned.

Magnesium is silvery white, has a crystalline and sometimes fibrous fracture, is malleable, ductile, and fusible at a dull red heat; it is sufficiently hard, however, to work under the file and chisel. Its specific gravity, as determined by various experimenters, ranges from 1.87 to 2.24. Dry air produces no action upon it, but in damp it is tarnished, and covered with a layer of magnesia. At a red heat it consumes with a brilliant white flame. Cold water is only very gradually and with difficulty decomposed by this metal, which is quickly dissolved in acidulated water. Finally, it ignites when brought into contact with hydrochloric acid, whilst concentrated sulphuric acid dissolves it with difficulty.

Oxide of magnesium, or *magnesia*, is a fine, light, white powder, void of taste or smell. It requires for complete solution more than five thousand parts of cold, and *thirty-six thousand* parts of boiling water. Its specific gravity is 2.30. It is fusible only by the heat of the oxyhydrogen blow-pipe. Magnesia changes the purple infusion of red cabbage to a bright green. It attracts carbonic acid very slowly from the air. Its equivalent is 20, and its composition as under:—

		Centesimally.
1 Eq. of magnesium,.....	12	60.00
1 Eq. of oxygen,	8	40.00
1 Eq. oxide of magnesium,.....	20	100.00

This oxide occurs in nature as carbonate, forming immense masses of rock in various parts of the globe; also associated with carbonate of lime under the forms of dolomite and magnesian limestone; and as sulphate of magnesia—Epsom salts—occurring in many saline springs.

It is best obtained pure by heating the carbonate to redness; but it is also procured by precipitating with potassa or soda the sulphate, filtering and well edulcorating the deposit with distilled water.

Carbonate of potassa or soda causes a precipitate in solution of magnesia; but carbonate and sesquicarbonate of ammonia, owing to the formation of a soluble double salt, gives only a partial precipitate; and, for the same reason, oxalate of ammonia does not occasion any turbidity in liquids containing magnesia. By this last character the earth is separated from lime. The most delicate test for magnesia in a solution is to add, first, carbonate of ammonia, then phosphate of soda— 2 Na O, HO, PO_5 —which forms an insoluble double phosphate of magnesia and ammonia— $2\text{ Mg O, NH}_4\text{ O, PO}_5$ —in the form of a dense crystalline powder. It will be at once seen, that in the above change the ammonia merely replaces the water in the phosphate of soda. The salts of magnesia are isomorphous with those of oxide of zinc.

Physiological Effects.—When taken inwardly, magnesia neutralizes the free acids contained in the stomach and intestines, and forms therewith soluble salts.

As an *antacid* it is as efficacious as the alkalies, while it has an advantage over them in being less irritant and not caustic, and thereby is not apt to occasion any derangement of the digestive organs. It may be employed to neutralize acids introduced into the stomach—as in cases of poisoning by the mineral acids—or to prevent the excessive formation of, or to neutralize when formed, acid of the animal economy. Thus it is administered to relieve heartburn, arising from, or connected with, the secretion of an abnormal quantity of acid by the stomach; its efficiency is best seen in persons of a gouty or rheumatic diathesis, in which the urine contains excess of uric acid. It relieves the headache to which such individuals are not unfrequently subject. It is most efficacious in diminishing the quantity of uric acid in the urine in calculous complaints; and, according to BRANDE, it is sometimes effectual where the alkalies have failed.

As a laxative, magnesia is much employed in the treatment of diseases of children. It is tasteless, mild

in its operation, and antacid—qualities which render it most valuable as an infant's purgative. Independently of these, HUFELAND ascribes to it a specific property of diminishing gastro-intestinal irritation by a directly sedative influence.

As a purgative, the dose for adults is from a scruple to a drachm; for infants, from two to ten grains. As an antacid, the dose is from ten to thirty grains twice a day. It is conveniently given in milk. Magnesia has been used with success as an antidote to arsenic. —*Pereira.*

The Editor will now describe cursorily those salts of magnesia which are of importance, and which are much used in the arts.

SULPHATE OF MAGNESIA.—This salt is found in certain mineral springs, as those of Seidlitz, Leydschütz, Egra, and formerly Epsom, in Surrey, whence the name *Epsom salts*. Dr. GREW first obtained it from the Epsom waters. It has had a variety of names, such as *bitter purging salt, sal anglicum, sal seidlitzense, sal catharticum*, and *vitriolated magnesia*. At the Lymington Salt Works, says PEREIRA, it is called *physical salt*, to distinguish it from common salt. Its presence in the above-named springs appears to proceed from the reaction of the sulphate of lime, held in solution, upon the magnesian limestone of the soil.

Sulphate of magnesia is also obtained by the action of sulphuric acid upon calcareous rocks rich in carbonate of magnesia, such as *dolomite*. The compound is calcined, and reduced to powder by being aspersed with water; it is then diffused through water, and sulphuric acid is added: sulphate of lime and sulphate of magnesia are formed, the one barely soluble in water, and the other very much so; consequently, they are readily separated.

Epsom salts are also extensively made from the bitter or mother-liquor remaining after the evaporation of sea water, and the separation of the chloride of sodium therefrom.

At Lymington, in Hampshire, sulphate of magnesia is manufactured from bitter during the winter months. The liquor is boiled for some hours in the pans used during the summer for the preparation of chloride of sodium. During the ebullition, some chloride of sodium deposits. The lighter impurities are separated by skimming, and the strong solution is removed into wooden refrigerators, where, in a day, one eighth part of crystals of sulphate, called *single Epsom salts*, or *singles*, are deposited. These are drained, dissolved, and recrystallized; they are then termed *double Epsom salts*, or simply *doubles*.

At Monte della Guardia, near Genoa, sulphate of magnesia is prepared from schistose minerals containing sulphur, magnesia, copper, and iron. PEREIRA states that the ores, after roasting, are converted into sulphates by moistening, *et cetera*. They are then lixiviated, and the solution is deprived, first of copper by refuse iron, and afterwards of iron by lime. At Baltimore, sulphate of magnesia is procured from the silicious hydrate of magnesia, or *marmolite*, by reducing the mineral to powder, saturating with sulphuric acid, and calcining the dried mass to sesquioxide of iron. It is then redissolved in water, heated with

sulphide of calcium to remove the remaining iron, and crystallized. By a second crystallization it is obtained nearly pure.

A very large quantity of sulphate of magnesia is manufactured at Newcastle-upon-Tyne. It is made from magnesian limestone, calcined and washed to separate the lime, then adding sulphuric acid, *et cetera*. Another mode is by calcining rough Epsom salts along with magnesia.

From Magnesian Limestone.—In England, says KNAPP, the sulphate is sometimes manufactured directly from magnesian limestone and sulphuric acid, in conjunction with other products. The carbonic acid produced by the action of the sulphuric acid is employed in the manufacture of bicarbonate of soda, while the mixed sulphate of lime and magnesia are thrown into large wooden vessels, fitted with a false bottom. Water is now poured upon the thick mass, and drawn through by the action of a pair of pumps, worked from an engine shaft in any convenient manner. In this way, the whole of the sulphate of magnesia is extracted with the least expenditure of water; and the solution, after being pumped into a reservoir, is allowed to filter through layers of sandstone and charcoal, to render it clear and bright. The menstruum is now concentrated by evaporation, and made to crystallize as rapidly as possible, in shallow wooden troughs lined with lead, in order that the crystals may be as small as possible, to meet the prejudice of the trade in this respect. The sulphate of lime left on the filter or false bottom is worked up in the manufacture of Venetian red.

The process, however, which is more generally pursued is as follows :—

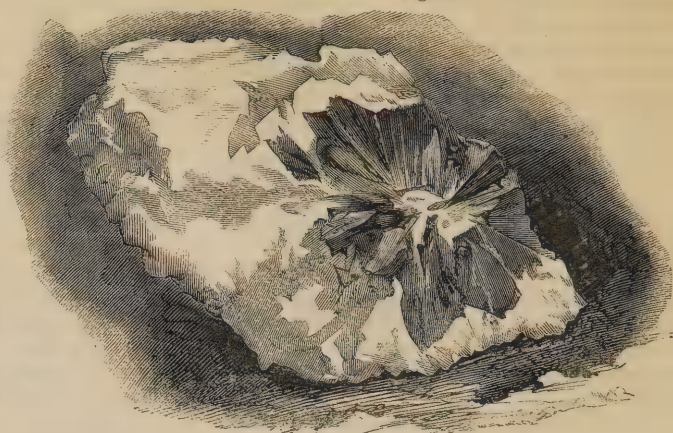
Magnesian limestone is calcined in an ordinary lime-kiln, and repeatedly washed with water to remove as much of the lime as possible. The extent to which this is carried may be inferred from the following analyses, by RICHARDSON, of a sample of lime in its natural state, and after it had been calcined and washed :—

NATURAL.	
Carbonic acid, <i>et cetera</i> ,	47.12
Lime,	27.49
Magnesia,	22.22
Insoluble matter, alumina, <i>et cetera</i> ,	3.17
	100.00
WASHED.	
Water, <i>et cetera</i> ,	32.51
Lime,	7.34
Magnesia,	44.41
Insoluble matter, alumina, <i>et cetera</i> ,	15.74
	100.00

The limestone selected by the manufacturer for this purpose is soft, and similar to that known as *flexible*; such samples as have the appearance shown in the engraving—Fig. 354—do not usually contain so much magnesia.

From Refuse Alum Liquors.—In the manufacture of alum as conducted near Whitby, the *salts' mothers*,

Fig. 354.



according to RICHARDSON, contain in the gallon :—

	Grains.
Sulphuric acid,	2697.61
Sulphate of magnesia,	8190.40
Sulphate of alumina,	852.24
Sulphate of potassa,	3693.32
Sulphate of manganese,	106.06
Sulphate of nickel and cobalt,	traces
Sulphate of iron,	3026.67
	19286.30

Which, by crystallization, produces a crude sulphate of magnesia, called *Rough Epsoms*, and having the following composition :—

Sulphuric acid,	32.26
Magnesia,	15.35
Protoxide of iron,	1.73
Oxides of nickel and cobalt,	0.12
Lime,	0.09
Alumina,	1.33
Potassa,	0.83
Water,	48.29
	100.00

These rough Epsoms are mixed with the magnesian lime in such proportions that all the sulphuric acid, except that in combination with the potassa and magnesia, is taken up by the free alkaline earths. The mixture is then calcined in an ordinary reverberatory, at a dull red heat, which assists the transfer of the sulphuric acid, and raises the metals to a higher degree of oxidation, thereby insuring their insolubility. The calcined product is afterwards thrown into a large circular cistern, filled with water, and in which a pair of edge-stones are made to revolve by suitable machinery. By this arrangement, the large pieces are ground to powder, while the agitation produced by the motion of the edge-stones facilitates the solution of the Epsom salt.

The sulphate of magnesia liquor is subsequently clarified in the manner previously described, and crystallized in the usual hollow pans. When the liquid has drained off from the crystals, they are removed to a stove, and exsiccated at a low temperature. In this

dry state, they are thrown into a species of sieve or temse, which reduces still further the size of the crystals, and renders the whole of a more uniform appearance.

From Native Carbonate of Magnesia.—Mr. CHANCE has lately imported a very pure natural carbonate of magnesia from the Mediterranean, to which he adds sulphuric acid, and proceeds in the usual way for the production of the sulphate; and having, it is understood, secured the entire produce of the mine, he is likely to become a formidable competitor to the other manufacturers.

Another article which is manufactured to some extent, requires a passing notice, namely, the salt termed *Mock Epsoms*, which is simply sulphate of soda crystallized very rapidly in shallow vessels, for the purpose of adulterating the genuine article.

The sulphate of magnesia crystallizes in right prisms, which at 60° are soluble in their own weight of water. When exposed to the air, they effloresce, and are reduced to powder. The intensely bitter taste of this salt is well-known. It is composed of,—

	Centesimally.
Magnesia,.....	16·26
Sulphuric acid,.....	32·52
Water,.....	51·22
	100·00

Mr. ALEXANDER S. STEVENSON informs the Editor that about two thousand tons a-year are made in Great Britain, and of this quantity the Jarrow Chemical Company of South Shields produce one half.

Hydrated sulphate of magnesia, $\text{MgO}, \text{SO}_3 + 7 \text{HO}$, crystallizes at the ordinary temperature, in four-sided prisms, with reversed dihedral summits or four-sided pyramids. They are doubly refracting, and their density is 1·70. When crystallized at a high temperature, the salt contains only six equivalents of water, and if crystallized below 32°, large crystals are the result, having twelve equivalents of water. If heated to 460°, sulphate of magnesia still retains one equivalent of water, but it becomes anhydrous beyond this degree of heat; hence the Editor represents its composition as follows— $\text{HO}, \text{MgO}, \text{SO}_3 + 6 \text{aq}$. The crystals are soluble in about three ounces weight of water at 60°, and in three-fourths their weight of boiling water—as given by TOMLINSON. One hundred parts of water at 32° dissolve 25·76 parts of the anhydrous salt, and for every degree above this temperature, the water takes up 0·26564 parts additional. It is somewhat remarkable that sulphate of magnesia is much more readily dissolved by hydrochloric acid than by water. Sulphate of magnesia is insoluble in alcohol. Pure crystals exposed to the air have a slight tendency to effloresce; the commercial article always deliquesces on account of the presence of more or less chloride of magnesium. Sulphate of soda is often used to adulterate the sulphate of magnesia; the fraud is easily detected by exposing a portion to the blowpipe flame. If any soda be present, the characteristic yellow color appears.

Annexed is the centesimal composition of the official Epsom salts:—

		Theory.	Found.
1 Eq. Magnesia,.....	20	16·26	16·04
1 Eq. Sulphuric acid,...	40	32·52	32·53
7 Eqs. Water,.....	63	51·22	51·43
	123	100·00	100·00

Physiological Effects.—In moderate doses, sulphate of magnesia is a mild and perfectly safe antiphlogistic purgative, which promotes the secretion as well as the peristaltic motion of the alimentary canal. It is very similar in its operation to sulphate of soda, than which it is less likely to nauseate, or otherwise disorder the digestive functions, while it acts somewhat more speedily on the bowels. It does not occasion nausea and griping, like some of the vegetal purgatives, nor has it any tendency to create febrile disorder or inflammatory symptoms; but, on the other hand, has a refrigerant influence: hence it is commonly termed a cooling medicine. In small doses, largely diluted with aqueous fluids, it becomes absorbed, and slightly promotes the action of other emunctories: thus, if the skin be kept cool, and moderate exercise conjoined, it acts as a diuretic. Dr. CHRISTISON mentions a case of supposed poisoning, in a boy of ten years old, by two ounces of Epsom salts. The symptoms were, staggering, imperceptible pulse, slow and difficult breathing, extreme debility, and death within ten minutes, without vomiting. More recently, an old man, a confirmed drunkard, was poisoned by imbibing several pints of beer drugged with sulphate of magnesia. He was seized with violent purging, and died within forty-eight hours. The quantity taken was not ascertained, but there is reason to believe the dose was large.

On account of the mildness and general safety of its operation, its ready solubility, and its cheapness, sulphate of magnesia is by far the most commonly employed purgative, both by the public and the profession. The only objection to its use is its bitter and unpleasant taste. To state all the cases in which it is administered would be to enumerate nearly the whole catalogue of known diseases. It must, therefore, be sufficient to mention, that it is excellently well adapted as a purgative for febrile and inflammatory diseases, obstinate constipation, ileus, lead colic, even incarcerated hernia, narcotic poisoning, *et cetera*. It may be used as an antidote in poisoning by the salts of lead and baryta.

As a purgative, it is usually administered in doses of from half an ounce to an ounce and a half; but if taken in the morning, fasting, a smaller dose will suffice. Sulphate of magnesia is extensively used by veterinary surgeons.—*Pereira*.

CARBONATE OF MAGNESIA.—This compound is known in the mineral kingdom as *magnesite*; it is found in Piedmont and Moravia, and also in North America, in veins of serpentine, accompanying the native hydrate. It also occurs in combination with carbonate of lime, with which it is isomorphous. Most of the calcareous rocks contain a small quantity of magnesia. In the species of marble called *Dolomite*, which occurs abundantly in the Alps, about forty per cent. consists of carbonate of magnesia; the marble itself is a double carbonate of lime and magnesia, $\text{CaO}, \text{CO}_2 + \text{MgO}, \text{CO}_2$. The magnesian limestone of Derby and Nottingham is

generally of a yellowish color; it dissolves less rapidly in dilute hydrochloric acid than the purer limestone, whence the French term it *chaux carbonatée lente*. It affords excellent lime for cements, but is not adapted to agricultural purposes, probably in consequence of the lime remaining so long caustic.

When an alkaline carbonate is poured into a solution of a salt of magnesia, a white gelatinous precipitate is formed, which is a hydrated carbonate of magnesia, or a combination of the hydrate and of the carbonate. The proportions of these two compounds vary according to the quantity of alkaline carbonate employed, the strength of the solutions, and the temperature. This product is made in large quantities in pharmaceutical chemistry, and is the *magnesia alba* of the pharmacopœia. Two kinds, identical in composition, are prepared, namely, the *light* and the *heavy*. For *heavy* magnesia, add one volume of a cold saturated solution of carbonate of soda to a boiling mixture of one volume of a saturated solution of sulphate of magnesia, and three volumes of water; boil until effervescence has ceased, constantly stirring with a spatula; then dilute with boiling water, set aside, pour off the supernatant liquor, and wash the precipitate with hot water on a linen cloth; afterwards dry it by heat in an iron pot. *Light* magnesia is prepared by employing dilute solutions of the sulphate of magnesia and carbonate of soda. If no heat be used, it is apt to be gritty.

A heavy granular magnesia is prepared by separately dissolving twelve parts of sulphate of magnesia, and thirteen parts of crystallized carbonate of soda, in as small a quantity of water as possible, mixing the hot solutions, and washing the precipitate. The light cubes of magnesia are prepared as follows:—A solution of one hundred parts of sulphate of magnesia in one hundred of water, is put into a vat heated by steam; a solution of one hundred and twenty-five parts of crystallized carbonate of soda is quickly stirred into it, and the temperature raised to 176° , to expel carbonic acid, which holds some of the magnesia in solution; the liquor is then decanted off the precipitate, and this is washed three times by subsidence, and decantation with lukewarm water, free from salts of lime. It is then transferred to linen strainers, and allowed to drip from twenty-four to forty-eight hours, and is transferred in a wet state to cubical boxes without bottoms, placed upon a table of plaster or porous stone, which quickly absorbs the water: after some time, the boxes are turned upside down, so as to present the upper side of the magnesia to the absorptive surface: the exsiccation is completed in warm rooms.—*Tomlinson*.

PEREIRA remarks that the *heavy* carbonate of magnesia is a granular substance, and contains no traces of the prismatic crystals observed in the light carbonate. When submitted to microscopic investigation, it is seen to consist of granules of various sizes; the larger ones are highly refractive, globular, and composed of concentric layers of a radiated structure. When examined by the polarising microscope, they are found to possess a doubly refracting structure; and, like the globules of carbonate of lime deposited from the urine of horses and bullocks, show the black cross. When

placed over a plate of selenite, and examined by polarised light, the quarters or spaces between the arms of the cross are colored: those next to each other show complementary tints—the alternate ones the same tints. Thus, if the first quarter be green, the third will be green also; but the second and fourth will be red.

The carbonate of magnesia of commerce is likewise obtained in various ways from bittern. It is also separated from magnesian limestone by a process adopted by Mr. PATTISON, which consists in calcining it at a dull red heat, by which only the magnesian carbonate is decomposed; the calcined stone is then diffused through water, and subjected to the action of carbonic acid, under pressure, by which the magnesia alone is dissolved, and is afterwards obtained by rapidly boiling down the solution. It is a beautiful white substance, very light, and without taste or smell. It dissolves in two thousand five hundred parts of cold, and in nine thousand parts of hot water, and is generally composed of—

	Centesimally.
Magnesia,	53.60
Carbonic acid,	41.73
Water,	4.67
	100.00

By passing a current of carbonic acid through a mixture of water and carbonate of magnesia, a clear solution is obtained, which, surcharged with carbonic acid, is a useful preparation that has been extensively advertised under the name of *soluble magnesia*, or *bicarbonate of magnesia*. This compound cannot be obtained in the solid or crystalline form, for the solution gives, by evaporation, oblique rhombic prisms of hydrated carbonate of magnesia, which on being put into cold water are decomposed, carbonate of magnesia being dissolved, and a subcarbonate deposited.—*Tomlinson*.

Citrate of Magnesia.—This is prepared by saturating a solution of citric acid with carbonate of magnesia. It is a white pulverulent insipid salt, very soft to the touch, heavier than magnesia, and when a slight excess of citric acid is present, is dissolved readily by water. Its composition is— 3 MgO , Ci , HO , or 3 MgO , $\text{C}_{12} \text{ H}_5 \text{ O}_{11}$, HO ; equivalent weight, 234.

It is a slight and agreeable aperient, and its superiority over other saline deposits consists in its being devoid of any disagreeable taste.

Tartrate of magnesia is obtained in a similar way to the preceding salt, substituting tartaric for the citric acid, and evaporating the solution to dryness at 212° . The resulting crystals consist of 2 MgO T , 8 HO , or 2 MgO , $\text{C}_8 \text{ H}_4 \text{ O}_{10}$ + 8 HO . Equivalent weight, 234. This salt has been used with success in painful chronic maladies of the spleen.

Sulphate of Magnesia.—This salt is now largely manufactured in Manchester, and is employed as a disinfectant, *et cetera*. Full particulars with regard to its use are given in Vol. I., page 565.

Steatite or Soap-stone.—This substance, remarks KNAPP, is known also under the more familiar names of Spanish or Venetian chalk, and is composed of silica,

magnesia, alumina, oxide of iron, oxide of manganese, and water. It is found in North America, Sala in Sweden, Cornwall, and China. It is employed in polishing articles made of serpentine, marble, sulphate of lime, and plate-glass; it is also sometimes used as a substitute for grease for the axles of carriages. It is further used for sketching in outline on silk, linen, and glass; as crayon; for painting on glass, and for removing stains in woollen and silk goods. It has also been added in some cases to the materials for porcelain, to improve the transparency, but it renders the mass much more brittle. The apparatus employed for the production of chlorine is occasionally manufactured from this material, as it resists the corrosive action of that remarkable gas.

Meerschäum.—Silicate of magnesia, under this name, is employed in manufacturing the celebrated tobacco-pipes; its composition is as follows:—

	Levant. Lychnell.	Madrid. Berthier.	Natalia. Thomson.
Silica,.....	60·87 ..	53·80 ..	42·00
Magnesia,.....	27·80 ..	23·80 ..	30·50
Lime,.....	— ..	— ..	2·30
Alumina,.....	0·09 ..	1·20 ..	2·00
Oxide of iron,...			
Water,.....	11·24 ..	20·00 ..	23·00
Loss,.....	— ..	1·20 ..	·20
	100·00	100·00	100·00

MEERSCHAUM FROM MOROCCO ANALYSED BY DAMOUR.

Silica,.....	55·00
Magnesia,.....	28·00
Alumina,.....	1·20
Oxide of iron,.....	1·40
Lime,.....	1·00
Potassa,.....	·52
Water,.....	10·35
Sand,.....	2·50
Loss,.....	·03
	100·00

Asbestos.—This material is of frequent use in the laboratory, and in the manufacture of various articles destined to resist the action of fire, such as lamp-wicks, *et cetera*. Annexed is its composition:—

	Kobell.	Richardson.	Thomson.
Silica,.....	43·50 ..	43·25 ..	40·95
Magnesia,.....	40·00 ..	33·85 ..	34·70
Oxide of iron,...	2·08 ..	10·90 ..	10·05
Alumina,.....	·40 ..		
Water,.....	13·80 ..	7·00 ..	12·00
Loss,.....	·22 ..	5·00 ..	1·00
	100·00	100·00	100·00

BRANDE states, that the salts of magnesia are mostly soluble in water, and bitter; they are all soluble in hydrochloric acid; their aqueous solutions are precipitated by potassa and soda, the precipitate being soluble in hydrochloric, nitric, and sulphuric acids, and in hydrochlorate, nitrate, and sulphate of ammonia. Ammonia only throws down part of the magnesia, and forms a double salt, and carbonates of potassa and soda only throw down part of the magnesia, except the solution be heated, when nearly the whole is precipitated. Chloride of ammonium redissolves the deposit, and when previously added to the magnesian solution, no precipitate ensues on adding the alkaline carbonates, unless the liquor be warmed. The bicarbonates of

ammonia, potassa, and soda, give no precipitate in magnesian solutions, except the liquor be boiled. Common phosphate of soda only precipitates concentrated magnesia solutions, but if ammonia or carbonate of ammonia be added, the magnesia is thrown down in the form of ammonio-magnesian phosphate. Moistened with nitrate of cobalt, and heated before the blow-pipe, *the magnesian salts give pale rose-colored compounds*: the tint is only distinct on cooling, and never very intense.

The separation of magnesia and lime is a problem of some importance in analytical chemistry, as they often exist together in the same mineral, especially in the varieties of magnesian limestone. PHILLIPS proposes the following process:—To the hydrochloric or nitric solution of lime and magnesia, add sulphate of ammonia in sufficient quantity; evaporate the mixture gradually to dryness, and then heat the residue to redness, till it ceases to lose weight, by the volatilization of the chloride of ammonium or nitrate of ammonia formed. Note the weight of the mixed salt, reduce it to powder, and wash it with a saturated solution of sulphate of lime till all the sulphate of magnesia appears to be dissolved; dry the sulphate of lime left, and by deducting its weight from that of the mixed sulphates, the quantity of magnesia dissolved will appear. Dissolve the two earths in hydrochloric acid in excess, and saturate the acid liquor by ammonia, then add oxalate of ammonia, and collect the precipitated oxalate of lime on a filter; the magnesia which is retained in the filtered liquor, may be thrown down by phosphate of soda in the form of ammonio-magnesian phosphate, or the solution may be evaporated to dryness, and the residue heated red-hot so as to leave magnesia. Evaporate the hydrochloric solution of the two earths to dryness, and expel the excess of acid from the residue, by heating in a platinum crucible: powdered chlorate of potassa is then added so long as the evolution of chlorine is perceived. On treating the residue with water, chloride of calcium and chloride of potassium are dissolved, and pure magnesia remains, which is separated upon a filter, washed, ignited, and weighed; the lime in the filtrate may be precipitated by oxalate of ammonia.

Separation of magnesia from the fixed alkalis.—Add subphosphate of ammonia to the solution, to throw down the magnesia as ammonia-phosphate, and filter; add acetate of lead to the filtrate, as long as it occasions any precipitate; filter again and supersaturate the clear liquor with sulphide of hydrogen; separate the sulphide of lead, and evaporate the solution to dryness. The residue, consisting of acetates, may be converted by hydrochloric acid into chlorides of potassium and sodium, which may be dissolved in water, and chloride of platinum will then throw down the potassium, which may be estimated from the weight of the potassio-chloride.

Quantitative Analysis.—This alkaline earth is almost invariably precipitated from an ammoniacal solution by phosphate of soda; it is collected and washed, and ignited so as to be weighed in the state of pyrophosphate. Every one hundred parts of ammonio-magnesian phosphate, dried at 60°, indicate 16·26 of magnesia:

every one hundred parts of its residue, after ignition, indicate 35·7 parts of magnesia.—*Brande*.

LIEBIG proposed another method to separate magnesia from potassa and soda. The bases are combined with sulphuric acid, the solution is rendered neutral, and is precipitated by a solution of sulphide of barium, which separates all the potassa and all the soda from the magnesia. The alkalies remain in the liquor in the state of sulphide of potassium, or of sodium, together with the excess of sulphide of barium employed. This liquor is decomposed by sulphuric acid, and the sulphate of baryta produced is collected on a filter; by evaporating the alkali, the sulphate of alkali is obtained. This alkaline product is then to be weighed, and from this weight the quantity of the alkali may be calculated. The best method of extracting the magnesia from the precipitate produced by the sulphide of barium—a precipitate which consists of magnesia mixed with sulphate of baryta—is to use an acid, and sulphuric acid in preference—to filter, in order to separate the sulphate of baryta produced, and the magnesia may be determined afterwards as a sulphate of magnesia.

The sulphide of barium employed for this method of analysis, must be crystallized and washed with cold water; such as it is obtained from the boiling of the product of the calcination of a mixture of sulphate of baryta and of charcoal.

Hydrate of baryta may be substituted for sulphide of barium with the same result.

The fixed alkalies may be more easily separated from magnesia when these bases are combined with nitric acid. The nitrates are to be calcined, which may be done in a platinum crucible, by adding a little dry carbonate of ammonia to the mass, after exposure to the first impression of the heat, and then moderately urging the fire. When the calcining is finished, the residuum is treated with water, which dissolves the alkalies in the state of carbonates, and leaves the magnesia behind.

When the fixed alkalies and magnesia are contained in a solution in the state of metallic chlorides, the method formerly in use for separating them consisted in evaporating the liquor to dryness, and igniting the dry residuum; the water of crystallization of the chloride of magnesium converted the latter into magnesia, with disengagement of hydrochloric acid; after which the chloride of the alkalisable metal was separated from the magnesia by washing with water.

This method may often be employed with advantage in qualitative analysis, but in quantitative the results obtained by it *are quite inaccurate*; for even after a protracted ignition there remains a great quantity of undecomposed chloride of magnesium, which dissolves in the water with the alkaline chloride. If strong alcohol is employed instead of water for washing the strongly ignited mass, it does not give a better result, for alcohol dissolves the undecomposed chloride of magnesium, just as water does, and leaves the magnesia thus produced undissolved.

Yet if, after having put the mixture of chloride of magnesium and of the alkalisable metal in a small platinum crucible, it is exposed to a red heat for a long time over a gas lamp, placing at the end a small piece of carbonate of ammonia upon the mass, and then

igniting strongly, nearly the whole of the chloride of magnesium may be converted into magnesia; but the calcination with the ammoniacal salt *must be repeated several times*, and the salt must be moistened with a few drops of water before calcining. The operation is known to be at an end when the weight of the saline mass remains constant after ignition. It is then treated by water, which dissolves the alkaline chloride, and along with it a trace of magnesia. The magnesia which remains insoluble is ignited and weighed. It is completely soluble in nitric acid, and when tested by nitrate of silver hardly shows a trace of chlorine. During the ignition of the mass it is advisable to put the cover on the crucible, in order to keep in the vapor of carbonate of ammonia as long as possible, and to prevent, at the same time, the access of air.

When the operation is performed on a few grammes of a mixture of chloride of magnesium, and of the chloride of an alkalisable metal, the treatment with carbonate of ammonia and water must be repeated at least eight times. The unavoidable loss of chlorine, which takes place when this method is resorted to, does not amount to one per cent. Of course, the chlorides which the operator purposes to separate *must contain no trace of sulphuric acid*.

In order to avoid the tedious operations which are necessary for an actual separation of magnesia, potassa, and soda, particularly when they do not exist together in the state of pure chlorides, Dr. LIST endeavored to determine them conjointly by an indirect method. The following is the process he found practically applicable in the most complicated cases, such as is presented by the analysis of a silicate decomposed by hydrofluoric acid:—

The filtrate obtained after precipitation of all other bases, is evaporated to dryness in a water-bath, and the residue of sulphates and chloride of ammonium cautiously ignited in a platinum crucible to expel the ammoniacal salt. The perfect safety of this operation from all loss may be insured by employing a crucible lid with an interior convex surface. As it is an indispensable condition for the success of the subsequent result that sulphuric should be the only acid present, the ignited saline mass is moistened with a little sulphuric acid, and again evaporated to dryness. To change the acid salts into neutral, a piece of carbonate of ammonia is then placed in the crucible, and this again heated until the bottom becomes feebly red. This operation is repeated until the weight remains constant. This chemist ascertained that the pure sulphate of magnesia loses no sulphuric acid. The contents of the crucible are now dissolved in water, and the sulphuric acid in the solution determined by chloride of barium; when the excess of baryta has been removed by sulphuric acid, the magnesia is precipitated by ammonia and phosphate of soda, and determined in the usual manner.

Dr. LIST proved the applicability of this method by operating upon a known mixture of sulphates of potassa, soda, and magnesia. After having convinced himself of the purity of the individual salts, by a determination of their sulphuric acid, he mixed the three, and, analysing the mixture, found the required quantities within 0·001 per cent.

The sources of this minute error are certainly of much less importance than those which are found to exist in the process by direct separation, especially as the determination of sulphuric acid and magnesia is one of those operations which can be effected with the greatest accuracy.

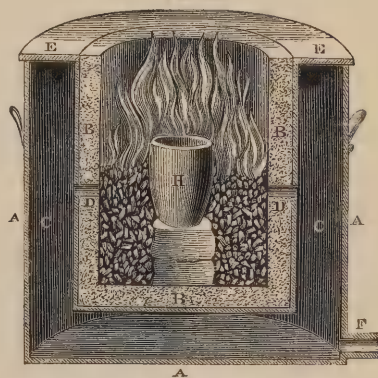
MANGANESE.—*Manganèse*, French; *Mangan*, German; *Manganum*, Latin.—The black mineral known in commerce by the name of manganese—*braunstein*, German—has long been employed to counteract the green tint of glass. It was formerly called *magnesia nigra*, from its resemblance to the magnetic oxide of iron, or loadstone. A mine of this mineral was discovered in England by BOYLE. Some experiments were made upon it by GLAUBER in 1656, and by WAIZ in 1705; but chemists do not appear to have directed particular attention to it until a later period. Mineralogists agreed in classing it among the ferruginous ores until POTR, in 1740, showed that it often contains mere traces of iron; after which, on the supposition that it consisted chiefly of a peculiar earth, a separate place was assigned to it in treatises on mineralogy. This hypothesis was, in the year 1774, distinctly proved to be correct, by the elaborate researches of SCHEELE and BERGMAN. GAHN subsequently showed that this earthy base contained a metal, not hitherto isolated, upon which he bestowed the appellation of *magnesium*. As, however, this term was afterwards employed to distinguish the metallic base of magnesia, it was superseded by the designation now in use. The metal manganese, owing to its powerful attraction for oxygen, does not occur in a free state in the earth's crust; but its mineral oxides are abundant, and are extensively employed in the arts, chiefly in the manufacture of glass and pottery, and in the preparation of chlorine for the production of bleaching-powder.

PREPARATION.—From the difficulty of its isolation, metallic manganese has not been rendered available for any useful purpose. The processes for its reduction are generally conducted on a small scale, in the laboratory. Like iron and cobalt, it is very difficult to be obtained in a state of absolute purity. It is necessary, in the first place, to procure a pure oxide of manganese, which may be effected by any of the following processes:—The common black oxide of manganese of commerce is digested for some time with dilute hydrochloric acid, washed, in order to free it from carbonate of lime, and then heated with strong hydrochloric acid. During the solution of the mineral, chlorine gas is abundantly disengaged, and, when the action is complete, the solution contains chloride of manganese and sesquichloride of iron. The liquid, after filtration, is evaporated to dryness in a porcelain basin, and the dry residue is strongly heated, with constant stirring, until it assumes an ash-grey hue, and no longer evolves acid fumes. By this treatment the chloride of iron is in part volatilized, and in part converted into sesquioxide of iron and hydrochloric acid. The residue is now digested with water, the solution filtered, and carbonate of soda, in slight excess, added to the liquid. The precipitated carbonate, after washing and drying, is ignited, when it furnishes a pure oxide; or the solution in hydrochloric acid is diluted with

water, and treated with repeated quantities of carbonate of soda, with continued digestion and stirring, until the liquid, rendered clear by subsidence or filtration, gives a pure white precipitate with a further quantity of carbonate of soda, showing that all the oxide of iron has been precipitated. This having been attained, the whole solution is freed by filtration from the precipitate, and the clear liquid precipitated by carbonate of soda in excess.

FARADAY recommends the following process for the preparation of pure protochloride of manganese:—Finely-powdered and strongly-calined black oxide, previously cleansed from carbonate of lime, is ignited with half its weight of chloride of ammonium, beginning with a moderate heat, and gradually raising the temperature to low redness. The chloride of manganese formed is dissolved out and the solution filtered. The pure oxide of manganese, prepared by the process already indicated, is moistened with oil and heated to redness several times, then made into a thick paste with oil, introduced into a charcoal-lined crucible, covered with charcoal powder, and a lid luted on the mouth of the crucible, which is afterwards exposed, for two or three hours, to the strongest heat of a smith's forge or a powerful blast furnace. SEFSTROM's apparatus, represented in Fig. 355 is commonly employed for the reduction. In a cylindrical iron case, A, is placed a second cylinder, B, lined with

Fig. 355.



fire-brick. The crucible is arranged as represented in the drawing, and surrounded with glowing charcoal or coke. The blast is admitted at F into the space which intervenes between the two cylinders, from which, after becoming considerably heated, it is forced into the fire-chamber through a series of openings, D D. The metal collects in the form of a button at the bottom of the crucible.

PROPERTIES.—Metallic manganese, as thus obtained, presents a greyish-white color without much lustre, and a fine granular texture. It is rather soft and brittle, and is readily split or broken. Its specific gravity is stated by JOHN to be 8.013. Its equivalent is 27.6. When pure it is not attracted by the magnet. It is exceedingly difficult of fusion, requiring for liquefaction the most intense heat of a wind furnace. The manganese prepared by the process described is always contaminated with carbon and silicium, and resembles,

therefore, common pig or cast iron. On subjecting the metal to fusion with borax, the carbon is separated, and the regulus becomes more fusible; but it is probable that the product, in this case, contains boron or sodium. Manganese readily tarnishes by exposure to the air—hence, like potassium, it must be kept under naphtha. When heated to redness in open vessels, it absorbs oxygen with rapidity. It decomposes water slowly at common temperatures, with disengagement of hydrogen gas; but at a red heat oxidation is very rapid. It also dissolves readily in dilute acids, with escape of hydrogen. By fusion at a high temperature, manganese may be alloyed with various other metals. A compound of about four equivalents of manganese and one equivalent of iron, was produced in considerable quantity by BUTTRAY, in a furnace employed for fusing cast-steel. This alloy became only slightly tarnished when freely exposed to the air, and did not affect the magnetic needle. When manganese is combined by fusion with six or seven *per cent.* of silicium, a regulus results which possesses the appearance of the ordinary metal, but differs much from it in its chemical characteristics; it does not oxidise, even at a red heat, and withstands the action of nitro-hydrochloric acid—*Sefström*.

BERZELIUS expressed the opinion, that the presence of the small proportion of silicium is not suffi-

cient to account for this total change of properties, and that there must exist in the compound or alloy, an allotropic modification of the metal, the alteration being effected or induced by the presence of the silicium at a temperature at which it would not occur with manganese alone.

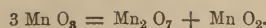
C. BRUNNER has recently prepared metallic manganese, by acting upon the fluoride with half its weight of sodium, the process being similar to that employed for the reduction of aluminium. Manganese thus obtained possesses properties essentially different from those usually attributed to this metal. Its color is like that of some cast-iron; it is brittle and very hard, not yielding to a steel file, but, on the contrary, scratching the best-tempered steel. It is capable of the most perfect polish. It is not altered even in moist air at the ordinary temperature. When heated, it acquires nearly the same colors as steel, passing afterwards to brown, by covering itself with a layer of oxide. The specific gravity of different specimens varied from 7.138 to 7.206. It is not attracted by the magnet, even when in powder, and has no influence on the magnetic needle. Acids attack it violently, even in the cold.

OXIDES.—Manganese forms at least five distinct compounds with oxygen, besides several compound oxides. The composition of these oxides is exhibited in the following table:—

Protoxide, or manganous oxide,.....	Mn O.
Sesquioxide, or manganic oxide,.....	Mn ₂ O ₃ .
Binoxide, or peroxide—black oxide,.....	Mn O ₂ .
Manganoso-manganic oxide—red oxide,.....	Mn ₃ O ₄ , or Mn O, Mn ₂ O ₃ .
Varvicite,.....	Mn ₄ O ₇ , or Mn ₂ O ₃ , 2 Mn O ₂ .
Manganic acid,.....	Mn O ₃ .
Permanganic acid,.....	Mn ₂ O ₇ .

Of these the first only possesses marked basic properties; the sesquioxide is a very feeble base; and the two compounds at the bottom of the list are, as their names indicate, acids. The protoxide is readily obtained by heating the oxalate in a covered crucible or in a glass tube closed at one end. When a caustic alkali is added to a solution of chloride or sulphate of manganese, the hydrated oxide falls as a flocculent white precipitate, which rapidly acquires a dark tint on exposure to the air. Binoxide of manganese may be prepared by passing chlorine gas through a solution of the acetate. Sesquioxide of manganese is produced when the binoxide is kept for a considerable time at a moderate red heat: it also occurs in nature as *braunite* and *manganite*. The red or manganoso-manganic oxide is always produced when any of the higher oxides is exposed to a white heat, either in closed or open vessels, or when hydrated protoxide is exposed to the air. It is the most permanent of all the oxides of manganese; it is not affected by exposure to any temperature, while all the other oxides readily pass into it, under the influence of heat. When finely powdered it is brownish-red while cold, and nearly black while warm. When fused with borax or glass, it communicates to these bodies a beautiful violet or amethyst tint, a character by which manganese may readily be detected before the blowpipe. Many colored minerals—for example, the amethyst—owe their tint to the presence of this oxide. Manganate of potassa is readily produced by

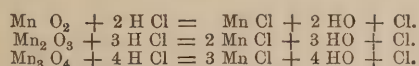
fusing binoxide with carbonate or hydrate of potassa, with or without the addition of chlorate. The compound has a fine green color. Upon the ready formation and great coloring power of manganic acid, E. DAVY has founded an elegant method for the detection of manganese. The substance is heated on silver foil, with a drop of a strong solution of caustic potassa, and the dry residue is gently ignited, when it will exhibit, if manganese be present in appreciable quantity, a very distinct green color. When compounds of manganese are heated before the blowpipe with carbonate of soda, on a loop of platinum wire, a green bead is obtained, manganate of soda being formed. Manganate of potassa has received the name of *chameleon mineral*, from the circumstance that the dark-green solution obtained by digesting it in a small quantity of cold water, assumes various shades of color on being diluted, the ultimate result being a liquid, having a fine carmine-red tint. The change of tint, which is induced more readily by the addition of an acid, is owing to the resolution of the manganic into permanganic acid, which remains in solution, and binoxide of manganese, which falls as a precipitate.



CRUM's test for manganese depends upon the formation of permanganic acid. The compound under examination is dissolved in a little nitric acid, and binoxide of lead added, when, the fine red tint of per-

manganic acid will be communicated to the liquid. Solution of permanganate of potassa is much employed in the German and French laboratories as an oxidising agent: in this country the bichromate is more generally used. The solution is best prepared by the method recommended by GREGORY. Four parts of finely-pulverized binoxide of manganese, and three and a half parts of chlorate of potassa, are intimately mixed together, and added to five parts of hydrate of potassa dissolved in a small quantity of water. The mixture is evaporated, and the residue completely dried, pulverized, and exposed to a low red heat, in a platinum crucible. The agglutinated mass is again powdered and added to a considerable quantity of boiling water, and the solution allowed to settle. When clear it is decanted, and is ready for use. It is quite permanent when preserved in well-stoppered bottles.

All the higher oxides of manganese are reduced to the condition of protocompounds by the action of warm sulphuric or hydrochloric acid, with the elimination of oxygen or chlorine, as the case may be. The following equations represent the action of hydrochloric acid upon the binoxide, the sesquioxide, and the red oxide of manganese:—



Protoxide of manganese is a powerful base of the magnesian class. Its salts are sometimes quite colorless; but they frequently possess a pink shade, probably from the presence of traces of permanganic acid, or oxide of cobalt. The soluble salts are nearly neutral, and when dissolved exhibit the following reactions:—

Caustic Potassa,.....	} A white precipitate of hydrated protoxide, which becomes brown by the absorption of oxygen.
Ammonia,.....	
Alkaline carbonates and bicarbonates,.....	} White precipitate.
Ferrocyanide of potassium,....	
Sulphide of hydrogen,.....	} Do.
Sulphide of ammonium,.....	
	} No effect in acid solutions.
	} A flesh-colored precipitate.

For the detection of minute quantities of manganese,

especially when mixed with other metals, CRUM's test, already detailed, is probably the most delicate.

ORES.—The compounds of manganese which occur native are numerous, but as those only are of importance in the arts, which consist solely or chiefly of one of the higher oxides, the minerals which come under consideration in this place are comparatively few in number.

Pyrolusite is the name applied to the native binoxide in its anhydrous and crystallized state. It is chiefly this variety that is employed by the glass-makers, while *wad* and other less pure ores are consumed in the elimination of chlorine from hydrochloric acid or chloride of sodium. The crystalline form of pyrolusite is the rhombic prism, and it generally occurs in the form of minute crystals grouped together, and radiating from a common centre. It has the same form as *manganite*, which consists of hydrated sesquioxide, and appears to be formed from that mineral by absorption of oxygen and loss of water, some masses of crystals having been observed to consist of pyrolusite externally and manganite internally. Pyrolusite has an iron-black or dark steel-grey color, and a metallic lustre. It is not very hard; its specific gravity is 4·7 to 4·97. It frequently contains *manganite*, *psilomelane*, sesquioxide of iron, alumina, silica, baryta, carbonate and sulphate of lime, and occasionally, according to PHILLIPS, traces of chloride of calcium. The following analyses of specimens of pyrolusite are by TURNER:—

	Elgersburg.	Ihlefeld.
Binoxide of manganese,.....	97·84	97·22
Baryta,.....	·53	·66
Silica,.....	·51	·55
Water,.....	1·12	1·57
Chloride of calcium,.....	—	traces
	100·00	100·00

This valuable ore is extensively worked in Ilmenau, Elgersburg, and various other districts in Thuringia; and the mines at Vorderschrensdorf, in Moravia, yield annually many hundred tons. It has also been found in several localities in America and elsewhere.

Name of Ore.	Locality.	Composition.							Analyst.	= MnO ₂
		Binoxide of manganese.	Sesquioxide of manganese.	Sesquioxide of iron.	Baryta.	Lime.	Clay.	Water.		
Wad,.....	Grorio, Mayenne,.....	64·2	11·0	6·0	—	—	3·0	15·8	Berthier.	70·2
"	Viodessos,.....	54·6	26·0	7·0	—	—	—	12·4	"	68·9
"	Granbunden,.....	22·6	31·0	3·6	—	—	Quartz. 33·6	8·8	"	39·6
"	Upton Pyne, Devon,.....	61·7	26·2	—	1·4	—	—	10·7	Turner.	76·1
"	Ilmenau,.....	51·6	27·0	1·0	8·1	—	Silica. 2·5	9·8	Scheffler.	66·4
"	Rubeland,.....	66·0	15·0	1·0	·3	And KO. 6·9	·5	10·3	Rammelsberg.	74·2
Ochrey Wad,.....	"	73·3	23·6	—	trace	—	—	3·1	Turner.	86·3
Varvicite,.....	Warwickshire,.....	50·	45·	—	—	—	—	5·	"	74·7
Psilomelane,.....	Schneeberg,.....	54·5	22·7	—	16·4	—	·2	6·2	"	66·0
"	Baireuth,.....	74·3	17·0	—	—	Potash. 4·5	—	4·2	Fuchs.	83·6
Braunite,.....	Elgersburg,.....	—	96·8	—	2·3	—	trace	·9	Turner.	53·2
Manganite,.....	Ihlefeld,.....	—	89·9	—	—	—	—	10·1	"	49·4
Hausmannite,.....	"	30·7	68·3	—	·1	—	·4	·5	"	37·5

Wad is the native hydrated binoxide. It is this ore that is commonly employed in the preparation of chlorine. It is tolerably abundant, and is found in England, Ireland, Sweden, Germany, and America; it appears generally in the form of brownish-black masses, or loosely agglomerated brown scales. Some varieties are hard and compact, and difficult to pulverise; others are comparatively soft and ochrey. *Wad* consists essentially of hydrated binoxide of manganese, $\text{Mn O}_2 \cdot \text{HO}$, but it is always more or less mixed up with manganic or manganoso-manganic oxide, and generally with variable quantities of sesquioxide of iron, clay, quartz, baryta, carbonate of lime, *et cetera*. Some specimens contain much oxide of cobalt, and a few contain oxide of copper. Analyses of specimens of *wad* from various localities, and of other ores of manganese capable of being applied to economic purposes, are exhibited in the preceding table. The last column of the table shows the amount of pure binoxide corresponding with the quantity of chlorine yielded by one hundred parts of the ore.

Psilomelane is one of the most generally diffused ores of manganese. It is compact and fibrous; specific gravity 4 to 4.328; rather hard. It has a dark steel-grey color, and submetallic lustre; it generally occurs in botryoidal masses.

Braunite is met with in octohedral crystals, and also massive; it is commonly nearly pure sesquioxide of manganese. *Manganite*, or grey manganese ore, is the hydrated sesquioxide, $\text{Mn}_2 \text{O}_3 \cdot \text{HO}$, and is generally very pure, and, therefore, well adapted for the manufacture of glass. It occurs in rhomboidal prisms, and also in columnar and granular masses. It is moderately hard; specific gravity 4.3 to 4.4; color between iron-black and steel-grey, with a submetallic lustre. It is found at Ithfeld in the Hartz, in Aberdeenshire, Bohemia, Saxony, and other localities.

USES.—The most important applications of manganese ore in the arts, are the production of chlorine and the decoloring of glass. Although, in the manufacture of glass, the purest materials are employed, yet traces of iron compounds are invariably present in one or more of the materials, giving to the product a very faint but distinct green, olive, or yellow tint, according to the state of oxidation of the metal. The cautious addition of black oxide of manganese destroys or conceals the objectionable tint. Its action was formerly supposed to be merely the oxidation of the green protoxide of iron to the faint yellow sesquioxide; but LIEBIG has suggested that the effect is not chemical but optical, and that the amethyst color communicated by the red oxide of manganese counteracts the yellow or greenish-yellow tint of the oxide of iron. This is probably the correct explanation of the action, since other oxidising agents, red oxide of lead for example, do not produce the desired effect. Chemists employ the binoxide of manganese for the preparation of oxygen and chlorine gases, and it is employed, in conjunction with dilute sulphuric acid, as an oxidising agent in organic chemistry.

Bin oxide of manganese has been employed for increasing the siccative quality of linseed oil; and the artificial bin oxide, mixed with the same oil, has been

recommended as a black paint, which may be used with advantage for the manufacture of printers' ink.

Of the numerous combinations of manganese with the halogens, and of the oxides with acids, the acetate, protochloride, and the sulphate of the protoxide are the only compounds which are manufactured on the large scale or applied to economic purposes, and are, consequently, sufficiently important to claim consideration in a work on technology.

Acetate of Manganese.—A full description of this salt is given in Vol. I., page 46.

Chloride of Manganese.—A solution of this compound in a state of purity is most readily obtained by the method recommended by FARADAY, already detailed, or by digesting a solution of purified black oxide of manganese in hot and strong hydrochloric acid, with carbonate of manganese, until all the sesquioxide of iron is displaced and thrown down. When the solution is highly concentrated by evaporation, it yields crystals of the hydrated salt, $\text{Mn Cl} \cdot 4 \text{ HO}$. These crystals are highly deliquescent, and they dissolve in two-thirds of their weight of water at 60°, and in a much smaller quantity at a higher temperature. The salt may be rendered anhydrous by the application of the heat of a spirit flame, while inclosed in a glass tube through which a current of dry hydrochloric acid gas is made to pass. It is a rose-colored crystalline mass.

Chloride of manganese is a refuse or waste product in chemical factories where chlorine is prepared from manganese and hydrochloric acid. It has been employed in the purification of coal gas. It may be used in dyeing for the production of *manganese-brown*, but the sulphate is generally employed for this purpose. A crude solution of chloride of manganese, neutral and free from iron, may be prepared by digesting the refuse menstruum already referred to with powdered chalk, which decomposes the sesquichloride of iron, but does not affect the manganese salt.

Sulphate of manganese is obtained in transparent, slightly rose-colored crystals, by dissolving the pure carbonate in dilute sulphuric acid, and concentrating by spontaneous evaporation. The crystals have the form of sulphate of copper, and a similar composition, $\text{Mn O} \cdot \text{SO}_3 + 5 \text{ HO}$; but by evaporation and crystallization at various temperatures, crystals with greater and less proportions of water may be obtained. The crystals are remarkably soluble in water.

This salt is prepared on a considerable scale for the use of the dyer and calico-printer. The mode of preparation generally adopted is as follows:—Black oxide of manganese is ignited with a small quantity of charcoal powder, in order to reduce it to the state of protoxide. This product being now treated with moderately dilute sulphuric acid, a crude sulphate is obtained containing a considerable proportion of sulphate of iron, to get rid of which the solution is boiled down to dryness, and the residue ignited or roasted. The mass is digested with water, when the manganese salt dissolves, while the iron remains insoluble as a basic sesquisulphate. The salt is obtained from the solution by evaporation. Another mode of preparation is, to ignite a mixture of black oxide of manganese and sulphate of iron, then to digest in water, and evaporate the

solution. *Manganese brown*, or *bronze*, is produced by immersing the fabric in a solution of sulphate of manganese, and then in one of dilute caustic alkali to precipitate the protoxide, which is raised to a higher state of oxidation either by simple exposure to the air, or, more rapidly, by transmitting it through a solution of bleaching powder.

PROCESSES FOR THE RECOVERY OF MANGANESE.—It has been customary for manufacturers who eliminate chlorine on the large scale, to throw away the chloride of manganese that results. To prevent this enormous loss of valuable material, various methods have been proposed and patented for recovering the manganese, or reconverting the chloride into the binoxide or sesquioxide. It is well known that the protoxide of manganese is readily converted by the oxygen of the air into the sesquioxide by gentle ustulation; and it was mentioned long ago by FORCHHAMMER, that carbonate of manganese, when heated in an open vessel to 500°, is converted for the most part into binoxide, an observation which does not seem, until very lately, to have attracted that degree of attention which its importance merits. The two most recent patent processes for the recovery of manganese, are those of BALMAIN and DUNLOP.

The invention of W. H. BALMAIN, whose patent is dated 31st March, 1855, is a method for attaining an economical recovery of the oxide of manganese by carrying on the process in conjunction with the manufacture of chloride of ammonium from the ammoniacal water formed in making coal gas. The mode of proceeding is as follows:—Into a convenient tank or pan, a quantity of the ammoniacal gas water is run, and to it is added the solution of manganese produced in the manufacture of chlorine, until a further addition of the solution causes no precipitation or thickening, or until the supernatant clear liquor does not effervesce with acid. The mixture having been allowed to stand for some time, the clear liquor is drawn off and evaporated for the purpose of crystallizing out the chloride of ammonium which it holds in solution. Water is then run upon the sediment, which is agitated, and is then allowed to subside. The supernatant clear liquor is then drawn off and treated in the same manner as the first liquor, in order to extract from it the remaining chloride of ammonium. The sediment is now removed to a bed of sand or cinders, and allowed to lose as much water as will mechanically run off by drainage. It is then placed upon a hearth or ordinary furnace-bed, and heated to redness, either by means of an open fire or by flues above and below, until it ceases to burn like tinder, and has assumed a black color; by which time it will have been converted into an oxide of manganese, fit for use, in the manufacture of chlorine, or for any other purpose to which it might have been applied in its original form.

When the manganese is to be used for producing chlorine, it is advisable to mix lime with the sediment before drainage, or as soon as it dries upon the hearth, and thus resolve it more or less into manganate of lime, which increases its power of eliminating chlorine.

When the gas water to be operated upon is in a

town at a distance from the spot where the solution of manganese is produced, or when the recovered manganese is to be used in the manufacture of glass, the liquid chloride of manganese is boiled down, and heated in a furnace to such a temperature as will render oxide of iron insoluble; in which state it is carried to the neighborhood where the gas water is produced, and being redissolved in water, is mixed and treated as described in the first instance.

The oxide of manganese having been used a second time, may be again recovered a third and a fourth time; and if no lime or alkali-waste has been used in neutralizing the excess of acid, it may be recovered an indefinite number of times.

The patent granted to CHARLES TENNANT DUNLOP, and dated 31st May, 1855, relates to the employment of the residuum obtained in the manufacture of chlorine, which residuum ordinarily consists of chloride of manganese, in the preparation of an artificial oxide of manganese, that is well suited for the manufacture or production of chlorine. The special process preferred by the patentee in carrying out his invention, is the transformation of the chloride of manganese into a carbonate of that metal by the agency of any of the means already well known to chemists, and then subjecting the carbonate, thus prepared, to the action of heat in contact with atmospheric air. Whatever impurity the chloride of manganese may contain—as chloride of iron for instance—is first separated either by calcination, or by the agency of a suitable precipitant. Practical working has decided that the carbonate of manganese, thus treated, yields an oxide of manganese of a richness equivalent to about eighty per cent. of pure sesquioxide.

The carbonate of manganese may be obtained by precipitation from the chloride, by the agency of carbonate of ammonia. The chloride of ammonium resulting from this treatment, may either be sold or employed as such, or it may be converted into a carbonate in the usual way, and then again employed for the precipitation of fresh chloride of manganese. Hydrate of lime is also employed in the production of carbonate of manganese from these residual matters; the hydrated oxide of manganese being subsequently transformed into carbonate by the transmission through it of carbonic acid.

By another process, carbonate of manganese is obtained by passing carbonic acid through the solution of chloride of manganese, which has been previously mixed with a quantity of carbonate of lime. The carbonate of lime, under the influence of the carbonic acid, decomposes the chloride of manganese into carbonate, from which the oxide of manganese can be obtained, as well as chloride of calcium, which remains in solution. The production of oxide of manganese, suitable for the preparation of chlorine, has often been attempted by following the process of precipitating the manganese as an oxide, and then bringing it to a higher state of oxidation by heating it in contact with atmospheric air, as well as by other means. But the essential feature of this invention is, the production of oxide of manganese from the residuum of the chlorine manufacture, by first manufacturing or producing the carbonate of manga-

nese, and then heating this carbonate in contact with atmospheric air. DUNLOP's process has been most extensively and successfully carried out by the Messrs. TENNANT of the St. Rollox Chemical Works, Glasgow. The carbonate is obtained in this establishment by heating in an iron boiler, under pressure, chalk and the refuse chloride of manganese, from which any iron which it may contain has been previously separated by the action of chalk in the cold. The carbonate of manganese thus procured is freed from the chloride of calcium in vats, collected, and then exsiccated in a chamber on a series of iron trays, in such a gradual manner as to expel the carbonic acid, and by elevating the temperature in a current of air, to obtain the black oxide.

QUANTITATIVE ESTIMATION.—Manganese is weighed almost invariably as the red oxide Mn_2O_3 , 114.8 parts of which are equivalent to 82.8 of metallic manganese, 106.8 of protoxide, and 130.8 of binoxide. When no other base is present, or only the alkalis, the moderately dilute solution is heated to boiling, and the manganese is thrown down as carbonate by the addition of carbonate of soda in excess. The precipitate is collected on a filter, washed with boiling water, dried and ignited over a powerful lamp or in a furnace, until the weight ceases to vary. The residue in the crucible is pure red oxide. If the liquid contains ammoniacal salts, it must be boiled with carbonate of soda in excess until the odor of the volatile alkali is no longer perceptible.

When any of the metals precipitable by sulphide of hydrogen are contained in the liquid, it must be rendered acid by the addition of hydrochloric acid, and treated with this agent, in order to remove them. Sesquioxide of iron is most readily separated by the addition of succinate of ammonia to the nearly neutral liquid. Manganese may be separated from the alkalis, earths, and the oxides of iron, nickel, and zinc, by the ingenious method of SCHIEL. The acid menstruum is nearly neutralized with carbonate of soda, acetate of soda added, and chlorine gas passed through the liquid to saturation. The manganese is completely deposited as hydrated binoxide, which may be converted into red oxide by ignition; the other bases remain in solution. The absolute separation of manganese and cobalt is attended with considerable difficulty; but the following simple method gives results which are sufficiently accurate for all technical purposes:—The two metals are precipitated by sulphide of ammonium and excess of acetic acid then added, when the sulphide of manganese dissolves, and the sulphide of cobalt remains intact.

The separation of manganese from nickel is given under the latter metal. Having obtained the sulphide of manganese by the process mixed with sulphide of zinc, it will be well to give here the mode of obtaining the manganese *per se*. Dissolve the sulphide in hydrochloric acid, then nearly neutralize with carbonate of soda, add acetate of soda, and next conduct chlorine gas into the mixture. The manganese salt is hereby decomposed, and the whole of the manganese separates as binoxide. The zinc remains in solution.

For the valuation and testing of manganese ores, the

reader is referred to the article BLEACHING POWDER, Vol. I., page 329.

Physiological Effects.—The effects of manganese upon the system are imperfectly known. KAPP regards it as a permanent stimulant, and says it promotes the appetite and digestion. VOGT places it among the tonics, and considers it to be intermediate between iron and lead; but his views are altogether theoretical, as he does not seem to have prescribed it. Dr. COUPER has described several cases of disease which took place among the men engaged in grinding it at the chemical works of Messrs. TENNANT and Company, in Glasgow; from these, it appears that, when slowly introduced into the system, it produces paralysis of the motor nerves. The disease commences with symptoms of the paraplegia. It differs from the paralysis of lead in not causing *colica pectorum*, or constipation; and from mercury, in first affecting the lower extremities, and in not exciting tumors of the afflicted part.

Manganese is rarely used in medicine; it appears to have been employed in the last century in the treatment of inflammatory fevers. GRILLE long since observed that the workmen in the manganese mines at Maçon were not subject to the itch; and that others who became affected with this disease, were cured by working in the mines. This led him, as well as MORELOT and others, to employ it in cutaneous maladies. KAPP administered it, as well as the salts of manganese, both internally and externally in various forms of syphilis; he used it with benefit in herpes, scabies, and the scorbutic diathesis. BRERA gave it in chlorosis, scorbutus, hypochondriasis, hysteria, *et cetera*. OTTO administered it in cachectic complaints, with favourable results. ODIER employed it in cardialgia. It has been applied as an absorbent in the treatment of old ulcers, as a depilatory, and as a remedy for skin diseases, especially itch and porrigo. KUGLER gave it with benefit in scrofula.

Manganic Acid.—HUNEFELD gave to a rabbit nearly two drachms of manganic acid in three days, in doses of ten or fifteen grains. The only obvious effect was increased secretion of urine. The animal being killed, the peritoneum and external coat of the colon were found of a greenish color—protoxide of manganese is of a pale grass-green color—the muscles were readily lacerated and livid, the liver was inflamed, the bile increased.—*Pereira*.

STATISTICS.—For all purposes, about twenty-five thousand tons of manganese are used annually; and of this quantity, from seventeen to eighteen thousand are employed for the manufacture of bleaching powder. The largest makers of the latter article are the TENNANTS of Glasgow, and MUSPRATTS of Liverpool, and Flint, North Wales.

MANURE.—*Engrais*, French; *Dünger*, German. The term, *manure*, is applied to all those substances which render soils more fertile. Manures produce their effects by contributing directly to the nutriment of plants, by improving the texture of soils, or by acting as chemical agents on the inert matters of the soil, by which they are transformed into a state fit for the use of plants.

Manures consist of vegetal and animal substances,

and of their products of decomposition, or of earthy, saline, and other bodies derived from minerals; consequently, they have generally been classed into vegetal and animal manures, mineral and mixed manures.

The history of manures cannot date so far back as the origin of agriculture, which was coeval with the foundation of society itself. In the earlier periods of the world, when the face of the ground was but thinly inhabited, and a virgin soil exhibited abundant fertility, the wants of man were readily supplied. With ample choice of ground at his command, he had only to remove to another spot, when land already under cultivation for some time no longer yielded the same increase. The fact of diminished productiveness, by prolonged cultivation, was no doubt early observed; but the reason of this did not probably give rise to much speculation, so long as the remedy was at hand in the fresh soil around. But as population increased, and the habits of men became less nomadic, the necessity of restoring to the exhausted soil its fertility, would become a question of serious consideration. The mode of doing this in the simplest way, would suggest itself by the observation of what passed around them. The refuse materials ejected from their habitations, the ordure of man and animals, the decaying carcasses of the latter, allowed to accumulate and rot on the surface of the ground, gave rise to a luxuriant vegetation on these spots, far surpassing that of the adjacent soil. The repeated observation of such facts cannot fail to have arrested attention, and to have led, on reflection, to connect cause and effect. It was thus early seen, that organic structures in a state of *eremacausis*, the filth from crowded habitations, and other matters which are offensive to the organs, when allowed to decay on exposure, were intended by nature to be buried under ground, and thus to effect at once the removal of pollution from the air that was breathed, and to restore the lost fertility of the soil. Hence the earliest form of manure, and that which has remained unchanged through succeeding ages, and at the present day still forms the standard of comparison for other manures, was a mixture of thecrement and urine of animals with other decaying animal and vegetal matter. In the writings of the Greeks and Romans are found many notices of the attention they paid to agriculture and manures.

COLUMELLA, who flourished during the early part of the first century of the christian era, wrote a great work, divided into twelve books, on agriculture. In the second of these he speaks of the breaking up and preparation of the ground, and gives an account of the different kinds of grain, pulse, and artificial grasses, with the tillage appropriate for each. He gives directions for carefully collecting the excrement of cattle, for littering them with straw, which was to be removed when soiled to the dunghill; and also advises the collection of all kinds of ashes, and the burning of weeds, shrubs, trees, and stubble, in fields; and the application of the incinerated matter as manure. The writings of this and other authors prove, that the ancients not only paid attention to the management of farmyard manure, but that they were well acquainted with the mode of preparing artificial and all ordinary composts. COLU-

MELLA says he is not ignorant that there are some farms in the country in which neither the dung of cattle nor of birds is to be obtained. However, he is a slothful husbandman who has no manure. He may, states the same authority, collect any kind of leaves, the cuttings of briars, and rakings of highways; he may cut ferns, and mix these with the cleanings of his courtyard; he may dig a hollow place such as was directed for the dunghill, and throw into it ashes, the dirt of the kennels, all kinds of straw, and everything that is swept from the house. Indeed, the various processes now followed by agriculturists to render the soil fertile, were known by the Romans. They incorporated light with heavy soils, and rendered them more porous; and although unacquainted with the theory of the operation, they may be said to have originated the principle of the modern process of subsoil-ploughing; for in some districts it was the custom every fifth or seventh year to dig as deep as the rain penetrated, and turn up the bottom of the mould, by which the corn-fields were said to be renewed, the particles of earth proper to the nourishment of the plants being supplied, to be carried downwards along with the rain. The practice of economising and employing farmyard manure and composts in general, may be said to have been transmitted from the Romans, with little change, to the beginning of the present century, varied only by the use and incorporation into composts of such articles as particular districts afforded. Thus chalk was employed in some places as a great adjunct to farmyard manure for turnips and all kinds of grain; in others, marl superseded lime; and along the sea-coasts, calcareous sea-sand, and seaweeds, were in high repute. In other districts, where manufactures were established, the refuse materials, such as soap-waste, under the name of soap-ash, woollen rags, *et cetera*, were in common use. Later still, animal matters, such as fish and bone, and other dressings, were in demand.

Although by the foregoing one sees what knowledge even the Romans possessed of manures, still they were far behind the Chinese in their system of agriculture. The basis of their mode is, as so often reiterated by LIEBIG, *to return to the soil every ingredient that has been removed by a crop*. The result has been, that instead of the land becoming impoverished, it has augmented in fertility with a continually increasing population, since the time of ABRAHAM or of the Egyptian Pyramids. All those means, says LIEBIG, which the German agriculturist considers perfectly indispensable for the increase of his produce, are not only quite unnecessary for the Chinese, *but without them* he produces crops more than double those of his Teutonic brother. No doubt other conditions exist in China different to Germany; some of them are Buddhists, and eat no meat, while here meat is partaken of for which fodder is required; but that is not the question—here principles are involved which must guide practice. The agricultural preceptors do not teach the planting of fodder with the view to obtain meat, but in order to have *dung*; and by this they prove that they do not understand a scientific law. In fixing a scientific principle, the first question is, not whether it is advantageous, but whether it be true? In scientific agriculture *dung*

no longer exists. All the ideas conveyed by this word are now exploded. Like the word *phlogiston*, which became obsolete at the end of the last century, as long as it was not known what phlogiston was, it served as an aggregate term to bind together a number of unknown causes to render them comprehensible. After it was ascertained what phlogiston represented, the right ideas were substituted, and the explanation of phenomena became true and reliable. Wood does not burn otherwise than formerly, air is what it was, water moistens as before; but what immense progress the human race has made since the right conception of air, oxygen, and the process of combustion took the place of the word phlogiston? A similar, but greater and more blessed advancement, must follow from the right knowledge or perception of the nutritive process in plants and animals; and it is as absurd for a chemical teacher to explain phenomena by phlogiston, as it would be for the farmer to employ the word dung in explanation of any agricultural process; for, in the place of this word, which is now without meaning, the word manure or compost is now substituted, expressing that for each plant there are certain ingredients serving as food, from the great effect of which the phenomena must be explained.

THEORY OF MANURES.—To understand the part which manures play in rendering soils productive, recourse must be had to the analysis of plants themselves. The composition of these will necessarily indicate the materials which must be supplied in order to promote their healthy growth. Now, when soils are submitted to the action of fire, it is found that there is an organic portion which burns off completely, and a residual one incapable of combustion, consisting of mineral substances. The same result follows the action of heat on plants. Healthy plants invariably contain a certain number of these mineral ingredients, and in fact always the same substances; the nature and quality, or the varying proportions of which, are ascertained by finding the composition of the ashes of the plants. The organic portion, dissipated by heat, consists mainly of the elements carbon, hydrogen, nitrogen, and oxygen, which produce by their union the various proximate principles of which plants are composed. The development of a plant, therefore, requires the presence of bodies capable of furnishing carbon, nitrogen, water or its elements, and the mineral matters which are likewise essential to vegetables. The latter ingredients can only be derived from the soil, but the supply of the elements which form the organic part may be quite independent of the soil. Lichens, which were at one time supposed to be destitute of roots, have been shown to be possessed of these organs with seemingly greater power than those of trees and herbs: for they are able to disintegrate and take up the necessary portions of the rocks to which they are attached, and fix them as a part of their constitution. Their organic constituents under these circumstances can come from only one source, namely, the atmosphere.

Origin of the Organic Portion of Plants.—As carbon the essential ingredient of organic bodies, is in its separate state altogether insoluble in water, it is plain that this element must be presented to plants in

such a form that it can be easily absorbed. This can readily be effected when the carbon is in the form of a complex compound quite soluble in water, or in the simple state of carbonic acid, a gas which is also freely dissolved by water. Hence have arisen two schools of vegetal physiologists—the one holding that organic substances which can be dissolved by water, are by its means conveyed through the rootlets of plants, and contribute directly to their nourishment equally with carbonic acid; the other holding that though such complex organic substances may pass in solution through the roots into the interior of plants, yet they in no way contribute to their nourishment, but must, previously to entering the plant, be decomposed into carbonic acid before they can be utilized. In other words, one school asserts that the carbon of plants is derived from soluble organic substances, as well as from carbonic acid; the other, that it is derived from carbonic acid *alone*. To the first school belong SAUSSURE, BOUSSINGAULT, MULDER, and PAYEN; to the second, LIEBIG and his followers.

The Humus theory of the Nutrition of Plants.—All plants and vegetal structures, after death, undergo decomposition by fermentation, and by a slow process of combustion, called by LIEBIG *eremacausis*. By these processes they lose carbon as carbonic acid, and are gradually converted into a dark-brown matter, which is known by the name of *humus*. Under this designation is included a variety of bodies, which have different chemical constitutions. Humus exists in larger quantities in virgin soils, and as such soils are noted for their fertility, the presence of this matter came to be regarded as the source of fertility of all soils. It was considered to be the principal nutriment of plants. The water of the soil, it was believed, dissolved the carbonic acid produced by the conversion of the vegetal fibres into humus, and those portions of humus soluble in water; and both of these, being absorbed by the roots of plants, contributed directly to their nourishment. Hence farmers added vegetal manure in large quantity to the soil, with the view of providing food for their intended crops. Want of space will not permit the discussion of the humus question. It will be sufficient to notice the objections brought against it by the supporters of the opposite views of the nutrition of plants. *First*, Springs of water arising out of the richest vegetal mould are quite clear, and contain no humus in solution. *Second*, Not the slightest ground exists for the belief that those substances called ulmin, humic acid, humin, *et cetera*, products of decomposition of vegetal matter by alkalies, exist in nature, in the form, and endowed with the properties, of the organic constituents of mould; and there is no proof that one of these exerts any influence on the growth of plants. *Third*, The experiments of SAUSSURE, which are generally adduced in favor of the humus theory, only show that the quantities of soluble organic substances taken up by the roots of plants, are just in the proportion in which they would run through filters. Thus, sulphates of the alkalies, which percolate a filter faster than acetate or nitrate of lime, were also taken up in greater quantity by the roots of plants. Sugar dissolved in water filters more easily than gum, and much more so than humus extract;

plants took up twice as much gum, and four times as much sugar as humus extract. *Fourth*, Granting that water does dissolve certain organic matters as well as carbonic acid, and convey them into the interior of the plant, it does not follow that such organic matters contribute to their growth. The roots of plants may absorb all soluble matters, organic as well as inorganic, with which they come in contact, yet only such portions be retained as are necessary to their organism; the remainder being returned to the soil. Did this power of selection not exist, the quantity of mineral constituents in plants, for example, would soon become enormous. The soluble organic matter, with the surplus mineral matter, is again returned to the soil. *Fifth*, There is great probability that the roots of plants have the power of selection, for as yet, even in the outer cells of the rootlets, not a trace of humus extract has been actually discovered. The presence of a substance resembling humic acid found in some diseased plants, is no argument in favor of its general presence.

The second theory of the supply of carbon to plants, rejects altogether the intervention of soluble organic matters. Woody fibre in the soil, by the access of oxygen, gives rise to carbonic acid. If this carbonic acid be removed, and a fresh portion of oxygen be admitted, a fresh portion of carbonic acid will be formed. This process is slow, and the presence of water is necessary to its maintenance. Woody fibre in this progressive state of *eremacausis*, is called humus, and when the decay is complete, and there is no longer formed any carbonic acid by the access of oxygen, there is left a brown coal-looking substance, which is mould. In every fertile soil there is, therefore, an atmosphere of carbonic acid surrounding every particle of decaying humus. This is dissolved by water in the soil, and at once absorbed by the roots of plants. By loosening the soil all round the roots, the access of air is accelerated, and a further portion of carbonic acid is the result. The roots, from the first moment of their formation, extract from the soil their proper nourishment, namely, the carbonic acid generated by the humus. As soon as the leaves have appeared, they also begin their functions by absorbing carbonic acid from the air. The quantity of this gas in the atmosphere, amounting to about one-tenth per cent., appears to be a trifling source of carbon. But when the immense mass of the air is taken into account, and it is recollected, that by the law of diffusion of gases, carbonic acid is in the same proportion in all parts, it can easily be shown by calculation that the atmosphere contains no less than three thousand and eighty-five billion pounds of carbon—a quantity which greatly exceeds the weight of all the plants existing in the world. This amount of carbon is, therefore, more than adequate for the growth of all plants, even if they were confined to this source of supply alone.

When a plant is fully developed, and the organs by which it obtains food from the atmosphere are formed, it may be said to be independent of the soil for its carbon. But as the functions of the organs of plants cannot be conceived to cease for a moment during their life; and as soils in which plants vegetate vigor-

ously always contain moisture, holding in solution carbonic acid, either produced within the soil, or brought to it by rain from the atmosphere, it follows that plants during their life must constantly absorb carbonic acid by their roots as well as by their leaves. It is thus seen, that on the one hand, a plant when placed under peculiar circumstances can depend on the carbonic acid of the atmosphere alone for its carbon, and that it has an abundant supply of this element in the air; yet under the ordinary normal condition of vegetal life, the supply must come from the carbonic acid of the soil as well as the air.

SOURCE OF NITROGEN OF PLANTS.—The quantity of nitrogen present in plants is small when compared with their carbon, hydrogen, and oxygen. One hundred parts of hay, oats, and potatoes, when dried at 240°, contain respectively one and a half, two and a half, and one and a fifth parts of nitrogen. But, though existing in such small proportions, this element is one of the most important in the constitution of vegetal products which serve as food for animals; their value in the scale of nutrition rising with the quantity of nitrogen they contain. It has been a subject of considerable discussion of late years, whether the nitrogen of the air is not absorbed by plants, and contributes directly to their nourishment. In a memoir presented to the Academy of Sciences, VILLE affirmed that the nitrogen of the air is assimilated by plants. BOUSSINGAULT showed by a series of carefully-conducted experiments, that this supposition of VILLE was incorrect. A committee, of which CHEVREUL was reporter, was appointed by the Academy to investigate the point. They made a series of experiments which, they stated, resulted in favor of VILLE's views. Still later, BOUSSINGAULT reinvestigated the subject, and by a series of the most carefully-conducted experiments, appears to have settled the question; and though VILLE, by still more recent experiments, thinks his prior views confirmed, yet for the present the results obtained by the former lead to the conclusion, that nitrogen is not directly assimilated by plants. The nitrogen of plants can, therefore, be derived from only two sources, namely, from ammonia and nitric acid.

When a large quantity of rain water which falls after long dry weather, or melted snow is evaporated to dryness, with a little sulphuric or hydrochloric acid, the residue is found to contain ammonia, which can be detected by its peculiar odor, on the addition of a little slaked lime. This ammonia, which at all times exists in the air, is derived from the putrefaction of animal substances, and from numerous other sources, from which it is evolved chiefly as carbonate. It is very soluble in water; hence every shower of rain removes it from the atmosphere, which again receives a constant supply from the sources just stated. Ammonia is the last product of the putrefaction of animal bodies. But if this ammonia be placed under favorable circumstances, it undergoes *eremacausis*, or slow combustion. The oxygen of the air converts its hydrogen into water, and its nitrogen into nitric acid. There is another mode in which nitric acid may be produced, namely by the direct combination of its elements, nitrogen and oxygen, by

means of electricity. This effect is often observed in thunder-storms. There is thus a constant supply of nitrogen from the atmosphere, in the form of ammonia and nitric acid. The amount present in a given portion of air is very small; but the total quantity which may be derived from this source in a given time is not inconsiderable, when it is recollected, that a generation of a thousand million men is renewed every thirty years; and thousands of millions of animals cease to live, and are reproduced, in a much shorter time.

The ammonia and nitric acid in solution in water in the soil, are at once absorbed by the roots of plants, and in both forms assimilated by their organs for the production of the nitrogenized matters which they contain. This fact has been proved by many observers. The juice of maples, birches, tobacco-leaves, when evaporated with lime, emits a quantity of ammonia. The evolution of ammonia from the juice of beet in the process of clarifying by lime, is familiar to every beet-sugar manufacturer. The tobacco plant, sunflower, *Borago officinalis*, *Apium Graveolens*, contain in their juices considerable quantities of nitric acid in the form of nitrates. The presence of nitrates in the sap of plants has been supposed to prove that the nitrogen of the nitric acid is not employed in the organism for the production of compounds containing that element. But this conclusion cannot be drawn from the presence in the juice of nitric acid, any more than from the presence of ammonia and carbonic acid. It only proves that these substances after absorption have not yet undergone decomposition and fixation in the plant, or that they exist as a surplus not required for its further development.

The employment of animal manures for those crops which are most important as food of animals, is a satisfactory proof that their nitrogen is derived from ammonia. An increase of animal manure gives rise not only to an increase in the number of seeds, but also in the proportion of those substances in them which contain nitrogen. One hundred parts of wheat grown on a soil manured with cow dung, a manure which contains the smallest quantity of nitrogen, afforded only 11·95 parts of gluten, and 62·34 parts of starch; whilst the same quantity grown on a soil manured with human urine, which is highly nitrogenized, afforded the maximum of gluten, namely, 35·1 per cent. In a subsequent portion of this article, the question of the supply of ammonia to plants will be again noticed.

In the foregoing remarks it is seen, that the conditions necessary for the production of the organic constituents of plants are moisture, and the presence everywhere of bodies to furnish carbon and nitrogen. The essential food of plants must not be one which is found in one place, and is absent from another. Wherever water is, there must be found these sources of carbon and nitrogen. No substances fulfil these conditions but carbonic acid and ammonia. Hence the whole theory of the nourishment of a plant, so far as the formation of its organic portions is concerned, consists in the constant supply of carbonic acid and ammonia, and as a substitute for the latter, nitric acid, from which carbon and nitrogen are assimilated.

THE INORGANIC FOOD OF PLANTS.—Experience

has shown that, however abundantly carbonic acid and ammonia may be supplied to plants, yet they cannot live upon these alone. Seeds sown in sand, and aspersed with water impregnated with carbonic acid and ammonia, arrive at a certain stage of growth, and then begin to droop and die. The inorganic matter left on burning a plant is as necessary for its growth as carbonic acid and ammonia. The bones, muscles, and blood of animals cannot exist without a constant supply of inorganic elements, and these must be derived ultimately from plants which form the food of graminiferous animals. Hence plants must store up within themselves inorganic constituents for the wants of animals, as well as for themselves. The number of these inorganic constituents is comparatively small. They are chiefly potassa, soda, lime, magnesia, oxide of iron, and silica, phosphoric and sulphuric acid, and chlorine. It is not known what particular part they play in the vegetal organism; but that they are essential is proved by the power which is conferred on plants of selecting such substances as are necessary for the growth of their different parts. Sea-water contains a large quantity of soda, and but a mere trace of potassa; yet some sea-weeds, as dulse, contain much potassa and little soda; thus proving that the plant has selected out of a mass of soda the potassa, which is necessary for the perfect structure of its seed.

In the first instance, the roots of plants may take up all substances in solution without selection. But this action is not one of simple imbibition as in the case of sponges. LIEBIG, in a recent memoir, maintains that the spongioles, in obtaining their supply of saline matter, exert a real decomposing action on certain ill-defined compounds, which the saline matter forms with the insoluble constituents of the soil. Those substances which are conveyed to plants in solution are retained in greater or less quantity, or are entirely rejected when not fit for assimilation.

Carefully-conducted experiments have proved, that on whatever soil grown, if a plant is healthy and ripens its seed, the quantity and kind of ash which it contains are, within certain limits, and with certain admissible variations, nearly the same. Further experiments have also shown, that the ash left by two different species of plants grown on the same soil, is never exactly the same. Thus silica, alkaline and earthy phosphates, form invariable constituents of the seeds of all kinds of grasses; and bulbous and tuberous roots are characterized by the large quantity of potassa and soda they contain. The different parts, too, of the same plant have variable proportions of inorganic matter. Such constituents, according to LIEBIG, appear to exist in the smallest quantity in those parts of a plant in which the process of assimilation is most active, as in the mass of woody fibre; and their quantity is greatest in those organs, the office of which it is to prepare substances conveyed to them for assimilation by other parts. Hence there is a larger quantity present in leaves than in branches, and more in the latter than in stems.

The quantity of ash left by the different parts of cultivated plants is seen by the following table:—

PROPORTION OF ASHES LEFT BY ONE HUNDRED POUNDS OF THE SEEDS, HUSKS, AND STRAWS, OF THE USUALLY CULTIVATED GRAINS.

	Grain.	Husk.	Straw.
Wheat,.....	2.31 mean	—	5.39 mean
Barley,.....	2.54 “	—	5.86 “
Oats, without husk,.....	2.01 “	6.51 mean	6.14 “
Rye,.....	2.41 “	6.5 “	3.29 “
Indian corn,.....	1.3	—	4.54 “
Field beans,.....	3.0 “	—	5.0 “
Field peas,.....	2.7	Pod 7.1	—
Vetches,.....	2.4	10.8	6.0 mean
Lentils,.....	2.06	—	5.38
Linseed,.....	4.2 mean	—	Flax 1.28 and 4.5
Hempseed,.....	5.6	—	Hemp 1.78 —

PROPORTION OF ASH LEFT BY ONE HUNDRED POUNDS OF THE DIFFERENT ROOT CROPS—NAMESLY, OF CABBAGE, TOBACCO, *et cetera*, WHEN DRIED.

	Root.	Leaves.
Potatoes,.....	3.9 mean	21.5 mean
Turnip,.....	7.0 “	17.0 “
Carrot,.....	5.1	16.42
Parsnip,.....	4.3	15.76
Mangold-wurzel,.....	7.0	7.55
Cabbage,.....	—	22.00
Tobacco.....	—	23.08

PROPORTION OF ASH LEFT BY ONE HUNDRED POUNDS OF THE GRASSES WHEN DRY.

Lucerne,.....	9.5
Red clover,.....	7.5
White clover,.....	9.1
Ryegrass,.....	6.0
Knot grass,.....	2.3
Holcus lanatus,.....	6.2
Poa pratensis,.....	6.2
Scirpus,.....	2.3

PROPORTION OF ASH LEFT BY ONE HUNDRED POUNDS OF DIFFERENT KINDS OF TREES.

	Wood.	Seed.	Dried leaves.
Larch,.....	0.33	5.0	6.0
Scotch fir,.....	0.16	4.98	2.5
Pitch pine,.....	0.25	4.47	3.15
Beech,.....	0.35	—	5.4
Willow,.....	0.45	—	8.2
Birch,.....	0.34	—	5.0
Elm,.....	1.88	—	11.8
Ash,.....	0.5	—	—
Oak,.....	0.21	—	4.5
Poplar,.....	1.97	—	9.2
Sugar-cane,.....	1.45	—	9.4
Hop,.....	5.00	10.90	16.3

When the composition of the ash thus left by plants is examined, several important points are ascertained. It is seen that though silica is not always wanting for the grain of the corn-bearing plants and grapes, yet that it is absolutely necessary to, and may be said to be the characteristic mineral ingredients of their stems. In the ash of the grain of wheat it amounts to one per cent., whilst in the ash of its straw the quantity varies from forty to eighty per cent.

Phosphoric acid is the characteristic ingredient of the seeds of plants. It forms about one-half of the ash of the grain of the different cereals, when burnt with their husks, but is seldom present in any considerable quantity in their ripe straws.

As the ash of the stems of cereals is characterized by silica, so the ash of the stalks of leguminous plants, and the tops of the potato and turnip, are remarkable for the quantity of lime they contain.

Root crops have also their characteristic mineral ingredients. Potassa and soda, which are present to the extent of thirty per cent. in the ash of cereals, and

about forty per cent. in the ashes of beans and peas, amount to about fifty to sixty per cent. in the ash of the turnip and potato. Thus larger quantities of the alkalies are present in roots than in other crops raised for human food.

The following table shows the amount of essential inorganic ingredients contained in one hundred parts of the ashes of the commonly cultivated plants:—

	Potassa and soda.	Lime.	Magnesia.	Phosphoric acid.	Sulphuric acid.	Silica.
Wheat-grain,....	33	3	12	50	0.25	1
Barley “.....	22	3	7	39	0.10	27
Oats “.....	26	6	10	44	11.0	3
Rye “.....	34	5	10	50	1.0	0.4
Indian corn,....	33	1	16	45	3.0	1.0
Rice,.....	30	1	12	53	—	3.0
Beans,.....	44	6	8	38	1.0	1.0
Peas,.....	44	5	8	34	4.0	0.51
Wheat-straw,....	13	7	4	3	6.0	65.0
Barley “.....	7	10	3	3	2.0	71.0
Oat “.....	29	8	4	3	3.0	48.0
Rye “.....	18	9	2	4	1.0	65.0
Maize “.....	35	8	7	17	—	28.0
Rice “.....	14	—	5	1	4.0	74.0
Bean “.....	28	36	7	12	2.0	11.0
Pea “.....	17	40	8	8	7.0	10.0
Red clover,....	36	33	8	8	3.0	7.0
Potatoes, root,...	57	2	5	13	14.0	4.0
Turnip, “.....	47	14	5	8	14.0	8.0
Beet, “.....	50	9	5	8	2.0	10.0
Carrot, “.....	54	17	1.3	16	10.0	3.0
Cabbage,.....	32	21	6.0	12	22.0	0.74
Potato tops,....	44	17	7.0	8	7.0	4.0
Turnip “.....	34	23	3.0	9	13.0	1.0

JOHNSTON has made elaborate calculations in his agricultural lectures, to show the enormous amount of mineral constituents removed from the soil by cultivated plants. Only a few examples, by way of illustration, need be taken:—

Mineral Constituents removed per acre of Wheat.
—If the produce of a field of wheat be taken at the rate of twenty-five bushels per imperial acre, weighing sixty pounds a bushel; and if the straw averages twice the weight of the grain, then the quantity of inorganic matter carried off the soil by the crop will be, per acre:—

	Pounds.
In one thousand five hundred pounds of grain at two per cent. of ash,.....	30
In three thousand pounds of straw at six per cent.,.....	180
Total,.....	210

The composition of the matter thus carried off,

according to the mean of analyses of ashes given in the table, will be, in pounds:—

	Grain.	Straw.	Total.
Potassa,	7.15	22.44	29.59
Soda,	2.73	0.29	3.02
Lime,	0.85	12.09	12.94
Magnesia,	3.63	6.89	10.52
Oxide of iron,	0.20	2.35	2.55
Phosphoric acid, ...	15.02	5.54	20.56
Sulphuric acid,	0.07	10.49	10.56
Chlorine,	—	1.97	1.97
Silica,	0.35	117.94	118.29
	30.00	180.00	210.00

Mineral Constituents removed per acre by a Crop of Barley.—If the produce of an imperial acre of barley amount to forty bushels, each weighing fifty-three pounds, and if the straw averages one-fourth more than the weight of the grain, then the proportion of inorganic matter removed from each acre by a crop of barley, will be—

	Pounds.
In two thousand one hundred and twenty pounds of grain at two and a half per cent. of ash, ..	53
In two thousand six hundred and fifty pounds of straw at six per cent. of straw,	160
Total,	213

The composition of this ash will be found by the table to consist of—

	Grain.	Straw.	Total.
Potassa,	7.24	10.29	17.53
Soda,	4.32	0.92	5.24
Lime,	1.39	15.53	16.92
Magnesia,	3.97	5.25	9.22
Oxide of iron,	0.79	1.35	2.14
Alumina,	0.12	2.26	2.38
Phosphoric acid, ...	20.74	5.02	25.76
Sulphuric acid, ...	0.05	2.66	2.71
Chlorine,	0.02	1.58	1.60
Silica,	14.36	115.14	129.50
	53.00	160.00	213.00

Mineral Constituents removed per acre by a Crop of Turnips.—A good crop of turnips varies from twenty

	Grain.	Straw.	Bulbs.	Tops.	Hay.	Total.
Potassa,	14.39	32.73	142.66	88.82	38.22	316.82
Soda,	7.05	1.21	17.31	16.76	12.05	54.38
Lime,	2.24	27.62	46.24	72.14	44.45	192.65
Magnesia,	7.60	12.14	18.16	9.58	7.09	54.57
Oxide of iron,	1.11	5.96	4.35	2.67	0.58	14.67
Phosphoric acid,	35.76	10.56	25.77	28.80	15.12	116.01
Sulphuric acid,	0.12	13.15	46.24	38.81	9.20	107.52
Chlorine,	0.02	3.55	12.24	49.75	4.06	69.62
Silica,	14.71	233.08	27.03	2.67	78.23	355.72
	83.00	340.00	340.00	310.00	209.00	1282.00

This table is highly important, as showing the enormous quantity of soluble minerals removed from soils by cultivated crops. If the crops were removed from the ground, and no means were taken to return to the soil in some form the mineral constituents thus constantly taken off, the inevitable consequence would ultimately be *utter sterility*.

APPLICATION OF MANURES.—The facts adduced in the preceding pages tend to show what is the real nature of manures, and in what manner they act. They are the food of plants; hence the necessity of understanding, in the first instance, the mode in which plants are

to forty tons of bulbs per imperial acre. If twenty tons be taken as an average crop, and if the tops, which always vary much in the proportion they bear to the clean bulbs, be assumed as equal to one-third of the weight of the bulbs, the inorganic matter carried off by a crop of roots and tops will be as follows:—Twenty tons of bulbs contain two tons of dry matter, leaving seven and a half per cent. of ash, or about three hundred and forty pounds. Six tons and a third of tops contain one thousand eight hundred and fifty pounds of dry matter, leaving seventeen per cent. of ash, or about three hundred and ten pounds. Bulbs and tops thus remove in all six hundred and fifty pounds of mineral matter, having the annexed composition, in pounds:—

	Bulbs.	Tops.	Total.
Potassa,	142.66	88.82	231.48
Soda,	17.31	16.76	34.07
Lime,	46.24	72.14	118.38
Magnesia,	18.16	9.58	27.74
Oxide of iron,	4.35	2.67	7.02
Phosphoric acid, ...	25.77	28.80	54.57
Sulphuric acid, ...	46.24	38.81	85.05
Chlorine,	12.24	49.75	61.99
Silica,	27.03	2.67	29.70
	340.00	310.00	650.00

Mineral Constituents removed per acre by a Crop of Hay, consisting of one ton of rye grass, and half a ton of red clover:—

	Pounds.
Potassa,	38.22
Soda,	12.05
Lime,	44.45
Magnesia,	7.09
Oxide of iron,	0.58
Phosphoric acid,	15.12
Sulphuric acid,	9.20
Chlorine,	4.06
Silica,	78.23
	209.00

The total mineral constituents removed from the soil by this four years' rotation of crops, will be, in pounds:—

	Grain.	Straw.	Bulbs.	Tops.	Hay.	Total.
Potassa,	14.39	32.73	142.66	88.82	38.22	316.82
Soda,	7.05	1.21	17.31	16.76	12.05	54.38
Lime,	2.24	27.62	46.24	72.14	44.45	192.65
Magnesia,	7.60	12.14	18.16	9.58	7.09	54.57
Oxide of iron,	1.11	5.96	4.35	2.67	0.58	14.67
Phosphoric acid,	35.76	10.56	25.77	28.80	15.12	116.01
Sulphuric acid,	0.12	13.15	46.24	38.81	9.20	107.52
Chlorine,	0.02	3.55	12.24	49.75	4.06	69.62
Silica,	14.71	233.08	27.03	2.67	78.23	355.72
	83.00	340.00	340.00	310.00	209.00	1282.00

nourished. Plants must be furnished with matter to build up their organic and inorganic portions. Complex organic matters, as has been stated, do not nourish plants, until decomposed into carbonic acid, water, and ammonia. These substances exist in the air; this source might, therefore, be trusted for their supply, but a double source of supply, from air and soil, undoubtedly causes greater activity in a given time in vegetation. Inorganic constituents can come from the soil alone. Of the two kinds of food of plants, the gaseous and inorganic, which it may be necessary to add to a barren soil, by far the most important and indispensable is the latter.

The various facts already discussed, and the essential points connected with the application of manures, cannot be better summed up, than in the words of LIEBIG in his *Principles of Agricultural Chemistry*.

In the shape of agricultural produce of a field, the entire amount of those constituents which have become ingredients of plants is removed from the soil. After a series of years, and a corresponding number of harvests, the fertility of the soil or field diminishes. The change which is found to have taken place in the composition of the soil after harvest, is the probable cause of its diminished or lost fertility. By means of solid and liquid manure, or the excreta of men and animals, the lost or diminished fertility of the land is restored. Solid or farmyard manure consists of decayed vegetal and animal matters, which contain a certain proportion of the constituents of the soil. The excrements of men and animals represent the ashes of the food consumed, and which has been derived from the supposed soil. The urine contains the soluble, the solid excreta the insoluble constituents of the soil derived from the crops used as food, and reaped from the soil. By adding these to the soil, it recovers those constituents which have been removed from it in the crops.

Thus the restoration of its original composition is accompanied by the restoration of its fertility. It is therefore certain that one of the conditions of fertility in a soil, is the presence in it of certain mineral constituents. A rich fertile ground contains more of these than a poor barren one does.

Vegetal and animal matters, and animal excreta, when in the soil, undergo putrefaction and slow oxidation. The nitrogen of their nitrogenized constituents is changed in the process of putrefaction and decay into ammonia, and a small part into nitric acid, which is the product of the oxidation or decay of ammonia. There is every reason to believe that nitric acid can replace ammonia, as a source of nitrogen to plants. In animal manures, therefore, not only are plants supplied with the mineral substances which the soil must yield, but they are also supplied with those parts of their food which the plant obtains from the atmosphere. The latter supply is a clear addition to that which the air at all times affords.

The solid and liquid parts of the food of plants contained in the soil must enter the roots in solution in water, or, in the case of those substances not soluble in pure water, in water containing carbonic acid or some salt of ammonia. Hence animal manures, undergoing decay in the soil, render the air and water which pass through it richer in carbonic acid and salts of ammonia. They thus not only supply plants with a certain amount of their mineral and atmospheric food, but also provide them with those substances—carbonic acid and ammoniacal salts—which are the most indispensable for the introduction into the vegetal organism of the mineral constituents, which, by themselves, are insoluble in water, and this to a larger amount in the same time than could be effected without the co-operation of decaying organic matter. The mineral constituents which all plants, without exception, require for their nutrition, are phosphoric acid, sulphuric acid,

the alkalies, lime, magnesia, and iron. Some important genera require silica. Those which grow on the seashore and on the sea require chloride of sodium, soda, and iodides of metals. In some genera, the alkalies may in part be replaced by lime and magnesia, or these latter by the alkalies. All these substances are included in the term mineral food of plants; carbonic acid and ammonia being termed the atmospheric food.

From some recent experiments respecting the capacity of soils for absorbing the soluble constituents of manure, LIEBIG has been led to a new theory respecting the nutrition of plants, and which is quite opposed to the foregoing view. The inference deducible from the Baron's experiments is as follows:—That land plants do not receive their food from a solution of the ingredients already present in the soil, but that they abstract or absorb it *directly from the soil itself*, through the joint agency of water and of a force inherent in the roots.

The different substances necessary to the growth of a plant, or the different articles of their food, are all of equal value; that is to say, if one out of the whole number be absent, the plant will not thrive. The soils which are proper for the cultivation of all sorts of plants, contain all the mineral constituents necessary for them. But of two soils containing equal quantities of these mineral ingredients, one may be considered rich or fertile, and the other poor or barren, if in the former case they are present in a form soluble in water, and in the latter are insoluble. All soils adapted for culture contain the mineral food of plants in these two states. The quantity of the soluble ingredients can be increased from the insoluble, in other words, the soil made more productive by mechanical means. This process is called weathering, or fallow; the insoluble minerals being disintegrated by the aid of carbonic acid, oxygen, and water. Hence stagnant water in the soil—undrained fields—which excludes the air from access to the insoluble compounds, is an obstacle to this process of weathering. Land in which the necessary mineral constituents are not present in any form, cannot be rendered fertile by fallow or by ploughing.

As different kinds of plants require for their development in some cases the same mineral substances, but in unequal quantities, a soil may become barren for any one kind of plant, when by a series of crops one only of these constituents, as for example, soluble silica has been so far removed that the remaining quantity is no longer sufficient for a crop; but it may still contain sufficient mineral constituents for another kind of crop which does not require soluble silica. A third sort of plant may thrive on the same soil after the second, if the remaining mineral constituents suffice for a crop of it. Upon this fact depends the rotation of crops.

The nutritive substances necessary to the life of a plant must act together within a given time, if the plant is to attain its full development in that time. The absence or deficiency, or the want of available form in one necessary constituent, renders the others which are present ineffectual, or diminishes their efficacy, and the soil is rendered barren for all those crops to the life of which that one constituent is indispensable; but fertility is communicated if that one substance be added in due

quantity, and in an available form. The supply of more atmospheric food—namely, carbonic acid and ammonia—by means of ammoniacal salts and humus, than the air can furnish, increases in a given time the efficacy of the mineral constituents present in the soil. In a soil rich in the mineral food of plants, the produce cannot be increased by adding more of the same substances. In a soil rich in the atmospheric food of plants, rendered so by manuring, the produce cannot be increased by adding more of the same substances.

From land rich in mineral constituents, there may be obtained in one year, or for a series of years, by the addition of ammonia alone, in its salts, or of humus and ammonia, rich crops, without in any way restoring the mineral substances removed in these crops. The duration of this fertility depends on the supply of the available mineral constituents existing in the soil. The continued use of these manures produces sooner or later an exhaustion of the soil. If after a time the soil is to recover its original fertility, the mineral substances extracted from it by the crops in a series of years must be again restored.

These admirable propositions furnish the key to the application of manures. The continued fertility of a soil for all kinds of crops, depends on the constant return to it of *all* the mineral constituents removed by the different crops. If a great increase in one crop has been effected by the application of one manure alone—for example, of phosphate of lime, or of ammonia—this only proves that all the other ingredients necessary to that crop have been present in sufficient abundance in the soil. The agriculturist would not be warranted by the success of this one experiment in repeating it too often, or the infallible result would be the ultimate exhaustion of his land. No single mineral substance, in however large quantities, can confer *permanent* fertility. This result can only be attained by the combination of all those mineral salts found in the ashes of plants, or by the use of a compost, such as carefully prepared farmyard manure, which contains in itself these different ingredients.

Here perhaps may be the proper place to notice, that the views of the nature of manures advanced by LIEBIG have been combated by LAWES and GILBERT, who have endeavored to show by a series of experimental results, that this so-called mineral theory of LIEBIG is an entire failure as a guide to the use of manures in practical farming. In some respects their views may be said to be diametrically opposed to those of LIEBIG. As a rule the latter holds, that plants when abundantly provided with their mineral constituents in an available form, may get their carbon and nitrogen from the air, though it does not follow that this source alone is to be trusted to for these ingredients; the former think that their experiments warrant them in concluding, that minerals supplied to wheat crops in much greater quantity than equivalent to those taken off in the increased produce, were only available so long as there was a liberal provision of nitrogen in the soil; that when this artificially-supplied nitrogen was exhausted, the minerals remained inactive and useless; that in the very cases where minerals gave an increased produce, in the well-defined limit to their

action which is indicated, there is further proof of the necessity of an artificial supply of nitrogen in the soil for the increased production of corn, and the incapacity of the mineral supply to yield any increase, excepting when nitrogen is thus provided. They further concluded from their experiments, that there is a fallacy in supplying to plants a manure founded on the percentage composition of their ashes: for in the case of the turnip, which shows, both in the leaf and in the bulb, a proportion of alkalies to phosphoric acid of from four or five to one, it might be thought that alkalies were, therefore, the more appropriate and special manure for turnips, whereas common practice has determined in favor of phosphoric acid, and their own experiments proved that the addition of alkalies to superphosphates on turnips did not increase the return.

LIEBIG, in his recent work on the Principles of Agricultural Chemistry, has clearly proved that the conclusions of these gentlemen are based on the most palpable fallacy of selecting for their experiments a portion of land which, so far from being in a practically and agriculturally exhausted state, was by the showing of their own experiments, still so rich in mineral constituents as to have yielded, though unmanured throughout, in the seventh year a crop which exceeded by seventy-seven pounds of grain and five hundred and ninety-nine pounds of straw that of the first year. The conclusion drawn by them from their results, that nitrogenized manures are peculiarly adapted for the culture of wheat, is true only for their own land under the given circumstances, namely, containing a sufficiency of available minerals, and would entirely mislead the practical farmer if he applied it to other land of different quality, and placed in different preliminary conditions. For it can be proved, as LIEBIG states, in the same way, and by facts equally decisive, that ammoniacal salts alone, in thousands of wheat fields, do not in the smallest degree increase the produce; and that in thousands of other such fields, these salts do increase the produce for a year or two; and that then a further application of them to the same land is found to be utterly without effect; that salts of ammonia increase the produce only if the mineral constituents be present in the soil in due quantity, and in an available form, by rendering those minerals more soluble, and accelerating their action in a given time. Hence the use of ammoniacal salts alone tends rapidly to exhaust a soil, and if used by themselves without any mineral manure, no cultivation whatever can be permanently kept up.

In the opinion of LIEBIG, the experiments of LAWES and GILBERT, so far from disproving the mineral theory, afford, on the contrary, the strictest and most satisfactory proof of its truth. The reader is referred to LIEBIG's able work for a clear and distinct view of what is really his mineral theory, and to a paper by the same author in defence of his views, in the seventeenth volume of the Journal of the English Agricultural Society.

Farmyard manure is taken as the type of manures, because it contains all the constituents removed from the land, and again restored to it in a form in which they can be made rapidly available. The carbonic

acid and salts of ammonia produced by its decomposition, cause water to dissolve more rapidly the mineral constituents. Compounds of ammonia would thus seem to have two actions in the nourishment of plants, namely, *First*, As a source of nitrogen; *Second*, As a solvent for certain important mineral constituents of the soil.

An artificial mixture can be theoretically compounded to take the place of farmyard manure, but it must contain all its mineral constituents. The agriculturist must return to the land whatever has been removed from it; for it has been laid down as a rule, that no part of the constituents of a rich soil can be removed without making compensation, but at the cost of sooner or later impairing its fertility.

It is not to be supposed from the preceding, that practical empirical experiments with special manures are to be altogether condemned as useless. They are, on the contrary, highly valuable under certain conditions. The error lies in elevating the practical results into general laws. Experience has shown, for example, that nitrogenized manures have produced large crops of wheat, and superphosphate of lime has had the same effect with turnips. The experimenters, forgetting to inquire whether these results are universally true, or true only under certain conditions, have emphatically pronounced nitrogen and superphosphates to be the manures for these crops. Other experimenters have come forward and shown that nitrogenized manures in their hands have not always had good results, and bones in the hands of others have not answered at all, either for turnips or anything else.

These contradictory conclusions embarrass the practical farmer, but the man of science sees that the difficulty lies in having taken these special results for general truths. His science has taught him, that there is a law more general still for the successful cultivation of wheat and turnips under all circumstances, namely, that along with nitrogen and phosphates, they must have *all* their mineral constituents provided for them. He is able thus to show, that the application of nitrogen and that of phosphates are mere special conditions for the successful cultivation of these two crops, which can only hold good when the more general and universal conditions are fulfilled. Instead of altogether rejecting the practical results obtained by others, he endeavors to ascertain if the failure of the special rule, in any given case, does not arise from the land not fulfilling the conditions of the more general law.

Rules for the application of Artificial Manures.—The following rules have been given by W. Hannam, as useful in carrying into effect the judicious application of artificial manures:—

In all mixtures designed for application in autumn or winter, the ammonia or nitrogen should be supplied in a form that would as far as possible prevent its operating too quickly—for example, it would be preferable to supply the nitrogen in union with other organic matter, as in rape-dust, bones, woollen rags, partially decomposed blood, guano, mixed with charcoal, gypsum, *et cetera*, rather than in the shape of salts of ammonia, which are so speedily soluble:

That all winter dressings of artificial manure should be mixed in the soil:

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That all mixtures in which the ammonia exists in a saline form, should be applied as a spring top-dressing upon the crop, if possible in wet weather during the third or fourth week of April:

That all mixtures containing organic matter rich in ammonia, as rape-dust or guano, if applied with spring crops, should be harrowed in immediately; and if applied as a top-dressing, should be used only in wet weather:

That spring top-dressings, which contain organic matter, should be applied earlier than those purely saline:

That mineral manures which contain their phosphates and alkalies in the most soluble state, should be applied in spring crops:

That where a heavy saline dressing is required in spring, upon wheat, potatoes, or grass, it is advisable to apply it at two distinct periods about a month apart, as in April or May.

In a recent paper, just received from Baron LIEBIG, and which contains numerous experimental data, the good effects of chloride of sodium, nitrate of soda, and salts of ammonia are shown to depend, not so much on their intrinsic value, as upon their capacity of dissolving large quantities of phosphate of lime, thus rendering this important salt easily conveyable to the roots of the plants.

Absorbent power of soils for Manures.—At the time these rules were given, the absorbent powers of soil were not then known, and precautions were supposed to be necessary in the application of manures, which experiment has since shown to be superfluous.

THOMPSON first pointed out the power possessed by soils in arresting salts of ammonia, and WAX has extended the same observation to all the mineral constituents which serve as food of plants. He found that, without exception, the bases of the alkalies and alkaline earths were removed from their acids, and retained by soils; the acids, such as sulphuric and hydrochloric passing away in solution in combination with lime. There was one remarkable exception in the case of phosphoric acid, which never passed away like sulphuric acid, but was retained by the soil, though presented to it in the form of a soluble alkaline phosphate. Nitric acid, on the other hand, now and much employed in agriculture, was found to pass rapidly away. This acid, when in combination with potassa, soda, or ammonia, was found to give up these bases, and to pass off in combination with lime. In prosecuting his inquiries to find out what constituents of soil possessed this extraordinary power, he ascertained that it was due to clay alone. It is not a mere power of absorption, as is the case with charcoal, but a chemical action. It does not appear, however, that the whole mass of clay acts, but portions containing silicate of lime, which, in contact with the alkaline salts, gives up a portion of its lime to their acids, and retains their bases as double silicates. Whether or not this is the true explanation, the fact is certain, that clay is the absorbing material. Hence, sandy and gravelly soils not possessing a sufficiency of clay, might be expected to be less retentive of manure. The experience of all farmers proves this fact; such sandy and gravelly land being said by them not to hold

manures. On such soils, manures require to be applied more frequently and in smaller quantities than in stiffer clay soils, which have the power of retaining the manure for several crops.

A knowledge of this property of clay explains the fertility attending the application, as is practised in Norfolk, of clay to sandy soils. From some recent experiments and analyses, LIEBIG doubts whether the clay is the only absorbing material. In the Editor's opinion, the *physical condition* of the soil must have something to do with it.

In the case of ammonia, the supply to the soil is not derived alone from the manures, or the ammonia of the air brought down by rain; but absorption of this gas goes on continuously from the atmosphere by contact alone. LIEBIG, in 1846, caused the analysis of twenty soils to be made in his laboratory, from which he ascertained the enormous amount of ammonia really present in every soil. One acre of the most unfruitful soil taken, to the depth of only ten inches, contained more than a hundred times, and one acre of fertile soil, as much as from five hundred to a thousand times more nitrogen than is required for the heaviest crop of wheat, or than is given to it in the most liberal supply of manure.

If the experimental results of WAY be correct, it would appear that unnecessary alarm was felt a short time ago, that the system of tile-draining, which was so universally adopted with the happiest effects to agriculture, would ultimately tend to exhaust the soluble mineral ingredients of the soil.

In his paper on the composition of land-drainage water, WAY has, by a series of carefully-conducted analyses, found that the substances which exist in drainage water in largest proportion are those which are most abundant in the soil, namely, lime and magnesia, soda, and sulphuric acid; and that, with the exception of nitric acid, none of the essential mineral food of plants is found in any quantity. If 42·4 per cent. of the annual rain pass through the soil, and the latter be taken at 25 inches, the quantity of drainage water from an acre of land would amount to about two hundred and forty thousand gallons. Even where the land is very highly manured, he shows that this large quantity of water removes from the soil only inconsiderable quantities of the most important mineral ingredients of soils, namely, potassa and phosphoric acid. The quantity of ammonia carried off is very small; but nitrogen in the form of nitric acid, especially in highly manured land, is to be found in large quantity in the water of land drainage. VOELKER showed that clay soils exert this action on complex organic mixtures, such as the drainings of dunghills, as well as on simple salts. From the most highly mixed manuring substances, not only ammonia from the ammoniacal salts, but potassa, phosphoric acid, and all the essential ingredients of the food of plants, are all removed from solution in water, and retained in the soil.

These experimental results are fundamental facts of the utmost importance to agriculture. They explain the advantage of drainage, by showing that the manure which would be carried off the surface of the undrained land into the water-courses, is carried down by the water which is passing into the drains of a drained

field, but is separated from solution by the soil through which it percolates. They show that the best mode of applying manures is that which causes the most uniform distribution of it, namely, as a liquid. For if salts of ammonia, when once applied to the soil, combine with it and remain fixed, water would seem to have no further power of uniformly distributing them, and hence the frequent irregularity of crops in manured fields. The fear has hitherto been, that by too early an application of manures to the land before the crop, there was a risk of loss, by evaporation and by rain. This is true to some extent for sandy soils, on which, it appears, the true guiding principle should be, for the manure to be applied frequently and in smaller quantities at once. The retentive power of clay, on the other hand, may be fairly trusted to keep all that is bestowed upon well-drained clay soils.

Classification of Manures.—Manures may be divided into two great classes, namely, general and special.

General manures include all mixed substances, whether of an animal or vegetal origin, which contain all the constituents necessary to plants for luxuriant growth. Such manures confer permanent fertility on a soil.

Under this class may be ranged—Farmyard Manure, Guano, Night-Soil, Sewage Manure, *et cetera*.

Special manures are those substances which contain only one or more of the constituents necessary to the growth of plants. They cannot confer permanent fertility on the land, but on the contrary, their exclusive and continued use tends to render it ultimately sterile, by enabling particular crops to remove more rapidly and largely those ingredients which are actually in the soil. To this class belong bones, blood, woollen rags, horns, fresh rape-cake, sea-weeds, gas-liquor, salts of ammonia and of the alkalies and alkaline earths, *et cetera*.

It would be quite out of place in an article of this kind, to discuss at length the various substances used as fertilizers. It will be sufficient to take from these two classes one or two examples of the most commonly-employed manures, and to give under each the principal points connected with their theory, management, and applications, from which the principles connected with the application of other manures may be inferred.

GENERAL MANURES.—Farmyard Manure—History.—The first attempt to restore fertility to the soil must have been by the use of the excrement of animals, and must date from an early period of the history of mankind. The art of husbandry, and the preparation of mixed manures for their fields, occupied much the attention of the Romans. Their writers inculcate the formation of two manure heaps, one to receive the fresh dung, the second for the old manure, which was applied to the field after being kept a year. Their manure was recommended to be placed in a hollow to collect moisture, and to be covered with straw to protect it from the weather. These good rules were forgotten during the long period which succeeded the extinction of Roman civilization. It is only of late years that science has been brought to bear on this subject, and with that success which is its invariable accompaniment. The study of the composition, and of the chemical metamorphoses that farmyard manure undergoes, has enabled

scientific men to suggest the best means of collecting, preserving, and applying it.

Theory of the action of Farmyard Manure.—It has long been an opinion of the practical farmer, that nothing can be a complete substitute for farmyard manure. This opinion is to a considerable extent justified by analysis, for it contains, with the exception of a portion of carbon and hydrogen, all the materials which have been removed from the soil by plants. It is formed for the most part of cows' dung, pigs' dung, and straw, mixed and trodden together. Where green crops are extensively grown and many cattle kept, cow dung forms a great proportion of the manure. The composition and value of farmyard manure will, therefore, vary much with the feeding and the animals. Thus, the manure of cattle fed on turnips is inferior to that of cattle fed on oil cakes; the manure of horses fed on straw and hay, is much poorer than that of horses fed on corn; the compound manure which has an excess of cattle excrement is less powerful than one with an excess of the dung of the horse; the compound manure which contains no night-soil, is less fertilizing than one with a proportion of it. An analysis of one specimen of farmyard manure cannot be taken as a general expression of its composition, which varies with the circumstances above stated. The only process by which an approximative idea may be formed of the fertilizing powers of a given quantity of farmyard manure, is to observe the kinds of animal excrement it contains, and the proportions in which they are mixed with each other, and with vegetal matters.

Farmyard manure which is either quite fresh, or has undergone so little fermentation as to retain its litter in an undecomposed, and but partially broken state, is known by the name of *long dung*. When it has been

thoroughly fermented, so as to have been changed into a rotten powdery or saponaceous mass, or is so free from litter as to consist almost entirely of solid excrement, it receives the name of *short dung*. Much controversy has existed among farmers, as to the relative merits of these two forms. An examination of the chemical changes which have taken place in this process, throws some light on these controversies. KOERTE found by experiment, that one hundred loads of fresh dung become reduced by fermentation and exposure as follows:—

	loads.
In 81 days 100 loads were reduced to	73·3
In 285 " " " "	64·4
In 384 " " " "	62·5
In 499 " " " "	47·2

In sixteen months the quantity had been reduced to less than one half, and the most valuable salts lost.

The reduction of weight of farmyard manure depends on two causes, namely, the elimination of gases by fermentation, and the loss of soluble matters by drainage. The latter, the least feared, is by far the most serious source of loss. The former has been shown by VOELKER to be not so destructive as was formerly supposed.

By making a thorough mixture of the litter, and dung of fresh or long dung, VOELKER obtained a sample for analysis, and for experiments with fermentation. By comparing the composition before and after fermentation, he arrived at some valuable conclusions.

Fresh farmyard manure, composed of horse, pig, and cow dung, about fourteen days old, and on which no rain had fallen, was found to consist, in round numbers, of two-thirds of water and one-third of solid matters.

COMPOSITION OF FRESH FARMYARD MANURE, COMPOSED AS ABOVE STATED, AND FOURTEEN DAYS OLD.

	In its natural fresh state.		In its dry state.	
Water,	66·17	—	—	—
Soluble organic matter,	2·48	—	—	7·33
{ Containing nitrogen,	0·149	—	0·44	—
{ Equal to ammonia,	0·181	—	0·53	—
Soluble inorganic matter—ash composed of—				
Soluble silica,	0·237	—	0·703	—
Phosphate of lime,	0·299	—	0·884	—
Lime,	0·066	—	0·185	—
Magnesia,	0·011	—	0·033	—
Potassa,	0·573	—	1·695	—
Soda,	0·051	—	0·153	—
Chloride of sodium,	0·030	—	0·089	—
Sulphuric acid,	0·055	—	0·035	—
Carbonic acid and loss,	0·218	—	0·772	—
	1·54	—	—	4·55
Insoluble organic matter,	25·76	—	—	76·15
{ Containing nitrogen,	0·494	—	1·46	—
{ Equal to ammonia,	0·599	—	1·77	—
Insoluble inorganic matter—ash composed of—				
Soluble silica,	0·967	—	2·865	—
Insoluble silica,	0·561	—	1·659	—
Oxide of iron, and alumina with phosphates,	0·596	—	1·404	—
{ Containing phosphoric acid,	0·178	—	0·528	—
{ Equal to bone earth,	0·386	—	0·822	—
Lime,	1·120	—	3·335	—
Magnesia,	0·143	—	0·424	—
Potassa,	0·099	—	0·294	—
Soda,	0·019	—	0·077	—
Sulphuric acid,	0·061	—	0·210	—
Carbonic acid and loss,	0·484	—	1·722	11·97
	4·05	—	—	—
	100·00	—	—	100·00
Whole manure contains ammonia in free state, ..	0·034	—	0·10	—
" " " in form of salts, ..	0·088	—	0·26	—

This analysis of a fair average specimen of fresh farmyard manure, so far as an average can be taken of this substance, is instructive. It shows that farmyard manure is a perfect and universal manure, because it contains all the constituents which are required by the commonly-cultivated crops to bring them to perfection, and in states of combination which appear to be especially favorable to their luxuriant growth. It explains fully the slow action of fresh dung when compared with the effects of well-rotted manure; because the former contains only one-eighth of soluble matters as compared with the insoluble, whilst in the latter this quantity of soluble is much increased by fermentation, as will presently be seen. In this small soluble portion, the most important fertilizing substances are present.

The proportion of nitrogen in one hundred parts of the soluble organic matter, as compared with the insoluble, is as 6.04 to 1.92. The most valuable salts pre-

sent in considerable quantities are silicates of potassa and phosphate of lime.

The remarkable fact of the presence, in the watery solution, of phosphate of lime, usually considered an insoluble compound, is explained by the observation of WÖHLER, that bone-dust, moistened with a little water, in the course of a few days yields to water a considerable quantity of phosphate of lime, and this solubility rapidly increases with the putrefaction of the gelatine of bones. Hence, wherever earthy phosphates exist with organic matter, water will invariably dissolve a portion, progressively with the decomposition of the organic matter by fermentation. This fact is of the utmost importance to agriculture.

The effect produced on manure by fermentation is well seen by analysis. A well-mixed sample of rotten dung, of dark-brown color, at least six months old, and which was produced under the same circumstances as the fresh manure, was found to have the following composition:—

COMPOSITION OF WELL-ROTTED MANURE, SIX MONTHS OLD, CONSISTING OF MIXED HORSE, COW, AND PIG DUNG.

	In its natural fresh state.		In its dry state.	
Water,.....	—	75.42	—	—
Soluble organic matter,.....	—	3.71	—	15.09
{ Containing nitrogen,.....	0.297	—	1.21	—
{ Equal to ammonia,.....	0.360	—	1.47	—
Soluble inorganic matter, or ash, composed of—				
Soluble silica,.....	0.254	—	1.035	—
Phosphate of lime,.....	0.382	—	1.554	—
Lime,.....	0.117	—	0.476	—
Magnesia,.....	0.047	—	0.193	—
Potassa,.....	0.446	—	1.816	—
Soda,.....	0.023	—	0.140	—
Chloride of sodium,.....	0.037	—	0.151	—
Sulphuric acid,.....	0.058	—	0.235	—
Carbonic acid and loss,.....	0.106	1.47	0.380	—
				5.98
Insoluble organic matter,.....	—	12.82	—	52.15
{ Containing nitrogen,.....	0.309	—	1.26	—
{ Equal to ammonia,.....	0.375	—	1.53	—
Insoluble inorganic matter, or ash, composed of—				
Soluble silica,.....	1.424	—	5.79	—
Insoluble silica,.....	1.010	—	4.11	—
Oxides of iron and alumina, with phosphates,.....	0.947	—	3.85	—
{ Containing phosphoric acid,.....	0.274	—	1.11	—
{ Equal to bone earth,.....	0.573	—	2.41	—
Lime,.....	1.667	—	6.78	—
Magnesia,.....	0.091	—	0.37	—
Potassa,.....	0.045	—	0.18	—
Soda,.....	0.038	—	0.15	—
Sulphuric acid,.....	0.063	—	0.29	—
Carbonic acid and loss,.....	1.295	6.58	5.26	26.78
		100.00		100.00
Whole manure contains ammonia in free state,...	0.046	—	0.189	—
“ “ “ form of salts, 0.057	—	—	0.232	—

An examination of these two Tables shows that, during the fermentation of dung, the quantity of both soluble organic and soluble mineral matters rapidly increases; and that the proportion of ammonia and of phosphate of lime in these soluble matters also rapidly augments. Thus one hundred parts of dry soluble organic matter from fresh dung contain 6.14 of nitrogen, whilst one hundred from rotten dung contain 8.02, and the phosphate of lime is nearly doubled. The proportion of organic matter decreases as the fermentation goes on, but the loss is in carbonic acid and other non-essential gases. There is apparently no serious loss of ammonia by evaporation, as is commonly supposed. Direct experiments have shown that, in the cold, no ammonia is given off from the surface of farmyard manure, and

that a considerable amount of heat is necessary for this purpose. Now, as this occurs only in the interior of the heap when the fermentation is active, the liberated ammonia, in passing through the outer layers of decaying organic matter at a lower temperature, is arrested. This fact was proved by VOELKER by the analysis of fresh manure made into a heap, and left for six months. The amount of dry organic matter was found to have diminished from nine hundred and sixty pounds to six hundred and ninety; but the total amount of nitrogen at the commencement was 18.23 pounds, and at the end of six months 18.14, or nearly the same.

The practical result of these changes by fermentation is, that, weight for weight, well-rotted farmyard manure is richer in soluble fertilizing constituents than

fresh dung, and contains more readily available nitrogen, and, therefore, is more immediate and energetic in its action on vegetation.

It appears that, up to a certain point, the efficacy of farmyard manure is increased by a well-regulated fermentation, during which the loss of really valuable constituents is trifling. But there is a danger of serious loss if the fermentation is pushed too far and the manure heap is frequently turned, whilst there is great heat developed by this fermentation.

Another, and a far more serious loss, is incurred by keeping manure too long unprotected from the weather, not, however, by the volatilization of ammonia, but by the removal of salts of ammonia, soluble nitrogenized organic matters, and valuable mineral salts by rain;

well-rotted dung being more readily affected than fresh. This loss is great when the manure is kept in heaps, and the deterioration is still more rapid when the method of making manure is by animals kept in open yards. The dark-colored fluids from manure heaps, which are too frequently allowed to run into the next ditch, are but concentrated solutions of their most valuable constituents: they not only contain the valuable potassa salts and ammonia, but also phosphate of lime, a constituent brought into solution by the process of fermentation.

The following table shows the loss sustained at successive periods in twelve months, by two thousand eight hundred and thirty-eight pounds of manure put up in a heap in the usual way, and exposed to the weather:—

	When put up.			
	November 3, 1854.	April 30, 1855.	August 23, 1855.	November 15, 1855.
Weight of manure in pounds,.....	2,838	2,026	1,994	1,974
Amount of water in the manure,.....	1877·9	1336·1	1505·3	1466·5
Amount of dry matter in the manure,.....	960·1	689·9	488·7	507·5
Consisting of—				
Soluble organic matter,.....	70·38	86·51	58·83	54·04
Soluble mineral matter,.....	43·71	57·88	39·16	36·89
Insoluble organic matter,.....	731·07	389·74	243·22	214·92
Insoluble mineral matter,.....	114·94	155·77	147·49	201·65
	960·10	689·90	488·70	507·50

The amount of nitrogen and its equivalent of ammonia in the preceding soluble and insoluble organic matter is the following:—

SOLUBLE ORGANIC MATTER.				
Containing nitrogen,.....	4·22	6·07	3·76	3·65
Equal to ammonia,.....	5·12	7·37	4·56	4·26
INSOLUBLE ORGANIC MATTER.				
Containing nitrogen,.....	14·01	12·07	9·38	9·38
Equal to ammonia,.....	17·02	14·65	11·40	11·39
Total amount of nitrogen in the manure,.....	18·23	18·14	13·14	13·03
Equal to ammonia,.....	22·14	22·02	15·96	15·75
The manure contains ammonia in free state,.....	0·96	0·15	0·20	0·11
The manure contains ammonia in the form of salts, } easily decomposed by quicklime,..... }	2·49	1·71	0·75	0·80
Total amount of organic matters,.....	801·45	476·25	302·05	268·96
Total amount of mineral matters,.....	158·15	213·65	186·65	—

Management of Farmyard Manure.—The foregoing experiments teach that a certain amount of fermentation is good for farmyard manure, because it renders the fertilizing ingredients more soluble, and their effect more immediate. For the establishment and continuance of fermentation, a certain amount of heat, air, and moisture is necessary. These conditions are fulfilled when the latter is not in excess, and the excrement has been yielded by cattle fed on tolerably rich and succulent food. If the litter is in excess and but little excrementitious matter present, or not well mixed throughout with the litter, fermentation does not take place through the whole mass. Even when there is abundance of excrement, and fermentation has fully commenced, it is sometimes arrested by deficiency of moisture, and the interior of the heap presents, if no remedy is applied, a white appearance of dead, inert manure. This phenomenon is known under the name of fire-fanging. The prevention of this defect lies in the care that is taken to mix the excrement thoroughly on first collecting the manure; and if

there is a deficiency of natural moisture, in adding water from time to time. The remedy for it when present, is to turn the heap over, soak it with water, and mix it with horse-dung, or any animal offal that can be obtained. When manure has been once properly mixed and placed in heaps, which ought not to be more than three or four feet high, it should be left to itself undisturbed until carted out for use. Some farms, however, produce so large an amount of manure that it is a matter of convenience and economy to remove it during winter to the borders of the fields where it is to be applied. In these cases the manure should be stirred as little as possible when taken from its original place of deposit, and when emptied from the carts at the new heap.

The great loss to be dreaded in manure piles is, as has been seen, from the rain. The drainings from manure heaps being much more valuable than the urine of animals, it is of the utmost importance to protect the heaps from the action of rain, and to collect the fluids which escape from them, which might be

either applied as fluid manure, or, in smaller establishments, returned to the manure heaps. It might be advisable to incur the expense of covering with hurdles and straw, or with clay, such manure heaps as are placed in the fields. In these heaps the soluble salts are, in dry weather, continually brought by capillarity to the surface, only to be washed away by the next fall of rain.

Application of Farmyard Manure.—In old practice, a large dose of from thirty to fifty tons was given per acre, and not repeated till the land was nearly exhausted. The modern and improved practice is to give a moderate quantity, and repeat it often. Quantities, varying from ten to fifteen tons, are used according to the nature of the soil, the quality of the manure, and the kind of crop. It has been recommended to spread and plough it in, immediately after being deposited from the carts, on the supposition that it suffers great loss by evaporation. If the experiments of VOELKER and of WAY be correct, and there seems to be no reason to doubt their accuracy, this notion is quite false. The results of these gentlemen would seem to indicate the best mode of application to be, to spread the manure as evenly as possible on the surface of the ground, at a time when it is not saturated with moisture or bound up with frost, but in a season of frequent showers. The soluble organic and mineral matters would, in the course of ten days or a fortnight, according to the amount of rain, be washed into and retained by the soil, and the insoluble matters could then be covered up by the plough. The old method of depositing the manure on the field in heaps, and leaving it so for a length of time, is a very bad practice. The soluble matters are washed into the ground under and immediately adjoining to the heaps, and cannot afterwards be evenly distributed by rain through the soil, hence the result is irregularity in the crops of such fields.

Night-Soil and Urine.—Night-soil is in general a very rich manure, but its offensive smell has prevented it from being generally used. This exhalation may, however, be removed by various substances, such as charcoal, a charred mixture of vegetal matter and clay, *et cetera*. In the vicinity of large towns it is dried and manufactured in various ways into a portable manure, which is sold as *poudrette*, dried night-soil, *et cetera*. In China it is mixed with clay, and sold under the name of *taffo*. FORTUNE, in his wanderings in China, gives an amusing account of the extreme care exhibited by the Chinese in collecting, preparing, and applying night-soil.

BERZELIUS found the composition of fresh fæces to be—

	Centesimally.
Water,.....	73·3
Organic matter,.....	25·5
Salts,.....	1·2
	100·0

In general, human excrement contains three-fourths of its weight of water, and its composition and consequent value varies with the food, and the age and health of the individual. The following analysis of this substance by WAY shows that it contains all the fertilizing constituents necessary for different crops:—

ANALYSIS OF DRIED HUMAN FÆCES.

	Composition of the ash.	Composition of the dried excrement.
Organic matter,.....	—	88·52
Insoluble silicious matter,..	12·79	1·48
Oxide of iron,.....	4·66	0·54
Lime,.....	14·98	1·72
Magnesia,.....	13·48	1·55
Phosphoric acid,.....	37·17	4·27
Sulphuric acid,.....	2·10	0·24
Potassa,.....	10·40	1·19
Soda,.....	2·83	0·31
Chloride of sodium,.....	1·59	0·18
	100·00	100·00
Nitrogen per cent.,.....		5·00

Human Urine.—Human urine varies with the age, health, and food of the individual. It has been calculated that the average quantity voided in twenty-four hours by each member of a community is about three pounds. According to BECQUÉREL, the composition of urine in round numbers is, in a thousand parts:—

Water,.....	970·5
Solid constituents, 29·5 parts, consisting of—	
Urea,.....	13·5
Uric acid,.....	0·5
Fixed salts,.....	7·5
Organic salts,.....	8·5
	1000·0

The composition of the solid matter of evaporated urine was found by WAY to be as follows:—

	Composition of the ash.	Composition of the solid dry matter.
Organic matter and salts of ammonia,.....	—	67·54
Insoluble silicious matter,..	0·28	0·09
Oxide of iron,.....	0·14	0·05
Lime,.....	1·89	0·61
Magnesia,.....	1·49	0·47
Phosphoric acid,.....	14·31	4·66
Sulphuric acid,.....	1·43	0·46
Potassa,.....	5·64	1·83
Soda,.....	none	none
Chloride of potassium,.....	16·65	5·41
Chloride of sodium,.....	58·17	18·88
	100·00	100·00
Nitrogen per cent.,.....		19·43
Equal to ammonia,.....		23·60

When the total quantity of excrement and urine voided in twenty-four hours is taken into account, it is found that the latter is the most valuable. If the quantity of fæces for one individual for twenty-four hours be taken at one and a quarter pounds, and the quantity of urine at three pounds, the amount of nitrogen in each would be as follows:—

	Containing		
	Dry matter. Grains.	Salts. Grains.	Nitrogen. Grains.
Solid excrement voided in twenty-four hours, ..	1,750 grains— $1\frac{1}{4}$ pounds	437·5	21·0
Urine voided in twenty-four hours,.....	21,000 grains—13 pints	619·5	158·0
		26·25	125·0

These analyses show how important it is to collect and add to the manure heap the excrement of men, which, in the proportion of valuable agricultural constituents it contains, far exceeds that of other animals.

Sewage Manure.—Sewage water may be considered as consisting of the solid and liquid excrements of a town population, with all the waste materials from manufactories and private houses which rain is capable of removing. That such a liquid must necessarily possess fertilizing properties is seen by turning to the analysis of human excrement already given. But when the supply of water to each individual is taken in addition to the rain daily passing through the drains, it has been estimated by WAY that the solid matter of the urine and feces passed in twenty-four hours by one individual, is mixed with fourteen hundred times its weight of water. If only the insoluble matter of the sewage were to be separated by filtration, it would be necessary to filter nearly three thousand tons—more than half a million of gallons—to obtain from it one ton of dry manuring matter. This enormous amount of liquid constitutes the real difficulty in the way of the application of sewage liquid to agricultural purposes; still even this difficulty is simply mechanical, since it follows from LIEBIG and WAY's experiments, that, no matter how dilute a fertilizer may be, when applied, all its valuable constituents are retained by the land. The Chinese system seems to confirm the foregoing, as they prefer using their manures in a highly diluted form. Two modes of applying sewage manure have been proposed—the first, directly by irrigation; the second, by precipitating the solids and making use of them.

Where a natural fall exists for the outlet of the drains, the first plan has been most successfully carried out in various places. The rent of a meadow near Portobello, in the neighborhood of Edinburgh, was by this means raised from a few shillings to twenty-five pounds per acre. Various plans are now in agitation to carry away by a system of pipes the sewage of towns, and deliver it at a distance for agricultural purposes.

For effecting the second object—namely, the precipitation of the solids—various substances have been proposed. Among the most important of these are charcoal, lime, sulphate of lime, clays burnt and unburnt, the salts of alumina, and of zinc and iron, the compounds of magnesia, burnt magnesian lime-stone, and certain silicates. By none of these bodies are all the valuable fertilizing constituents precipitated, and many of them have little or no action at all on these substances. A good process for extracting at a moderate price the valuable constituents of sewage water is, therefore, still a desideratum.

GUANO.—**HISTORICAL NOTICE.**—This name is given to the accumulated fecal matter of sea-fowl, and is derived from the Peruvian word *huana*, signifying manure or dung. There is scarcely anything more remarkable in the history of agriculture than the introduction into Great Britain of guano as a manure. The old faith in farmyard manure was so firmly established, that the new fertilizer was received with utter distrust.

The report of its constant employment as the sole manure with the most marked success by the natives of the country from which it was imported, the results of trials with it by eminent Englishmen at home and elsewhere, obtained so little attention from the agricultural world generally, that in 1840 no greater quantity than twenty casks of it were imported. In 1841, the Earl of DERBY—then Lord STANLEY—introduced it to the notice of the public at the dinner of the Liverpool meeting of the Royal Agricultural Society of England. From this time it came rapidly into use; and, at the present moment, agriculturists have gone to the other extreme, and appear to think that they cannot get on without it. The quantities imported into Britain during the first five years after its fair introduction to agriculturists, and whilst it was slowly making its way with them, compared with the importations of the last five years, will show how enormously this substance has risen in repute:—

	Tons.		Tons.
1841,.....	1,733	1853,.....	123,166
1842,.....	13,094	1854,.....	235,111
1843,.....	4,056	1855,.....	143,136
1844,.....	81,902	1856,.....	191,501
1845,.....	220,914	1857,.....	288,362

The deposits of guano longest known, and for some time supposed to be the only ones, are those on the islands and sea-boards of Peru, between the thirteenth and twenty-first degrees of South latitude. The Peruvians are known to have made use of this substance as a fertilizer from the twelfth century. Their soil, which consists of sand and clay, and is naturally most barren, was enabled by the use of guano to produce year after year abundant crops of grain.

The Chincha Islands, which afford the best guano, are, according to Dr. URE, three in number, and lie in one line from North to South, about half a mile apart. Each island is from five to six miles in circumference, and consists of granite covered with guano, in some places to a height of two hundred feet, in successive horizontal layers, each layer being from three feet to ten inches in thickness, and varying in color from light to dark-brown. No earthy matter whatsoever is mixed with this mass of excrements. In some of these islands, however, the deposit does not exceed three to four feet in thickness. The total quantity of guano estimated to be on these islands by M'INTOSH, in his report to the Admiralty, was eight million six hundred thousand tons. According to the Peruvian survey, the quantity is double of this—namely, eighteen million two hundred and fifty thousand tons. Dr. KINAHAN, in his paper in the Journal of the Royal Dublin Society for July, 1856, gives fifteen to twenty million tons; whilst others estimate it so high as from one hundred to one hundred and fifty million tons. From a rough estimate made by Mr. WALTON, it would appear that the deposit of guano in Peru continues by the yearly addition of a fresh quantity of excrement amounting to about thirty thousand tons, which, however, does not all become available. Since the demand for guano has so increased, other localities have been searched, and supplies have been obtained from other and widely-separated regions. The coasts of Chili, Bolivia, Patagonia,

Cuba, Labrador, Australia, and the isles of Ichaboe, Malaya, Augra, Peguena, and near the Cape of Good Hope, and of Kooria Moorla, near the coast of Arabia, have furnished supplies of greater or less magnitude, and of very varying qualities. It is highly probable that deposits of this substance will be found in every region much frequented by sea-fowl, and that further stores will yet be opened up when closer investigations have been made of the many uninhabited islands of the Pacific Ocean.

Fertilizing Power of Guano.—Guano owes its fertilizing power to its being a well-tempered mixture of nearly all the essential ingredients necessary for the nourishment of all cultivated crops. Its properties are particularly due to the large quantity of phosphates and ammonia which it contains, and these in a concentrated form. In the best guano—such as the Peruvian—there is present a considerable portion of alkaline phosphates, so that in itself guano combines all the good properties possessed by different manures separately. It contains soluble phosphates and salts of ammonia ready to be at once carried in solution in water into the roots of plants, and a further supply of these substances in a less soluble form, but which, by the aid of decomposition, and by the carbonic acid of the soil, are gradually dissolved and made available in proportion to the wants of the growing plant. There is only required the soluble silicates so necessary to the stems of the cereals, and which must be derived from some other source.

If the value of a manure be calculated, as is done by BOUSSINGAULT, according to the amount of nitrogen it contains, NESBIT estimates that one ton of good Peruvian guano is equal to

33½ tons of farmyard manure.
21 tons of horse dung.
35½ tons of cow dung.
22½ tons of pig dung.
14½ tons of mixed human excrements.

From the form in which the mineral constituents exist in guano, it is a manure peculiarly fitted for application in known quantities to the immediate wants of the growing crop.

It is not intended to convey by this, that the amount of mineral constituents to be removed by a given crop is to be calculated, and the exact corresponding amount of mineral matter in the guano to be added. As the roots of the growing crop are not likely to find *all* the substances added to the soil, a considerably greater quantity of mineral matter is actually employed than is likely to be removed by the crop. With this allowance the agriculturist is able to regulate his supply to the demand of the crop, and to go to no greater expense than what he may deem necessary for the existing wants. The materials are in a form in which they can be dissolved and made use of by the one growing crop; and if only added to the land in sufficient quantity for that one crop, no effect can be looked for in the succeeding crop.

The quantity of guano usually applied per acre varies from two to five hundredweight. It is applied directly as a top-dressing, spread broad-cast by hand over the surface, or in compost with other substances, either

broad-cast or in drills, and buried by the plough. From its caustic nature, guano should not be placed in contact with the seed. In the case of wheat it may be sown broad-cast over the young plants in wet weather, and then harrowed in. With grass, clover, and such seeds sown broad-cast, it may be applied ten days before the seed, the land being immediately harrowed and allowed to absorb the manure. For turnips and other drilled crops, when used as an auxiliary to farm manure, it has been recommended to be sown broad-cast over the drills before they are split by the plough, to cover the farmyard manure in the furrows; the guano is thus mingled above the manure with the earth in which the turnip seed is to germinate. Perhaps, as has been recommended by NESBIT, it would be preferable to apply two-thirds of the guano broad-cast and one-third in drill with the seed. For this purpose the guano must be mixed with four to six times its weight of the ashes of wood or peat charcoal. The guano and ashes are then mixed in alternate layers by the spade or a sieve, and, after being well turned and mixed, left for eight days, and, finally, thoroughly incorporated by sifting; it is then fit for use. Great care must be taken that, in the drill, this mixture fall below the seed, and that the latter be protected by the intervention of an inch or two of soil.

Analysis of Guano.—Guano is a very complex mixture, containing urate, oxalate, and phosphate of ammonia, earthy phosphates, soluble alkaline salts, and organic matter. The analysis of such a compound is attended with some labor. As the value of guanos, however, depends on the quantity of ammonia, phosphates, soluble and insoluble, and alkaline salts which they contain, a very simple analysis is quite sufficient for agricultural purposes.

The guanos brought from different localities may be ranged under two heads—the ammoniacal and the phosphatic. The Peruvian is the type of the former, and is valuable for the large quantity of ammonia which it eviscerates. The Bolivian or Saldanha Bay may be taken as the type of the phosphatic class, which contains a small proportion of ammonia, with large quantities of earthy phosphates.

The composition of the different kinds of guano more generally imported, is the following:—

The composition of the Peruvian is the average of seventy-eight analyses made by WAY.

COMPOSITION OF PERUVIAN GUANO.

	Centesimally.
Moisture,	13·67
Organic matter and salts of ammonia,	52·05
Earthy phosphates,	22·78
Alkaline salts containing 3·34 phosphoric acid, and equal to 6·89 soluble phosphate of lime,	9·67
Sand, <i>et cetera</i> ,	1·83
	<hr/> 100·00
Ammonia per cent.,	16·52

A variety of Peruvian guano, under the name of Augamos guano, is also met with in the market. It is the freshly-deposited faecal matter of birds, is richer than Peruvian guano in ammonia, and brings a higher

price. Only a few cargoes of this substance are annually obtainable. Its composition is subjoined:—

	Centesimally.
Moisture,.....	10·5
Organic matter and salts of ammonia,.....	62·5
Earthy phosphates,.....	17·0
Alkaline salts,.....	7·5
Sand, <i>et cetera</i> ,	5·2
	100·0
Ammonia per cent.,	21·1

ANALYSIS OF THE CHIEF PHOSPHATIC AND OTHER GUANOS—AVERAGE COMPOSITION FROM SEVERAL ANALYSES.

	Ichaboe; earlier importations.	Ichaboe; recent importations.	Saldanha Bay.	Patagonian.	Bolivian.	Chilian.	Kooria Moorla.
Moisture,.....	27·3	20·0	20·0	25·0	10·0	20·4	18·1
Organic matter and salts of ammonia,.....	34·3	24·4	14·9	18·3	21·7	18·6	12·4
Earthy phosphates,.....	30·3	20·4	56·4	44·0	51·5	31·0	42·7
Alkaline salts,.....	5·0	6·2	5·8	2·1	14·1	7·3	4·2
Carbonate of lime,.....	—	—	—	—	—	—	4·1
Sand, <i>et cetera</i> ,	3·1	29·0	2·9	10·6	2·7	22·7	18·5
	100·0	100·0	100·0	100·0	100·0	100·0	100·0
Ammonia per cent.,.....	7·3	6·0	1·47	2·5	4·5	5·47	2·05

The following is a simple method for analysing guano, which gives sufficiently accurate results for commercial and agricultural purposes. The sample of guano, which ought to be taken from different bags, is to be well mixed, and about two pounds of this taken for analysis. If there are lumps in the sample, these are to be finely pounded, and the whole repeatedly passed through a sieve so as to get a uniform mixture. To determine the moisture, about fifty grains are to be dried at 212° till they cease to lose weight.

For Ammonia.—If the sample is rich in ammonia, about twenty grains, and, if poor, about fifty grains are taken, a few drops of hydrochloric acid added to prevent the loss of this alkali, which takes place in some guanos on exsiccation, and then dried at 212°, and burnt with soda-lime, which must also be previously desiccated and cooled immediately before use. The mixture is introduced as rapidly as possible into the combustion tube. No appreciable loss of ammonia occurs if the substances are well dried before mixing. For ordinary purposes, sufficiently exact results are obtained by simply evaporating the chloride of ammonium on a water bath to dryness. One part of this salt represents 0·315 of ammonia.

Fifty grains of the sample are burned at not too high a temperature, till they cease to lose weight. The loss in weight represents the moisture, organic matter, and ammoniacal salts.

After being weighed, the ash is digested in warm water, filtered, and washed two or three times. The residue, dried and weighed, represents matters insoluble in water; the loss represents the soluble alkaline salts, which generally consist of chlorides and sulphates; and in the case of the better class of guanos, such as Peruvian, also of alkaline phosphates. The aqueous filtrate may be divided into two portions, in one of which the phosphoric acid is determined by the addition of sulphate of magnesia, ammonia, and chloride of ammonium. One hundred parts of the precipitate, dried, ignited, and weighed, contain 64·30 parts of phosphoric acid. It will be sufficient to evaporate almost to dryness about one ounce of the second por-

tion of the fluid, and to test for the presence of potassa, soda, sulphuric acid, and chlorine.

The ash left by the water is treated with dilute hydrochloric acid, filtered, and the residue washed and weighed. The undissolved portion is sand, clay, and, in recent or adulterated guanos, gypsum. By boiling the residue for half an hour in a concentrated solution of carbonate of soda, filtering, washing the residue, and then acting on it in the filter with dilute hydrochloric acid, and again washing, the gypsum will be tolerably well removed from the sand and clay. The difference in weight represents the sulphate of lime. If gypsum is present, the portion of this dissolved in the watery solution is apt to be reckoned as soluble alkaline salts: correction should be made for this.

The hydrochloric-acid solution is precipitated by ammonia, and the earthy phosphates filtered, dried, and weighed. The precipitate obtained by ammonia when added to the sand and gypsum, ought to be nearly the same as the weight of ash left by the water. When this is not the case it is due to impurities, such as carbonate of lime, and the loss of weight corresponds to the quantity of this substance present.

Adulterations of Guano.—From its high price there is no manure so subject to adulterations as guano. The substances generally made use of for this purpose are sand, marl, limestone, clay, powdered bricks or tiles, gypsum, chloride of sodium, *et cetera*. One or more of these substances mixed with the strong smelling guanos, such as the Ichaboe, and by the addition of a few feathers, form altogether so prime-looking an article, that even experienced buyers are deceived by it. Chemical analysis alone can reveal the deception.

Various simple experiments have been proposed to enable inexperienced unscientific persons to say whether a given sample of guano is or is not sophisticated. The conclusions are drawn from the specific gravity, the color of the ash, effervescence with an acid, *et cetera*. But such conclusions would only be correct for certain specimens of guano—not for all.

The following are simple means by which adulterations of genuine Peruvian guano can be detected.

When burnt it leaves a perfectly white ash, when pure; but if adulterated with sand, marl, *et cetera*, the ash is more or less of a brown, or reddish-brown color. On the addition of strong acetic acid or hydrochloric acid to the ash, there is no effervescence if pure, but strong effervescence if adulterated with marl or chalk.

On the Mode of Estimating the Money Value of Guano.—If the money value of a manure is to be calculated, it is only necessary to ascertain the prices at which its valuable ingredients can be purchased in the market. Agricultural chemists have endeavored to fix the market value of the different constituents of manures, but their scales are not uniform. The following table gives the value per ton of the different constituents of manures, according to four different agricultural chemists:—

	Way.			Hodges.		
Ammonia,	£56	0	0	£56	0	0
Insoluble phosphates, ..	7	0	0	7	0	0
Soluble phosphates,	32	13	0	25	0	0
Potassa,	30	16	0	20	0	0
Alkaline salts,	1	0	0	1	0	0
Organic matters,	1	0	0	0	10	0
Gypsum,	0	0	0	0	0	0

	Nesbit.			Anderson.		
Ammonia,	£60	0	0	£56	0	0
Insoluble phosphates, ..	8	0	0	7	0	0
Soluble phosphates,	24	0	0	28	0	0
Potassa,	0	0	0	20	0	0
Alkaline salts,	1	0	0	1	0	0
Organic matters,	1	0	0	0	0	0
Gypsum,	1	0	0	0	0	0

Discarding the decimals below 0·5, reckoning those above 0·5 as an additional unit, and leaving out of the calculation the value of the organic matter and potassa, the price of Peruvian guano would be the following, supposing the market value of its constituents to be as above stated according to WAY:—

	Value per ton.			Total.
Moisture,	13·67	....	—	....
Organic matter,	52·05	....	—	....
Earthy phosphates,	23·0	....	£7 0 0	£161
Soluble phosphates,	7·0	....	32 13 0	228
Alkaline salts,	10·0	....	1 0 0	10
Potassa and the al- kalies,	3·0	....	30 0 0	90
Ammonia,	16·50	....	56 0 0	924

SPECIAL MANURES.—*Bone Manure History.*—Bone manure is said to have been long in use in hothouses in Germany, whence it was first introduced into England. ARTHUR YOUNG in his Northern Tour, 1770, mentions, that in the neighborhood of Sheffield bones were a very common manure for grass. About the same period, bones were used for turnips and arable crops in the limestone district of Yorkshire, and Lincolnshire. Like guano, it was at first received with distrust, and only after many years took its place in agriculture as one of the most valuable special manures known. In 1823, the declared value of bones imported into Great Britain was only fourteen thousand three hundred and ninety-five pounds sterling, and in 1837, it was two hundred and fifty-four thousand six hundred pounds sterling. In 1815, the quantity imported into Hull was about eight thousand tons, in 1833, it was seventeen thousand five hundred tons, and in 1835, was twenty-five thousand seven hundred tons. The chief supply comes from Germany and Russia,

and from the coasts of the Baltic. The earlier form of using this manure was as calcined bones, or when uncalcined, they were broken in pieces and distributed at the bottom of the manure heap, to undergo decomposition. In 1840, an increased impetus was given to the employment of bones, by the recommendation of LIEBIG to render it more readily soluble and available to plants by the action of sulphuric acid.

Theory of the Action of Bones.—Bones consist of two portions, organic and inorganic, in the proportion of about thirty-three of the former, to sixty-seven of the latter. The chief portion of the inorganic part, the phosphate of lime, called in agricultural language, bone earth, is supposed by BERZELIUS, to be a peculiar basic compound of eight equivalents of lime, united to three of phosphoric acid, and having the following per centage composition:—

	Centesimally.
Lime,	51·12
Phosphoric acid,	48·88
	100·00

MITSCHERLICH and others, however, regard it with more probability as a compound of three equivalents of lime and one of phosphoric acid, its composition being

	Centesimally.
Lime,	53·86
Phosphoric acid,	46·14
	100·00

The thirty-three per cent. of organic matter yield, by decay, about five and a half per cent. of ammonia. Hence fresh bones are valuable as a manure for the large quantity of earthy phosphates they contain, and the considerable amount of ammonia they are capable of yielding.

LIEBIG's axiom is, that no special manure can be of any use if the soil does not possess the other ingredients necessary to the crop. Bones are, therefore, only valuable when these conditions are fulfilled. Under such circumstances they have been proved to be the manure for turnips.

As bones furnish only two substances to crops, science as well as experience indicates that they are more likely to be useful when used as auxiliaries—for example, with farmyard manure, *et cetera*. At all events, that this is true, when bones are to be used for some years, may be deduced from the mineral theory. A striking instance of this fact occurred in Nottinghamshire. The soil was supposed to have become deficient in bone earth, and as the first applications produced very good results, it was supposed that by the constant repetition of a larger quantity increased fertility would follow. These hopes were disappointed, until it was shown by other experiments that other mineral constituents were necessary. By the addition of these, the accumulated stores of dormant bone earth immediately began to develop wonderful effects. This is but another instance of the truth of the mineral theory of LIEBIG.

The rapid fertilizing effects of bones depend on the state in which they are presented to the roots of plants. When buried in the entire state, they undergo decomposition very slowly. Hence it has been found neces-

sary to make them more rapidly available by grinding them, in which state they undergo fermentation readily, are reduced to powder, and thus made more soluble; or the ground bones, instead of being allowed to ferment, are first acted on by sulphuric acid, by which they are converted into a soluble form, known under the name of superphosphate.

Steamed Bones.—Mr. BLACKALL found, that bones submitted to high-pressure steam decomposed rapidly in the soil. This method was recommended by him as a good process for agricultural purposes. Others have found it necessary to crush the bones after steaming, to render them fit for application. In this method there is a loss of nitrogen in the gelatin dissolved out by the steam.

Fermented Bones.—Another mode for the decomposition of bones, so as to render them more readily available, is by fermentation. The process consists in mixing the bones with earth, ashes, farmyard manure into a compost, and leaving them to ferment. Certain substances, such as peat-ashes, have been supposed to cause this action more rapidly. Mr. PUSEY showed in 1847, that by mixing bones with an inert substance, such as sand, and watering the heap, and then closely covering up the whole with earth, putrefactive fermentation was generated.

The process would be still more effectual, and produce a better mixture, if instead of sand, wood or peat ashes were added to the ground bones, and urine employed to moisten the mass instead of water. As there might be a loss of ammonia by the heat generated, it would be advisable to spread a layer of sulphate of lime between the bones and the covering of clay; or to mix two or three hundredweight of gypsum with every ton of bones.

Dissolved Bones.—*Superphosphate of Lime.*—This term is bestowed on the commercial mixture of bones and sulphuric acid rendered dry by various absorbents. The mixture consists essentially of neutral phosphate of lime, which is scarcely soluble in water; biphosphate of lime, which is quite soluble; and sulphate of lime.

If the composition of the neutral phosphate of lime be taken according to BERZELIUS, as

Phosphoric acid,	48.5
Lime,	51.5
	100.0

and the biphosphate, as containing

Phosphoric acid,	71.5
Lime,	28.5
	100.0

Then one hundred parts of neutral phosphate can be converted into sixty-eight parts of biphosphate by the removal of thirty-two parts of lime by sulphuric acid. But as the materials from which superphosphate is manufactured, namely, bones, coprolites, *et cetera*, are not pure neutral phosphates of lime, a larger quantity of sulphuric acid is required. The average composition of raw bones may be taken as the following:—

Water, fat, and cartilage,	48
Phosphate of lime, with a little phosphate of magnesia,	46
Carbonate of lime,	4
Alkaline chlorides and sulphates,	2
	100

If the whole of this is to be converted into biphosphate, the following quantities of sulphuric acid, of specific gravity 1.70, would be required:—

	Pounds.
To neutralize the carbonate,	4
To convert the whole phosphate into biphos- phate	25
Total,	29

Provided the bones are finely ground, and the acid and crushed bones well mixed, theory would indicate that, by employing sulphuric acid to the extent of one-third of the weight of the raw bones, the whole of the bones would be converted into biphosphate.

Superphosphate of Lime from Coprolites.—Coprolites have been extensively used as a substitute for bones in the manufacture of superphosphates, but they do not produce so good an article. They are very hard, and unless well ground, which is frequently not the case, they are not readily acted on by acid; moreover, a larger quantity of acid is also necessary, as they contain a larger proportion of carbonate of lime.

Practical Rules for the Manufacture of Superphosphate of Lime.—The essential condition in this manufacture is, to reduce the bones or coprolites to be acted upon to as fine a state as possible before applying the acid. The sulphuric acid, mixed with twice its bulk of water, or further diluted with due regard to the subsequent drying, is added by degrees to the crushed materials, which are kept constantly stirred so as to bring all parts into contact with the acid. The absorbents, which are either ashes, mould, bones, coprolites, or some such materials, are then to be added, till the mass is sufficiently dry. Where machinery cannot be had, the following modification of a plan proposed by Mr. PUSEY has been found useful, on a small scale, for the conversion of eighty bushels of bones. A circular wall, in height about two feet, is formed of ashes. The space inclosed is about ten feet. The crushed bones are passed through a fine quarter-inch sieve. The coarser particles are laid flat in the centre, and the finer are placed round the ring, close to the ashes. Water is then added to the bones so as thoroughly to saturate them, after which they are turned over frequently in the course of a few hours. If a sufficient quantity of water has been added to the bones, it is not necessary to dilute the acid any further. If one part, by measure, of acid is to be used with three parts of water, it is better to use one-half of this water to saturate the bones, and to dilute the acid with the other half of the water. After the bones have been turned the acid is added gradually, the bones being constantly turned and mixed with the spade. In six or eight hours after the addition of the acid, the fine bone-dust, forming the second circle, is thoroughly mixed with the bulk. Next day the ashes forming the outer wall are thrown over the heap, which is then left undisturbed for a week. The heap is then opened out and thoroughly mixed with the ashes, and finally passed through a sieve. If not sufficiently dry for this last operation, a further quantity of ashes may be added to it.

Composition of Superphosphate of Lime.—It is extremely difficult to give the average composition of superphosphate of lime, which might serve as a standard

of comparison for this substance, as Peruvian guano does for manures of that class. This arises from the difference in the materials, and in the mode of manufacture.

According to theory, if one hundred pounds of raw bones could be perfectly acted on by twenty-nine pounds of strong sulphuric acid, the composition of the resulting superphosphate would be in round numbers—

Moisture,.....	10	
Animal matter and fat,.....	27	
Sulphate of lime,.....	39	
Biphosphate of lime,.....	24	{ = to 35 parts of bone earth phosphate rendered soluble.
	100	

The animal matter, about twenty-one per cent., would furnish about one and a half pounds of ammonia. It is, however, practically impossible with these quantities to convert the bones as completely as stated above, into superphosphate.

Of one hundred and seventy-one samples analysed by WAY, he found

	Per cent. of soluble phosphates.
11 samples containing.....	5
49 " " between.....	5 and 10
60 " " ".....	10 and 15
40 " " ".....	15 and 20
11 " " over.....	20

From these analyses he concludes, that a good superphosphate will contain between ten and twenty per cent. of soluble phosphate; that is to say, the biphosphate is calculated so as to represent neutral phosphate, which is thus represented as soluble. In round numbers, twenty-four parts of biphosphate are equivalent to thirty-five parts of bone-earth phosphate rendered soluble.

ANDERSON, WAY, and the Editor, from numerous analyses, have adopted fifteen per cent. as the average amount of soluble and the same of insoluble phosphate in the above article as vended. With these data, the average composition of superphosphate in the market in 1856 was

Moisture,.....	10	
Animal matter,.....	27	
Biphosphate of lime,.....	10	{ = to 15 per cent. of soluble bone earth.
Insoluble phosphate of lime,.....	15	
Hydrated gypsum,.....	34	
Alkaline salts,.....	4	
	100	
Ammonia, about 1·5 per cent.		

The money value of this superphosphate, calculated according to the plan adopted for guano, after leaving out the non-essentials, would be as follows:—

	Per ton.
Soluble phosphate of lime,.....	15 × £33 = £495
Insoluble phosphate of lime,.....	15 × 7 = 105
Gypsum,.....	34 × 1 = 34
Alkaline salts,.....	4 × 1 = 4
Ammonia,.....	1·5 × 56 = 84
	£722

Price about seven pounds five shillings per ton.

According to the opinion of some agricultural chemists, the manufacture of superphosphate of lime will be imperfect so long as insoluble phosphate figures as one of

its ingredients. Manufacturers now send superior articles into the market, and many samples of superphosphates are found in which no insoluble phosphates exist, and the proportion of the soluble phosphates is considerably above twenty per cent.

Analysis, Adulteration, et cetera, of Superphosphates.

—The analysing of superphosphate of lime is substantially the same as for guano. The determination of phosphoric acid in the soluble phosphates may be rapidly and conveniently made in the following manner: A considerable quantity, say a quarter of an ounce is taken and mixed with about four ounces, by measure, of hot water, and allowed to settle, and the supernatant fluid poured through a filter. The residue is treated in the same way, two or three times, with a fresh portion of water. About a quarter portion of this fluid is taken for analysis, neutralized with ammonia, and again rendered acid by acetic acid; and after the addition of acetate of potassa or ammonia, the phosphoric acid is precipitated by the addition from an alkalimeter of a solution of sesquichloride of iron of known strength. After being rapidly filtered, and washed with hot water and dried, the increase in weight over the known quantity of sesquioxide of iron added, represents the phosphoric acid, 48·5 of which correspond to one hundred parts of bone-earth phosphate rendered soluble, and 71·5 to one hundred of biphosphate of lime.

Application of Bone Manure.—As a manure for grain crops, bones are not in repute. Their addition, however, is of use on those soils, such as peats, in which phosphates are deficient. It is almost exclusively in the light of a turnip manure that bones hold their high place in agriculture. The mode of using superphosphate of lime is either in solution or in compost. The former is the more effectual method, but it is attended with more expense and inconvenience; hence the latter is the plan generally adopted. It is applied in drills with the seed. The quantity employed should vary with the circumstances of the soil, and with the quality of the manure. About five hundredweight per acre is an average quantity.

The remaining special manures may be regarded as divided into the nitrogenous, or those employed for their nitrogen; and the mineral, or those taken for the bases they contain.

The nitrogenous manures of vegetal and animal nature, such as wool, horns, and the like, are slow in their action. They undergo decomposition very gradually in the soil, with the liberation of ammonia; hence they are but of little value when an immediate effect is required. Recourse must then be had to a salt of ammonia, or nitrate of potassa or soda.

When the various points discussed in the preceding pages are borne in mind, it cannot but excite surprise to see, on the one hand, the loss sustained by old and long-known manures from utter unacquaintance with their really valuable ingredients; and, on the other, to notice how many sources are at present neglected, from which fertilizing agents, either general or special, might be obtained. The dire necessity of augmenting the production of the soil in proportion to the increase of the population, has compelled practical

agriculturists to call in the aid of science. The few years in which science and practice have been united have already effected the solution of many contradictory and crude opinions, based on blind empiricism, by showing wherein really consisted the value of manures, and the proper mode of treating them, so as to obtain their maximum fertilizing effects, and by directing attention, on well-grounded principles, to many hitherto-neglected sources of manures. The old struggle still continues between blind practice and the new views. The energy of the numerous scientific men who now devote their talents to agricultural chemistry leads, however, to the hope that, in a few years more, the laws which govern the proper tillage of the ground will be more thoroughly investigated and understood; agriculture will then take its stand as a more exact science than at present, and the cultivation of crops can then be entered upon as an art with as much certainty as any other manufacture.

ARTIFICIAL MANURES.—Twenty-five years ago, when the manufacture of spa and mineral waters began, they met with violent opposition from the members of the faculty, as being deprived of all the good qualities of the natural ones—as wanting, in a certain *conditio, sine qua non*—in a *spiritus rector*, or vital power, which alone gave them any medicinal qualities. Those times have passed now; chemistry has demonstrated to a certainty what the constituents of those various waters are, and under what forms and compounds they are united in them. It has succeeded in combining them exactly in the same proportions, and in rendering them not only equal to the natural ones, but *even more effective*. Physicians now connect certain effects on the human body with certain elements in the waters, and are enabled, by the light of science, to add more of this element, or more of that; nay, to apply, instead of the waters themselves, the one active element alone, as is, for instance, the case with iodine in indurations and struma. It is well known that at this moment there are extensive manufactories of mineral waters in England, at Berlin, at Dresden, at Vienna, *et cetera*. The mineral waters which are manufactured by the Messrs. ELLIS at Ruthin, in North Wales, and by a few other firms, are in every respect equal, if not superior, to the natural ones. Now, the Editor believes that the same principle may be applied, partially at least, to the use of manufactured manures; and, in fact, this is proved by the success that has attended the application of several. To dwell at large upon all the artificial manures that are now manufactured in hundreds and thousands of tons annually, would occupy more space than is at the Editor's command; he will, therefore, only append the analyses of those which have come under his immediate notice, and which have been eagerly sought after by the agriculturist. The recipes may be improved, no doubt, still the manufacturers of artificial manures may profit by studying the various per centages of the different constituents in each. Three of the best have been selected out of the numerous samples that have been analysed by the Editor. No. 1 is a manure manufactured by Messrs. KNIGHT and Company, Widnes, near Warrington, an inspection of whose works will prove

interesting to the agriculturist. No. 2 is made by the British Patent Manure Company in Manchester; and No. 3 is produced at the Runcorn Bone Works. Most satisfactory results have been obtained wherever the composts have had a fair trial:—

	1.	2.	3.
Water,.....	21-00	12-07	20-00
Sulphate of ammonia,.....	10-84	15-97	14-85
Phosphate of lime and magnesia, ..	35-50	16-84	24-07
Biphosphate of lime,.....	9-16	10-11	6-81
Sulphate of lime,.....	—	5-40	7-20
Sulphate of magnesia,.....	—	6-72	—
Alkaline chlorides,.....	1-08	4-12	5-54
Silicate of potassa,.....	—	5-47	—
Nitrogenous organic matter,.....	1-40	13-29	20-31
Insoluble matter, <i>et cetera</i> ,.....	18-02	10-01	6-22
	100-00	100-00	100-00

In concluding this article, the Editor feels great pleasure in expressing his thanks to his talented friend, Dr. BLYTH of the Queen's College, Cork, for much valuable matter that he has supplied during its compilation. The Editor could not have had a more competent contributor, for Professor BLYTH was for many years the agricultural chemist at the college of Ciren-
cester, where daily, under his inspection, were carried out experimental researches on the different kinds of manures.

MERCURY.—*Mercure*, French; *Quecksilber*, German; *Hydrargyrum*, Latin.—Mercury is a substance which has only of late been raised to the dignity of a metal, notwithstanding its being known long before the Christian era, and extensively experimented upon, more especially whilst the powerful idea of transmutation, and of the *elixir vitæ*, possessed the minds of the first chemical students—the alchemists. Its characteristics are very marked, and in one respect different from any other known metal, namely, its fluidity at all ordinary temperatures. It was this property, coupled with its silvery whiteness and metallic lustre, which determined its other popular name, quicksilver. Though it is not spoken of in the ancient scriptural writings, still THOMSON in his *History of Chemistry*, states, that its discovery must have preceded the earliest historical records. It was common in the time of MOSES; for, according to Dr. HERBERT, the Egyptian magi employed it in their so called *enchantments*, when every man cast down his rod and it became a serpent. ARISTOTLE relates, that DÆDALUS gave motion to a wooden Venus, by means of a current of mercury. DIOSCORIDES describes a method for its reduction from cinnabar, or *minium*, as it was then designated, and which is remarkable as being the first record of a process that led to distillation. The metal in those times was employed in gilding, much in the same way as at present, and the minium or cinnabar had its application in painting and decoration. PLINY mentions that CALLIAS, an Athenian, was acquainted with the preparation of the mercuric sulphide. The Greeks converted considerable quantities of the latter compound to this use, and were in the habit of drawing their supply from Spain, the mines of which were known and worked seven hundred years before the Christian era. In latter times the virtues of the sulphide as a medicine was established, and this, as well as the metal, was extensively administered by the professors of the healing art.

DIOSCORIDES, who cites some of the properties of the metal, had, it is evident, but an imperfect knowledge of it; for he states, that it could be retained in vessels of glass, tin, lead, or silver—an assertion which is now well known to be untrue, especially with regard to the metals that he named. PLINY also seems undecided as to its true nature, since evidently he thought that there was some radical difference between the mercury which was found in the virgin state and that obtained by the manufacture of the time. The former was known as quicksilver—*argentum-vivum*—and the latter as mercury—*hydrargyrum*. This doubt lurked in the minds of even the learned alchemists and philosophers till towards the close of the seventeenth century, when both kinds were submitted to numerous distillations—as in the case of BOERHAAVE, who distilled the same portion of mercury successively five hundred times, and the products were found to coincide in weight and all the then known properties. Still, at this period, owing to its fluidity especially, it was regarded as an imperfect or semi-metal, containing a principle regarded as pure vitrifiable earth—the silica of modern time. The fact of this terrestrial principle conferring solidity upon such bodies as contain it in abundance, being directly opposed to the fluid condition of mercury, induced BECCHER, an investigator of the first half of the seventeenth century, to admit the existence of another principle, a *mercurial earth*, which was supposed to possess weight and volatility to a very great degree. This chemist regarded quicksilver as a compound of three substances—namely, the vitrifiable, the inflammable or phlogistic, and the mercurial. He was supported in his views by STAHL and other learned semi-alchemists, till by the introduction of a course of experimental research and deductions, the nature of bodies came to be regarded in a simpler but truer light, which overthrew the hypothetical obscurity that pervaded all chemistry up till that time.

The knowledge that it could be solidified, acquired by the academicians of Petersburg in 1759, was the first means to remove the notion of its semi-metallic nature, and inquiries to which the announcement of the fact gave rise in the hands of PALLAS, HUTCHINS, BIEKER, BLAGDEN, and several others, led the way to its recognition as a true metal, and elementary body.

PREPARATION.—Several methods are known for the production of mercury from its saline combinations, many of which are practised on the large scale, and will consequently be described when treating of its smelting, but as these do not yield a pure metal, reference will be here made only to the methods that are calculated to afford such a product.

The mercury of commerce, which usually is contaminated with variable portions of lead, tin, and bismuth, may be distilled with one-tenth of its weight of cinnabar; and provided the distillation be carefully effected, the foreign impurities will be found in the retort, in the form of sulphides, after the pure mercury has passed over into the receiver. A purer product is, however, obtained when carefully prepared cinnabar or corrosive sublimate—chloride of mercury—that has been cautiously sublimed, is distilled with one part of quicklime or iron filings. The principal part of the impu-

rities is removed in the formation and sublimation of the sulphide or chloride taken, and the last traces are retained, with the sulphide of calcium, or iron, generated in the second part of the process. Sometimes agitation with concentrated nitric or sulphuric acids has the effect of rendering mercury much purer, but, in any case, can the product obtained by the process described be excelled. To ascertain its purity, it is only necessary to dissolve a portion in an excess of nitric acid, evaporate the solution, and heat the dry salt to redness; or fuse the metal with pure sulphur, and sublime the product in a glass matrass; in either case nothing should remain if the metal be pure, but if a residue appear, the impurities are proportionate to its weight. Observation has led to the adoption of a simpler, but less reliable test than the above; it is this, that pure mercury when dropped upon a smooth, but slightly-inclined surface, breaks up into drops which retain the spherical form, but if contaminated with tin, lead, or such adulterants or impurities, the form of the globules will appear elongated, so as to present or leave a *tail*.

PROPERTIES.—Mercury is a metal that possesses the metallic lustre in a high degree, and exhibits a silvery whiteness. It is fluid at all temperatures between 39.5° Fahr., and its boiling point, which is variously estimated by different experimenters, as ranging between 654.8° CHRICHTON; and 680° DULONG and PETIT—DALTON estimating it at 660.2°; and HEINRICH at 672.8°. At minus 40° it solidifies, and while in this state permits of being beaten out under the hammer, welded, *et cetera*, like other metals. When the refrigeration is effected by means of solid carbonic acid and ether in a dish, and if the yet unsolidified portion be poured off, the metal adhering to the walls of the vessel will present well defined octahedral crystals. Its density varies with the degree of temperature more than any other metal, owing to the freedom with which it expands. SCHULZE found it in the solid state to be 14.391. REGNAULT estimated the gravity at — 40° to be 14.4, but if it could be compressed by hammering, the number would doubtless be higher. At 39.2° KOPP estimated its gravity at 13.594; KUPFER at 13.588, and 13.535 at 78.8°; at the latter degree the number arrived at by CAVENDISH and BRISSON was 13.568; by FAHRENHEIT 13.757. KARSTEN determined its density at the ordinary temperature to be 13.559. Various researches show that this metal evaporates at common temperatures, as well in contact with air as *in vacuo*. This may be proved by suspending gold leaf in a flask containing some of the metal, when, after a few weeks, the lower portion of the leaf will appear amalgamated. KARSTEN asserts that at 32° mercury gives off as much vapor as to develop the image on a daguerreotype plate held over it at a convenient distance. BRAME affirms that sulphur in a finely-divided condition, as when precipitated from a state of vapor, is much more delicate than gold leaf. By its aid he found that at 53.6°, the tension of the vapor rises to the height of three feet, and even higher than this; but, in the latter case, the delicacy of the known tests is inadequate for its detection. This investigator is also of opinion that in air and vapor of sulphur, the vapor of mercury diffuses itself according to the law which governs other gases.

The specific gravity of the vapor of mercury was found by DUMAS to be 6.976, and by MITSCHERLICH 7.03—the latter number being that arrived at by theory. The property of expansion which mercury possesses, and the long range of temperature through which it exhibits this property with remarkable regularity, render it peculiarly adapted to the wants of the philosopher for determining the sensible heat of bodies. Repeated experiments have shown, that between 32° and 212°, the increase of bulk which it acquires, by the acquisition of equal increments of heat, is extremely regular, and corresponds to 0.00011 of its bulk at 32°, according to the experiments of DALTON. Between 38° below zero—the lowest degree of temperature that can be safely estimated by the mercurial thermometer—and + 32°, the freezing point of water, the gradation is not so regular, although the difference is so trifling as to be disregarded in most applications; but between 212° and 662°, it has been found to pass from the regular expansion observed between the limits of the freezing and boiling points of water, and to increase in this respect as the heat becomes more elevated. The annexed table exhibits the ratio of expansion of mercury between 32° and 212°, as determined by the investigators mentioned:—

•0200	Dalton.
•01887	Cavendish.
•01848	Lavoisier and Laplace.
•01818	Hallstrom.
•01801	Shuchburgh.
•01800	Dulong and Petit.
•01781	Deluc.
•01695	Roy.
•018153	Militzer and Regnault.

The following numbers, arrived at by DULONG and PETIT, show the variable and increased expansion of mercury above air by equal increments of heat:—

COMPARATIVE EXPANSION OF AIR AND MERCURY BY THE SAME INCREMENTS OF HEAT.

Dulong and Petit.		Rudberg.	
Air.	Mercury.	Air.	Mercury.
0°	0°	35.96	36°
100°	100.0	0°	0°
150°	151.3	+ 50.04	+ 50°
200°	204.6	100°	100°
250°	255.1	198.81	200°
300°	314.15	294.73	300°
350°	360.00	—	—

Mercury is not acted upon when exposed to air, oxygen, nitrogen, nitrous or nitric oxide, or carbonic acid gases. On the contrary, if shaken with water, ether, oil of turpentine, or fatty unctuous matters, it loses its metallic appearance, and is converted into a grey *æthiops per se*, in which the metal is not altered but *deadened*—that is, reduced to minute and isolated globules by the interposed stratum of the compounded matter. Ordinary mercurial ointments retain the metal in this state, but so finely divided as to render its detection by the unaided sight impossible. When pure it is tasteless and inodorous, although a peculiar odor has been observed from it when rubbed between the fingers. Poured upon dry bodies, it does not wet them like other liquids, but flows off in drops, except in the case of the metals with which it forms amalgams. On this account it is designated, sometimes, in old writings, *aqua non*

ma defaciens manus—water that does not wet the hands. Kept at a temperature approaching ebullition in contact with air, it suffers oxidation slowly. Water is not decomposed by it. The nitrous, nitric, iodic, chloric acids, *et cetera*, easily oxidise it without the aid of heat; sulphuric acid, when diluted, has no action upon the metal, even when aided by heat, but concentrated acid, at a high temperature, readily converts it into a proto-sulphate, sulphurous acid being eliminated. With selenium, sulphur, phosphorus, chlorine, bromine, and iodine, it unites with facility, giving rise to the haloid mercurial compounds of those radicals. It quickly combines with the noble metals—also with tin, lead, bismuth, zinc, and most of the soft metals, giving rise to amalgams which often possess particular interest. This is the case, more especially in a manufacturing sense, with the amalgams it constitutes with gold, silver, platinum, as they are available in the smelting or abstraction of these metals from the gangue in which they may be distributed. Indeed, a chief portion of the mercury annually extracted is devoted to this special application, so that a distinct relation between the yearly production of gold and mercury may be traced. Besides this application it has many others, such as gilding, plating, and the like. Many of its compounds are valuable in other branches of art, such as medicine, painting, *et cetera*, but more particularly in the former, where its administration is very varied and frequent. The metal is likewise very advantageous to the anatomist, who employs it as an injection, either alone or in the form of vermilion suspended in size. There are many other instances of its application, but not being very general, they will not be further dwelt upon.

Atomic Weight.—Before proceeding to notice the ores of mercury and the processes by which the metal is obtained from them, it may be mentioned that much difference of opinion has existed respecting the atomic weight of this element. The mercurial oxides are two in number—the *grey* and the *red*; and it is from the different view chemists have taken of the constitution of these bodies that 100 and 200, or a near approximation, have been respectively proposed as the equivalent of mercury. The composition of these bodies, denominated mercurous and mercuric oxides, is thus centesimally expressed:—

	Grey Oxide.	Red Oxide.
Mercury,	96.15	92.59
Oxygen,	3.85	7.41
	100.00	100.00

Now, if the *grey* be assumed to be the *protoxide*, then the value of an equivalent of mercury capable of saturating a full equivalent of oxygen, which is represented by 8, will be 199.8, or nearly 200; whilst, on the other hand, assuming this oxide to be the suboxide, and, halving that number, it will be represented by two equivalents of metal, and one of oxygen. Taking the equivalent of the metal, then, at 100, the atomic constitution of these oxides is thus represented:—

Grey oxide.		Red oxide.	
2 Eqs. Mercury,	200	1 Eq. Mercury,	100
1 Eq. Oxygen,	8	1 Eq. Oxygen,	8
1 Eq. Grey Suboxide, 208		1 Eq. Red Protoxide, 108	

The chemical symbol of the metal is taken from its Latin name, and is written Hg.

BERZELIUS, ERDMANN, MARCHAND, GMELIN, REGNAULT, THOMSON, GRAHAM, and many other chemists, have adopted 100 or something near it as the true atomic weight, and the preference is further justified by the fact, that though both oxides are salifiable, yet the grey is very unstable, and unlike a true protoxide in its characters, whilst the red is eminently persistent and basic; indeed, according to BRANDE, it almost approaches to alkalinity. Besides, the evidence adduced from the connection of the atomic heat of the metal with its atomic weight is decidedly favorable to that number which expresses the grey as a *sub*, and the red as a *protoxide*. The experiments of STRANBERG, published in the Memoirs of the Academy of Stockholm for 1845, go to prove that the atomic weight of mercury cannot be less than 99.90.

ORES OF MERCURY.—The minerals into the composition of which mercury enters, are by no means numerous, and few of them are important. The metal itself occurs native in the form of fluid globules scattered through its gangue. The quicksilver mines of Almaden in Spain, of Idria in Carniola, of Wölfsstein and Morsfeld in the Palatinate of Rosena in Hungary, and Sala in Sweden, supply specimens of the virgin metal, which was said at one time to fetch a higher price than that obtained by reduction. In some places native mercury is so plentifully dispersed through its ores, that when an opening is made it escapes, and trickling out, collects in considerable quantities at the bottoms of the levels.

A native amalgam of silver, amorphous and crystallised, is also met with. Not unfrequently this mineral occurs in the form of flattened plates. A specimen, said to be from Peru, the specific gravity of which Dr. DALZELL determined, did not exceed 13.995, but usually it is 14.119. From the average of the analyses of three specimens examined some years ago by the same chemist, along with the analysis of other specimens by KLAPROTH and CORDIER, it consists centesimally of—

	Dalzell.	Klaproth.	Cordier.
Mercury,.....	56.1	64.	72.5
Silver,.....	43.9	36.	27.5
	100.0	100.	100.0

That the composition of this mineral should vary considerably does not seem surprising, since it has been proved that mercury evaporates from mercurial ointment and amalgams. *Argirite*, an argentiferous amalgam of great value, is found in considerable quantity in the province of Coquimbo in Chili. It contains 13.5 parts of mercury, and as much as 86.5 per cent. of silver. Indeed, this is one of the chief ores of silver in the rich mines of Arguiros. An amalgam of gold, analysed by SCHNEIDER, and which occurred along with platinum ore from Columbia, contained mercury 57.40, gold 38.39, and silver 5.0. Native amalgams of lead, containing selenium, have been analysed by ROSÉ.

Horn quicksilver—subchloride of mercury, or native calomel—is found associated with the other ores of quicksilver at Idria, at Deux-Ponts, in Spain, and elsewhere. It is a yellowish or ash-grey mineral, sectile, and subtranslucent. Sometimes it occurs as a crust, or forms granular concretions. At other times it crystallizes in four-sided prisms. Its specific gravity is 6.482, whilst that of the powdered calomel of the shops is 7.14, and that of the crystallized factitious subchloride is 7.2.

Iodides, bromides, and selenides of mercury also occur, but rarely. The iodide has been met with in Mexico, associated with the selenide. A specimen of the bromide Dr. DALZELL found to contain, besides bromine, traces of iodine, selenium, and sulphur. ROSÉ has described the selenide as composed of selenium 6.49, sulphur 10.30, and mercury 81.33.

The principal ore of mercury is the sulphide—the *zinnober* of the Germans and *minium* of PLINY. The color of native cinnabar varies from cochineal red to brownish-red and leaden grey. The streak is scarlet, and the lustre usually adamantine. The density of this mineral is 8.098, and when pure it contains 86.29 parts of mercury with 13.71 of sulphur. Specimens of the purest ore have, occasionally, all the richness of hue which the best vermilion presents.

The following table shows the composition of cinnabar from various quarters of the world, the amount of the constituents being centesimally expressed :—

	Mercury.	Sulphur.	Bituminous matters.	Gangue.	Water.	Carbon.	Silica.	Alumina.	Iron.	Copper.	Lime.	Magnesia.	Total.	
Japan,.....	84.50	14.75	—	—	—	—	—	—	—	—	—	—	99.25	Klaproth.
".....	79.30	14.50	—	—	—	—	—	5.67	—	—	0.63	—	100.10	Dalzell.
Idria,.....	51.80	8.20	6.80	32.0	3.20	—	—	—	—	—	—	—	102.00	Lebererz.
Idrian } ..	81.80	13.75	—	—	0.73	2.30	0.65	0.55	0.20	—	—	—	99.00	Klaproth.
Swaore, } ..	85.00	14.25	—	—	—	—	—	—	—	—	—	—	99.25	"
Neumarktel, } ..	18.00	—	—	—	—	—	—	—	73.31	—	—	—	91.31	Bealey.
Wölfsstein, } ..	37.84	16.22	—	—	—	—	35.12	—	—	—	—	—	89.18	"
Almaden,	37.75	16.22	—	—	—	—	35.12	—	—	—	—	—	98.28	Dalzell.
".....	56.94	15.97	—	—	2.58	—	42.79	—	traces.	—	—	—	100.00	"
".....	41.79	16.72	—	—	—	—	41.49	—	—	—	—	—	98.77	Bealey.
California, ...	69.36	11.38	—	—	—	—	14.30	0.61	1.23	—	1.40	0.49	99.59	"
".....	70.13	11.21	—	—	—	—	14.52	0.61	1.23	—	1.40	0.49	99.59	"
".....	70.23	11.21	—	—	—	—	14.52	0.61	1.23	—	1.40	0.49	99.59	"
".....	72.00	12.80	—	—	1.20	—	—	—	14.0	—	—	—	100.00	Dalzell.

Geologically, the ores of mercury occur amongst stratified deposits. The volatility of the metal may account for its not being met with in any large quantity in

crystalline or igneous rocks. Thus, it is found most abundantly in the independent coal formation, and in beds lying between primitive argillaceous schistus and

chlorite slate, associated with quartz, calcareous spar, spathic iron, and copper pyrites. In the famous quicksilver mines of Almaden in the province of La Mancha, a few miles from the frontier of Estremadura, which have been worked for many centuries, the veins traverse micaceous transition schists and sandstone grit, intersected here and there by granitic and porphyritic eruptions. A portion of the Almaden ore is extremely rich; but the larger proportion is so intermixed with quartzose and argillaceous gangues, that the yield is not over ten per cent. of metal. At Quença in New Granada, Durasno in Mexico, and in some of the Peruvian mines, the mercurial ore occurs in the red sandstone above the coal; whilst at Deux-Ponts, at San Juan de la Chica in Peru, and in some other localities, it is placed in the subordinate porphyry. The mines of Idria are worked in a friable compound of dark carbonate of lime, and argillaceous schist. These mines were discovered in 1497, before which time the country was inhabited only by a few artificers in wood. Tradition thus records their discovery:—A cooper having one evening placed a new butt under a neighboring spring to try if it would hold water, when he returned the next morning to take it away, found it so heavy that he could with difficulty move it. Being an ignorant man he at first supposed his vessel was bewitched; but at length perceiving that it contained a heavy and brilliant liquid metal, he carried away some of it, and showed it to an apothecary in Laubach, who, being better informed than the peasant, and more cunning, kept the mercury, sent the man away with a small gratuity, and directed him to bring him all he could obtain. This the cooper did for a considerable time, till the affair became known, when a society was formed, and a further search for quicksilver instituted. The mines remained in possession of this society till the Archduke Charles of Austria, perceiving their importance, purchased the properties, and took the mines of Idria also under his control.

The subterranean passages of these mines are extensive; but owing to the loose and friable nature of the ground, large excavations are impossible. Their greatest perpendicular depth, taken from the entrance of the shaft, is about eight hundred feet; but as the galleries advance horizontally under a high mountain, the depth would be much greater if measured from the surface of the hill. The mine was formerly entered either by descending the shaft in a bucket, or by zig-zag ladders. By the first route the visitor was subjected to the inconvenience and danger of being stopped by some projection; or the bucket might even strike against the side and be upset. Nor was the ladder descent more safe and agreeable; for the steps being wet, slippery, and narrow, the utmost caution was requisite to prevent falling. Now, however, the entrance is through a large iron gate, by a horizontal passage to a descending flight of seven hundred and fifty-seven steps, cut in the limestone rock, and provided with a hand-rail. At the bottom of these steps there is a small chapel in which the miners perform their devotions, and from which a labyrinth of passages opens out. In some of the galleries the heat is so intense as to be almost insupportable. The noxious inhalations of the metal speedily

become so offensive that the visitor is glad to make his escape. The ascent is usually performed by a perpendicular shaft at a considerable distance from the spot where he entered, and through which he is raised in a cage or bucket.

In 1803 a fire broke out in the workings, and was with great difficulty extinguished. Fumes of mercury filled the air; and throughout the neighborhood, nine hundred people were affected with the most urgent symptoms of mercurial poisoning.

These mines continue to be worked by the Austrian government, which restricts their annual yield to one hundred and fifty tons. URE states, that but for this avaricious enactment for keeping up the price of mercury, six hundred tons would easily be produced yearly. Some of the ore yields fifty to sixty per cent. of metal. The richest qualities are termed *stahlerz*; and the poorer, bituminous sulphide, averaging only ten per cent., are called *zeigelerz*.

Besides the quicksilver works, there is a manufactory of cinnabar, which annually produces about ninety tons. Benevolent institutions have also been established for the treatment of those miners whose health has suffered from the action of the mercurial fumes.

The mercury mines of the Palatinate are not equal in richness and importance to those of Idria and Almaden. The workings at Drey-Koenigszug, at Potzberg near Kussel, give an annual yield of about thirty tons.—PHILLIPS. The ore there is sandstone, intimately mixed with sulphide; and the depth to which the explorations have been carried exceeds six hundred and sixty feet. The aggregate yearly average of several still smaller mines in Hungary, Bohemia, and other parts of Germany, does not, according to URE, exceed thirty to forty tons. The quicksilver mines of Huancavalica in Peru, the products of which are employed in the treatment of the gold and silver ores which abound in that neighborhood, have been worked since 1570. Up to 1800 their produce was fifty-three thousand seven hundred tons of quicksilver.

Several accounts of the Californian quicksilver mines of New Almaden have been published. The following early notice was communicated to Silliman's *Journal* by the REV. C. S. LYMAN, in a letter dated—Pueblo de San José, March 24, 1848—not quite two years before the supply from this quarter reduced the price of mercury:—The mine of New Almaden is situated a few miles from the coast, about midway from San Francisco and Monterey, and in one of the ridges of Sierra Azul mountain. The mouth of the mine is a few yards down from the summit of the highest hill that has yet been found to contain quicksilver, and is about twelve hundred feet above the neighboring plain, and not much more above the ocean. This hill extends longitudinally in a north-west direction, decreasing in height; and in various parts of it, for several miles, traces of the ore have been found, and some openings have been made which promise to be valuable. This range of hills consists of a variety of rocks—the prevailing one is a greenish talcose rock, which seems to embrace the bed of ore at the New Almaden mine, both above and below. The ore is interspersed through a yellow ochreous matrix, which forms a bed forty-two

feet in thickness, dipping north-westerly at an angle of about 45°. The richest ore is at present found in the upper part of the bed; the poorest ores being taken from the lowest portion.

This mine, known to the aborigines from time immemorial as a *cave of red earth* from which they obtained paint for their bodies, was first discovered to contain quicksilver about four years since, during experiments made by some Mexicans to smelt the ore for the purpose of obtaining *gold*, which they supposed it to contain. About two years ago it fell into the hands of BARROW, FORBES, and Company, who commenced working it. The great trouble was to obtain suitable apparatus for extracting the metal. At length four potassa kettles were found, which were set in a furnace of adobes, with condensers of mason work immediately adjacent,—a wretched apparatus indeed for managing a thing so subtle as mercurial vapor. The daily mode of working was to fill these pots in the morning with one thousand six hundred pounds—four hundred to each pot—of the ores of average quality, broken in lumps of the size of apples, put on the covers, and lute them with a layer of *sand*. The fires were then kept up till near night, when the furnaces were allowed to cool gradually. The next morning the condensers were opened, and the metal dipped up, which usually amounted to from two to three hundred pounds from the four pots. This was a much less per centage than the usual assay indicated, and it was obvious a large portion of the metal was lost. The upper part of the pots and condensers was found to be generally covered with a crust of sulphide of mercury. Mr. FORBES wished to devise some way of extracting the metal without mixing lime with the ore in roasting, but was unsuccessful. At length a kiln of lime, which occurs in the immediate vicinity was burned, and I am informed that the ores yield with this a vastly greater per centage of metal. In the last three weeks, about ten thousand pounds of metal have been extracted with the same apparatus, being a yield of over fifty per cent. The mine is probably giving a net profit of one hundred thousand dollars a year, with its present crude apparatus. With suitable furnaces, and iron cylinders or retorts, the mine would easily yield a million and upwards.—*Lyman*.

New Almaden, writes Mr. RUSSEL BARTLETT in 1853—that is five years later—now consists exclusively of the buildings belonging to the Company which owns the quicksilver mine. It embraces furnaces, store-houses, dwelling-houses for the officers and laborers, offices, mechanics' shops, *et cetera*. Many of them are of wood, but a large and fine range of substantial brick buildings is now in process of erection to take the place of the wooden ones; six furnaces are now in operation reducing the ore, all of which seem to be alike and of the most simple construction; the furnaces are kept going night and day, and the metal is collected in tanks, the largest of which holds twenty tons. The Californian metal comes into the market in wrought iron bottles, screw stoppered, and holding seventy-five pounds each. The bottle itself weighs about twenty-five pounds. A land carriage of about twenty miles, performed in the ore carts, brings them to the point for shipment. The New Almaden produce in

1853, equalled one hundred thousand bottles per month, or one million per annum. During the same year the following exports from San Francisco took place, the whole of the metal being the produce of the New Almaden mine.

	Pounds.
Hong Kong,.....	423,150
Shanghai,.....	60,900
Canton,.....	27,450
Whampoa,.....	22,500
Calcutta,.....	3,750
Mazatlan,.....	210,823
Shipped for { Mazatlan and San Blas,...	19,125
San Blas,.....	145,652
Callao,.....	135,000
Valparaiso,.....	148,275
New York,.....	138,375
Philadelphia,....	75,000

Further particulars of this interesting mine were published in 1856, in the *American Journal of Pharmacy*. The present entrance to the workings is by a horizontal shaft and railway twelve hundred feet long. The large masses of rich and compact ore, some of which weigh as much as twenty pounds, are separated from the small fragments which are mixed up with yellowish earth and clay. The latter are pounded, kneaded up with water, and dried in the sun; thus baked, they are called *adobés*. The smelting furnaces, of which with their condensing chambers there are fourteen, are situated a mile and a quarter from the entrance to the mine. Each range consists of a fire chamber three feet by five, placed at the end of a series of eight or ten chambers, seven feet long, four wide, and five high. The range is built of brick, plastered inside, and protected against expansion by heat by iron rods passing from wall to wall, and secured with screws and nuts. The tops are of boiler plate, luted with salt and ashes. The first or fire chamber is separated from the second or ore chamber by a network partition of fire-brick. The third chamber communicates with the ore chamber by a square opening at the right upper corner, and this first condensing chamber with the second, by a similar opening at the left lower corner, and so on; the top openings being on the right, and the lower openings on the left, alternately. From the last condensing chamber the vapors pass into a wooden hose, in which there is a continuous shower of cold water, while any uncondensed matters pass into the open air through tall wooden flues. The floors of the condensers are guttered, and by these the mercury flows into an open conduit, from the end of which it pours over a brush into the iron bottles already described.

The lumps of cinnabar and the *adobés* are piled like bricks in the second chamber, a wood fire is lighted in the furnace, and the flame plays through the brick network on the ore. Each ore chamber, when fully charged, contains ten thousand pounds of cinnabar, to exhaust which requires sixty hours. At this period, lime appears not to be used in the reduction of the ore. RUSCHENBERGER conceives that the addition of this substance would increase the yield, but not, he adds, sufficiently to pay the cost of the earth. This is singular, as LYMAN speaks of lime occurring in the immediate vicinity.

Assay of Mercurial Ores.—It may be well to state

here the means by which ores of mercury may be assayed, more with the view of showing how much metal should be obtained on the large scale, rather than giving a precise method of analysis. The methods followed are distillation of the product, whether it be oxide, chloride, sulphide, selenide, or iodide, with caustic lime; if only a sulphide be present, simply subliming it; but this offers no advantages, since a higher heat is required, and there is always a liability of a portion being reduced, the metal passing over with the cinabar, and exposing the results to error.

When lime is employed, from fifteen to twenty-five parts may be taken, according to the richness of the assay. This is intimately blended in a mortar with the finely ground ore, together with a tenth of the weight of the ore operated upon, of fine charcoal, and the whole introduced into an earthen or hard glass retort, with a long neck, and surrounded with cloths, on which a stream of water may be kept flowing for the purpose of condensing the vapors. The beak of the retort should likewise be inserted in a flask kept cool by wet cloths. The distillation may be carried on over a gas flame; or better, by means of a small charcoal fire and sandbath. All the mercury is transported into the neck of the retort in the state of vapor, where it condenses, and trickles into the receiver. When no more vapors arise, and the materials are carried to dull redness, the fire is removed, and any globules which may remain in the neck of the retort, made to flow over into the receiver by tapping it gently, or introducing a small brush; and after the whole has been collected, the product is weighed. In this way the yield of mercury is ascertained with a degree of accuracy which will be dependent upon the carefulness of the operator. The sulphur, or other mineralizing element of the ore, will remain united to the lime, or else form gaseous products with the carbon, and be retained or evolved according to their nature. Iron scales or carbonate of soda may be employed with equal effect; only, in case of iron being the agent, it should be finely divided and used in excess, to insure that none of the mercurial body may escape decomposition. When the experiments are carefully managed, the result in either case is very exact. Instead of using charcoal, hydrogen gas may be passed over the assay during the sublimation; but this is inconvenient, excepting where the resources of a well-regulated laboratory are available; and, besides, it does not make the results more correct in the hands of a careful assayer.

Reduction of Mercurial Ores on the large scale.—There is, with a few exceptions, very little diversity in the manner in which the smelting of mercurial ores is carried on. It is strange, however, that in the case of the largest and most important *lode* in the world, that of Almaden, the comparatively rude and inefficient method of working invented by JUAN ALONSA BUSTAMANTE more than two hundred years ago, should still be followed in all its details; a method which, however remarkable and advantageous it might appear at that period, is now acknowledged to be much more laborious and incomplete than several others which are in practice at other mines of this kind. The defect of the system does not only directly affect the quantity of

mercury extracted, and which, according to the testimony of M. LE PLAY, is far below the per centage contained in the ore, but, likewise, the workpeople in, and inhabitants of, the districts adjoining the seat of operations, in consequence of the baneful effects of the escaping mercurial vapors on the system. LE PLAY speaks upon this subject thus:—*Le mercure a sur la santé des ouvriers la plus funeste influence, et l'on ne peut se défendre d'un sentiment pénible en voyant l'impresement avec lequel des jeunes gens, pleins de force et de santé, se disputent la faveur d'aller chercher, dans les mines, des maladies cruelles, et souvent une mort prématurée.* JUSSIET, on the contrary, states, that the vapors which escape from the chambers of condensation at those works, have no pernicious effect either upon the inhabitants or vegetation in their neighborhood; still, from the consideration of the process, and the imperfections evident in it, coupled with the known noxiousness of mercurial fumes, every attentive observer would be led to conclude that life and vegetation must suffer to a great extent both in and around the factory.

Figs. 356 and 357 represent a section and plan of the kind of apparatus employed, which is known as the *butyrone* or *aludel* furnace. It consists of a circular or polygonal chamber, A A, about four feet in diameter, and divided into two compartments by a perforated

Fig. 356.

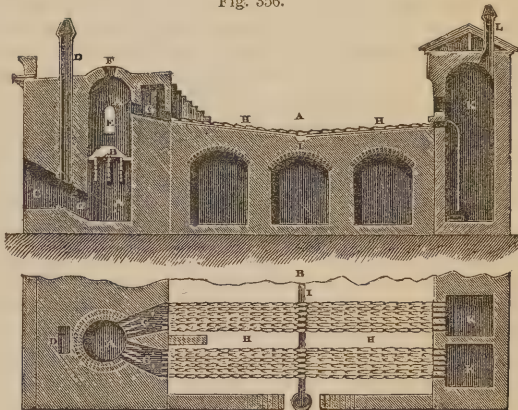


Fig. 357.

brick arch, B, about nine feet from the top. The heat is obtained from brushwood introduced at the aperture, c, into the fireplace, a, and the smoke is carried off in part by the chimney, d. A door, e, in the side of the cylinder, and an aperture, f, at the top, are used to introduce the charge of ore, the volatile products of

Fig. 358.



which escape into the condensing media by a system of openings, g, and which communicate with files of condensers of earthenware, called *aludels*, h, connected one with another, as represented in Fig. 358. These are laid on two planes of brickwork, inclining to

one another, supported on arches, as represented in Fig. 356. Where the two planes meet is a channel or gutter, *i*, leading to a conduit, *l*, in the brickwork, and thence by wooden pipes at the bottom to the receiving basins, *j j*, partly filled with water, and fixed in the floor of the smelting room. During the passage of the distilled vapors through the several files of aludels, the metal which condenses flows for the most part into the aludel which crosses the channel, *i*, and issues into the latter by a hole in its under part; the uncondensed products pass into the upper part of a condensing chamber, *k*, and are conducted towards the bottom by a screen, where a cistern of cold water receives the metal. Such portions as diffuse themselves in the chambers are deposited on the walls, in form of soot, and are from time to time brushed off and collected at the bottom. Sulphurous and other gases pass off by the chimney, *l*, but sometimes a second chamber is above the arch of the first, in which a further quantity of the metal is retained. Whatever is collected in this way is filtered, in order to purify it from other matters, and the dross is worked up with loam and fine or powder ore into bricks, and subsequently distilled over again. The charge of ore for this furnace averages from two hundred and twenty to two hundred and seventy hundredweight, and is divided into three varieties, each of which occupies particular places in the furnace. The larger pieces of the sandstone rock, slightly impregnated with cinnabar, and called *soleras*, are placed on the arch immediately above the fire. Being too poor to be worked by themselves, and requiring too much labour for preliminary dressing, it is worked off in this part of the furnace. Above the *soleras*, about twenty-two hundreds of rich mineral are laid on, then some poor ore in small fragments, and the remaining space is filled with the dross from the aludels and condensing chambers, some fine ore previously worked up with some clay and moulded into bricks. The door in the side, and also the aperture in the top, are then secured by the doors, and covers, and luting. After this, the adapters are arranged in proper order on the inclined planes, and the joinings secured by clay luting. The number of these vessels being so large, a good deal of time and labor is required for this work. There are six files in each bench, and forty-four vessels in each file, making, for the entire furnace, about five hundred and twenty-eight. From the aperture of the furnace to the condensing-chamber, the length is about sixty-five feet, so that each aludel is more than eighteen inches long. All things being ready, the fire is lighted and kept in active ignition by the supply of fresh brushwood. An abundant flame is thus produced, which passes up through the apertures in the arch of the furnace, and heats, first the *soleras*, and subsequently the remaining contents, and drives the whole of the metal into the aludels, volatilizing it with the sulphur in the form of sulphurous acid with a little sulphuric acid. According as the aludels become heated by the vapors, they begin to act more effectually the part of a series of chimneys, and so draw off the products more freely. The fire continues successively for twelve days to work off the charge, after which time it is permitted to die out; and three days further are

allowed to cool the earthen adapters before they are detached, and the portion of mercury in them collected. This work also consumes a good deal of labor, as each receiver, after being detached, is to be brought to the channel midway to be emptied. Any metal shed in the carriage, runs along the incline, but is not lost; it becomes soiled, however, so that it is necessary to submit the whole to a purifying process. That adopted is very simple, merely pouring the metal on the floor of the room destined for the work, which being slightly inclined towards one end, the metal flows down clean and bright into a receiver, and leaves the dross and soot behind it adhering to the floor. A good deal of metal remains in the residue; hence it is carefully collected and worked up in the next charge. Each charge affords from twenty-five hundred to three thousand pounds of mercury; sometimes, when the ore is a richer kind, as much as six thousand pounds are obtained; but the manager tries to average the ore, so that the yield may be about the first-mentioned quantity. If the charge be enriched by using more of the purer ore, the loss in mercury is considerably greater than if only an average kind be worked; besides, the trouble arising from the cracking of the lutes securing the connection of the aludels, and their renovation, is multiplied. This was particularly remarked in 1787, when an innovation was made in the ordinary course of working, by employing a larger quantity of rich ore than that already mentioned. Fully half the metal in the surplus was lost, owing to the draught of the aludels being inadequate to carry it off, and the injury to the health of the smelters from breathing so much mercurial vapors was very serious. Besides the mercury, another substance is found to encrust the earthen cones, which PROUST found to contain—

	Centesimally.
Finely-divided mercury,.....	66.0
Subchloride of mercury,.....	18.0
Cinnabar,.....	1.0
Sulphate of ammonia,.....	3.5
Sulphate of lime,.....	1.0
Free sulphuric acid,.....	2.5
Carbon, or soot,.....	5.0
Water,.....	2.5
Loss,.....	0.5
	100.0

The same chemist estimates the extent of its formation at about forty pounds per charge, or in its content of metal equal to 1.500 of the weight of the rich mineral wrought, and attributes the presence of the subchloride to its being contained in the ore, and volatilized as such. Doubtless portions of this compound do exist in it, but it is likely also that a chloride is produced by a process of double decomposition that takes place between portions of the cinnabar and the alkaline chlorides in the particles of ash which are drawn up into the furnace by the draught; or a sulphate of mercury may be formed during the roasting of the ore or in the aludels, and this, in contact with the chlorides already mentioned, may produce the effect; or the chlorides meeting the continually-forming sulphuric acid may be decomposed, setting free hydrochloric acid, which, passing over the sulphate of mercury condensed in the aludels, gives rise to the calomel and free

sulphuric acid. This loss is now, in part, avoided by mixing some quicklime with the *schlich* and clay in making the bricks, which occupy the upper space near the dome of the furnace. Cast-iron cylinders, bent, and surrounded with water, have been tried at Almaden, as a substitute for the aludels, but their use has been abandoned, in consequence of their being rapidly corroded by the free acid, although the mercury was found to condense very well in them. PROUST likewise analyzed the incrustation on these condensing pipes, and found—

	Centesimally.
Finely-divided mercury,	44.0
Sulphate of protoxide of iron,	23.5
Sulphate of alumina and sulphate of potassa—alum,	14.5
Subchloride of mercury,	3.3
Sulphide of mercury,	6.3
Carbon,	4.8
Sulphate of lime,	0.9
Loss,	2.7
	100.0

The alum arose from the action of the sulphuric acid on the clay pipes which connected the iron condensers with the outlets of the furnace, and the potassa was supplied from the ashes of the fuel.

A portion of the Almaden mines, probably that now called Little Almaden, was worked by the Romans. PLINY speaks of *Sisapo*, a territory of *Batica*, the mine of *minium* there forming a part of the revenues of the Roman people. Indeed, adds the same historian, there is nothing guarded with a more constant circumspection; for it is not allowable to reduce and refine the ore upon the spot, it being brought to Rome in a crude state, and under seal, to the amount of about two thousand pounds per annum. The modern town, which contains about seven thousand inhabitants, is built over the principal mine, the entrance to which is close to the houses, and the ascent and descent of the miners effected by ladders. Not long ago, and possibly even now, the water was pumped from the mine by a WATT engine, made about the year 1790! The produce of the workings is drawn to the surface by mules, up a wide and well-constructed stone shaft. Convict labour was formerly employed by the Spanish government, but now free workmen, to the number of about five thousand, have been substituted, who work almost naked, and from Spain receive a high rate of wages. Their health, however, always suffers; but, as the workings are only carried on during winter, a release from confinement, with fresh air during the summer, usually restores them to health, and permits of their return to labor on the opening of the mines.

The produce of the Almaden mines, which is sent to Cadiz and Seville for exportation, is packed in cylindrical cast-iron bottles, which are closed with a screw stopper. Each bottle contains three Spanish *arobas*, making seventy English pounds net per bottle. But the weight charged by the importers is on an average only sixty-nine to seventy pounds, arising from the tret of four pounds per every one hundred and four pounds; and one pound draft being allowed, and the tare being fixed at eight pounds, whilst the real tare averages sixteen to seventeen pounds.—*Pereira*. In the sixteenth century

these mines were rented by the brothers MARK and CHRISTOPHER FUGGER, the rich capitalists of Augsburg, under a contract for the payment of four thousand five hundred quintals of mercury yearly to the government. Unable to fulfil their agreement, they relinquished them in 1635. Ten years later, the Spanish government undertook their management. In 1831 N. M. ROTHSCHILD and SONS obtained from the Spanish government the contract for all the mercury they produced. With this monopoly the price, which in 1831 was one shilling and ten pence per pound, rose in 1849 to four shillings, whilst the cost of mercurial salts rose in the same proportion. Before 1850, however, Californian mercury appeared in the market, when the price of the metal per pound fell in the course of four years to two shillings and a penny.

Method of Reduction at Idria.—This famous mine was discovered so far back as 1497, but the working of the ore was very irregularly prosecuted for nearly a century afterwards, and even then there was no fixed establishment, but the ore and utensils necessary were carried about in the forests to where the charcoal-burner had chosen the site for his *meiler*, in order to make the heat of the burning wood available for the reduction of the ore. A number of earthen pots, with narrow necks, were filled with the ore, mixed sometimes with lime; the mouth was then stopped with a clay plug, so as to retain the charge, but allow the fluid metal to flow out into a wide-mouthed vessel, into which the charged one was inverted. As many of these as would fit in the base of the charcoal heap were arranged as described, and the clay or soil raised about the subjacent condensing pots, the connection between the two luted, and the wood arranged in the usual way for charring. During the combustion of the wood the heat was sufficient to set free the metal which collected in the bottom pot. This method of distillation *per descensum* was extremely wasteful. In 1635 there was a fixed establishment erected, and the gallery furnace analogous to that at the Palatinate, which shall be described further on, adopted; in 1750 the Almaden system was introduced—and, finally, at the close of the last century, the aludel furnace was substituted by the present arrangement. The commencement of the present Idrian process is the assortment of the ores into two classes, according to the size of the pieces. All from the size of a cubic foot to that of a nut belong to No. 1; smaller pieces, and the dust, to No. 2. In No. 1 are further subclassified—*a*, the poorest portions, yielding only about one per cent.; *b*, the pure sulphide, yielding nearly eighty per cent.; and *c*, fragments of various richness averaging from one to forty per cent. The subclasses of No. 2 consist of—*d*, fragments from the mine, yielding from ten to twelve per cent.; *e*, particles separated on the sieve, yielding about thirty-two per cent; and lastly, *f*, the *schlich* obtained from the washings, containing eight parts of the metal in a hundred.

Figs. 359 and 360 are a plan and elevated section of the great distillatory furnace erected at Idria. In the latter figure only one of the furnaces are seen, although there are two in the same block with a double row of condensing chambers, as represented in the plan. *a a'*

are the fire doors; *b*, the hearth where the fuel is consumed, and above which is the body, *d*, of the furnace, divided by perforated arches into three compartments, the top one being in communication with the first condensing chamber on either side, by flues, *ee'*. There are

Fig. 359.

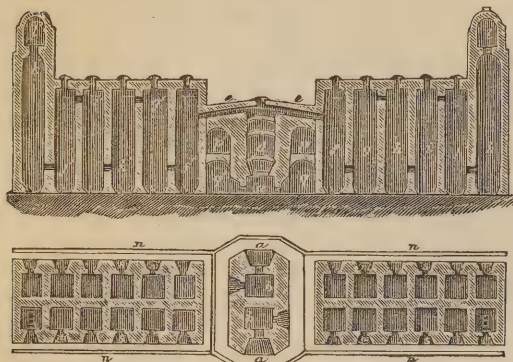
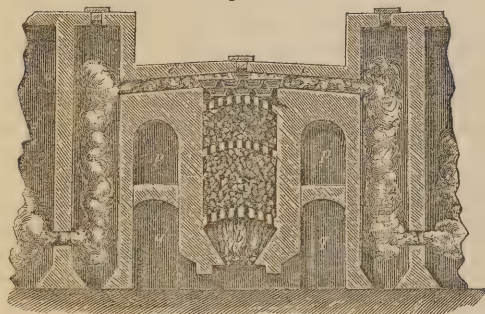


Fig. 360.

six chambers at each side of the furnace, *f, g, h, i, j, k, l*, the connection of one with another being placed alternately near the top and bottom, as at *f', g', h', i', j', and k'*, with the view of bringing the vapors over as much space as possible, that in the course of which they might deposit the quicksilver. Each of these chambers has an outlet, *s*, by which the condensed metal flows out into a receiver, *m m*, whence it is conducted by a conduit, *nn*, into the main tank. They have likewise an aperture at the top, which is closed, as also that at the base, during the period that the furnace is working. The last chamber in the series is usually furnished with a number of flanges, or inclined boards, which reach in a slanting direction almost to the opposite wall, upon which a stream of water is continually

Fig. 361.



falling from the top, so that the vapors, as they ascend through it, follow a sinuous course, and deposit the last traces of metal as they meet the flanges. *pp', qq'*, are arches which conduct air to the fire and interior of the furnace, for the oxidation or burning of the sulphur. By side-doors opening into the several compartments of the furnace, the ore is introduced; these are closed whilst the charge is being fired. The largest and poorest pieces of ore are placed on the first arch, and

the smaller ones in overlying beds till this part is full; in the next, the smaller fragments, which, however, allow sufficient space for the passage of the vapors, are deposited, and the upper compartment receives a number of earthen trays filled with the fine powder or *schlich*. All the spaces being thus replenished, and the doors and other apertures, where an escape would be possible, secured and luted, a brisk fire of beech or fir wood is made on the hearth, *b*, and maintained till the furnace acquires gradually a cherry-red heat; it is then kept at this degree for ten to twelve hours, during which the distillation lasts. The high temperature of the developed vapors, coupled with the great height of the furnace—about thirty feet—and the number of chambers that are in connection with it, create at the first a quick draught, which is sustained while the distillation continues. This is absolutely necessary, in order to draw as much air into the furnace as will suffice for the oxidation of the sulphur into sulphurous acid, and its removal from the metal. All the products of combustion, as well from the ore as from the fire, pass into the chambers, where they condense in part, the mercury falling upon the inclined slabs at the bottom, and collecting there, and the portions of cinnabar and mercurial soot forming upon the walls. The furnace is allowed five or six days to cool and condense the metal, at the end of which the upper apertures are opened, the portion condensed on the bottom drawn off, the walls brushed down, the separated mercury collected with the rest, and the grey powder and cinnabar gathered and put to one side, to be worked up in the next charge. This done, preparation is made to recharge and repeat the same process just described. One charge a week is the most that can be worked under these circumstances, and this charge, for the double furnace, amounts to ten or twelve hundred quintals, of one hundred and eight pounds avoirdupois each. A gang of forty men are employed in the charging, and the work lasts them three hours.

The yield of each charge averages eighty to ninety quintals of metal.

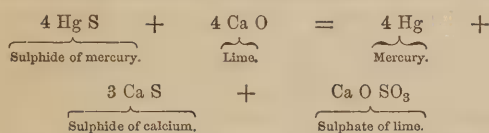
Lastly, the mercury is filtered through ticking cloth, and is then packed in cast-iron bottles for exportation. Each bottle contains sixty pounds. Only one such operation as has been described, can be effected weekly, since five or six days are required to cool the furnace, which is one hundred and eighty feet long, and thirty feet high.

Much inconvenience and injury attend the workmen at this establishment, owing to the dangerous effects of the mercury, inhaled whilst brushing down the walls of the chambers,—an operation which exposes the men to the vapors for two hours. Hence, it is no strange occurrence to observe many of the operatives salivated or affected with nervous tremblings.

DUMAS suggests, that to make the establishment at Idria continuous in its operations, it would be necessary only to multiply the chambers of condensation, and substitute for the furnace at present erected, another on the principle of a continuous lime-kiln, the ore being charged in large pieces, and the *schlich* worked up into bricks or balls with clay, and introduced into the upper part. With such modifications this method

would be, according to the last mentioned *savant*, the best in use; but the writer can hardly help thinking with URE, that it is most unchemical in its present aspect, and out of keeping with what might be supposed to exist in these, the second most extensive quicksilver works in the world.

A different system to that followed at Almaden and Idria, as well in principle as in manipulation, is pursued in the mercury smelting works of the duchy of Deux Ponts. In the former, the principle of the changes is the removal of the sulphur by its combustion into sulphurous and sulphuric acids, and with this view the furnaces are constructed, so that the air is freely drawn through them at the temperature necessary to cause the expulsion of the sulphur. In the latter, the same ends are attained—not, however, by roasting, but by the addition of bodies which take the sulphur from the valuable metal, by a process of chemical decomposition. Lime is the body always resorted to, it being the most plentiful and cheapest; but scales or grains of iron would likewise answer, and the heat causes the formation of a sulphide of calcium or of iron, and sets free the mercury which is driven off in vapor, thus:—



that is, four equivalents of sulphide of mercury, and four equivalents of lime, afford the whole of the metal, three equivalents of sulphide of calcium, and one of sulphate of lime. This decomposition is more complex than that effected by roasting, as may be seen from the following formula:— $\text{Hg S} + \text{O}_2 = \text{Hg} + \text{SO}_2$. But the volume of hot gaseous matter from which the mercury is to be condensed, necessitates the use of an extensive range of cooling media, whereas, in the distillation with lime, these are not required, as only the metallic vapors are emitted.

In the duchy of Deux-Ponts, mercurial ores, mixed with lime, are heated in earthenware retorts furnished

Fig. 362.

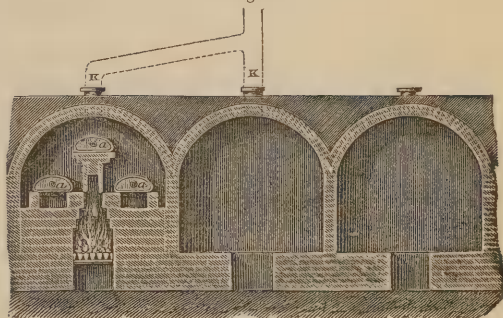


with receivers of the same material. A vertical section of the furnace gallery of the Palatinate is shown at Fig. 362. AA represent earthen cucurbits with their receivers, BB. Each of the former is filled about two-thirds with a charge containing ore and quicklime in the

proportion of sixty to sixteen, and the receivers are at the same time half filled with water. The retorts are arranged in a double row, one above the other. In this way from thirty to fifty-two cucurbits are included in one *gallery*. The fire, which is from pit-coal, is placed on a grate beneath them, and a draft is secured by means of apertures in the arched roof. When the mercurial gangue is sufficiently calcareous, it is only necessary to moisten and distil it. As soon as the mass in the retorts is exhausted, the contents of the receivers are emptied into a wooden basin standing over a bucket; the object of this operation being to draw off, along with the water which falls over the sides of the bowl, all the black sulphide with which the metal is mixed up. This black matter is afterwards taken up, dried, and again distilled with excess of lime.

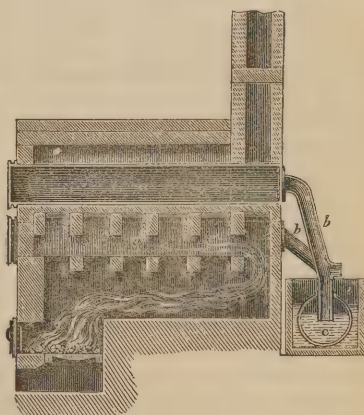
Method pursued at Lansberg.—One other metallurgic apparatus for the reduction of mercurial ores,

Fig. 363.



remains to be described. It is in use at Lansberg, near Obermoschel, in the Bavarian Rhein-Kreis, where it was erected in 1847, and is the contrivance of the late Dr. URE, who has thus figured and described it:—Fig. 363 is a section parallel to the front elevation of three arched benches of retorts. Each bench con-

Fig. 364.



tains three of these vessels, *aaa*, constructed of cast-iron, and somewhat like those employed in the manufacture of coal gas; the whole are set in masonry, the bottom of the uppermost retort being protected from the direct impingement of the flame by fire tiles. The

dotted lines leading to $\kappa \kappa$, show the direction of the chimneys. In Fig. 364, is represented in section the body of one of these retorts. The mouth on the right of the figure is closed with an iron lid, which is bolted, barred, and luted, after the charge has been introduced. An iron pipe, four inches in diameter, and having a nozzle hole at L , dips into the main condenser, C , and the same arrangement is shown at another section at Fig. 365, where $C C$ gives a longitudinal view of the main condenser, which consists of a pipe twenty feet

Fig. 365.



long, and eighteen inches in diameter. The backs of the retorts are shown at aa , and the eduction-tubes in the same figure at bb , dipping a short way beneath the surface of the water. At z is placed a water valve to obviate the risk of sudden expansion or condensation from inequalities of temperature, and at i is depicted a water trough, or outer vessel of wood, in which the condenser is placed. The inclination of the condenser is towards the left, so as to favor the exit of the mercury by the vertical delivery tube, d , into the lock-up reservoir, e . The end of this tube dips from the first into a small cistern of mercury, and at k is shown a floating and graduated gauge rod by which the quantity of mercury in the chest, e , may be always ascertained without the trouble of opening it.

Before charging the retorts, the ore is reduced to a coarse powder, then mixed with quicklime, and shovelled in. Six or seven hundredweight of the mixture, a sufficient charge for each retort, can, with a proper amount of heat, be worked off in about three hours. The process is continuous, and, with an efficient staff of workmen, could be daily made, by using nine such retorts, to decompose six tons of the mixture—a quantity which, if the ore was rich like that of the Idria or Almaden mines, would equal twelve hundred to a ton of mercury daily.

It is singular that the imperfect process of condensation by such barbarous apparatus as *aludels*, or the rude and cumbrous furnaces of Idria, should not have been superseded by an arrangement similar to, or equally efficient with, that just described. The outlay would be repaid in the course of a few months by the expedition with which continuous yields of metal could be obtained, and an enormous saving would take place through the complete condensation of the metallic vapors; whilst the duties of humanity would be attended to, and many, if not indeed all, of the miserable results of a poisoned atmosphere, would be avoided.

Purification of Mercury.—If, as is sometimes the case, the mercurial ore contains bismuth or zinc, portions of these metals will be carried over with the distillate. Lead, antimony, and tin, may also be present as adul-

terations, having been fraudulently introduced. Various methods have been devised for rendering the metal chemically pure. WITTSTEIN recommends, where not more than three pounds are operated on at once, that its redistillation should be effected in a small plain retort of thick glass, clean iron turnings being added to the mercury, in the proportion of one of the former to twelve of the latter. The retort rests in a deep sand bath, which is placed in a furnace; as much inclination as possible being given to the neck of the vessel, which should be lengthened with a cylinder of stout paper. The end of the paper tube dips into a receiver nearly full of water, which, again, rests on a ring of straw placed at the bottom of a larger vessel, also filled with water. The heat being assisted by wood and a chimney, now causes the mercury to boil, and its vapour, condensing, rolls down the paper tube and collects in the receiver. As soon as it is cold, the water is poured off, and any trace of iron, or of oxide of mercury, which generally appear as a thin film, is readily removed by hydrochloric acid. The mercury is then well washed in water, dried at a gentle heat, or run through bibulous paper till it ceases to damp it; after which it may be passed through a cone of writing paper, having a very small aperture, which removes all traces of mechanical impurity. Or, instead of glass, a wrought-iron mercurial bottle may be employed. This bottle should never be more than half full, and must be fitted with an iron delivery tube, to the end of which a canvas pipe is attached, on which a jet of water is directed; the condensed mercury falls into a vessel. A second method is by treatment with strong sulphuric acid. This is best effected by covering the metal with its own volume of concentrated oil of vitriol in a flat glass or porcelain dish, stirring repeatedly with a glass rod, and leaving the metal and the acid in contact for six or seven days. Pure mercury, as has been already said, is not attacked by this acid, and digestion in the cold has merely to be repeated with successive portions of oil of vitriol as long as sulphurous gas is given off, or the liquid shows any symptoms of turbidity. It is certain that by this process even lead may be removed, although, under ordinary circumstances, that metal is but little attacked by strong cold sulphuric acid. But, in the first place, the lead in this case is in the form of amalgam, which implies minute subdivision of its particles, and at the same time the tendency of the acid towards the lead appears to be increased by the presence of the mercury. Such metals as gold, silver, and platinum, which are not acted on by sulphuric acid, cannot, of course, be separated from mercury, except by distillation.

A third method is to heat the metal for several hours to 130° , with a small quantity of commercial nitric acid diluted with twice its volume of pure water. The foreign metals being more easily oxidised than the mercury, are dissolved, and this operation having been repeated as often as required, the purified metal is then washed and dried.

A solution of nitrate of mercury may be substituted for one of nitric acid. In this way an equivalent of metal is deposited for every equivalent of more oxidisable metal which is removed. These nitric processes

are, however, liable to this disadvantage, that the foreign metals can only be completely removed when some mercury remains in solution.

The process recommended by MELLON, and which REGNAULT employed to obtain pure mercury for his third determination of its density, is as follows:—He first agitated the metal for some time with weak nitric acid, using for two pounds of mercury an ounce and a half of acid and two ounces of water. By this means all the more oxidisable metals were acted upon. The solution containing these having been poured off, the mercury was again digested with strong nitric acid, till nine-tenths of it was dissolved. The resulting nitrate was converted thereafter into mercuric oxide, which, in its turn, was changed by heat into the metallic form. All traces of oxide having been removed by agitation with strong oil of vitriol, the product was carefully washed and dried *in vacuo*.

Dr. PRIESTLEY gives, in his *Observations on Mercury*, a simple process by which effectually to separate quicksilver from lead and tin. He employed continued agitation, with fresh portions of air supplied by repeatedly blowing into a small glass phial, in which the mercury was actively shaken. A little powdered sugar very much assists this process, by mechanically collecting and retaining on its particles the portions of foreign oxides as they are produced. The fluid metal may then be run through a cone of paper, having a very minute aperture at the bottom, by which all the solid particles, including dust, fibres, *et cetera*, are retained.

Other methods might be resorted to, such as the decomposition of the factitious cinnabar by heat and iron filings, or of the commercial red precipitate alone by heat, with the subsequent removal of all adhering oxide, by means of sulphuric acid. Or the metal may be sublimed along with one-tenth of its weight of powdered vermilion; or, according to the method of ULEX, two pounds of mercury may be agitated with half an ounce of solution of sesquichloride of iron; specific gravity 1.48. Ten minutes suffice to remove all metallic impurities of the ordinary kind, a result which the finely divided state of the metal seems to favor. Lastly, VIOLETTE proposes to make use of highly-heated steam. It is a well-known fact that when this metal is boiled with water in a flask, mercurial vapor rises, and is carried off with the steam. The distillation of mercury by the method of VIOLETTE has especial reference to its removal from silver in smelting houses. The process is said to effect a considerable saving of fuel, and of the health of the workmen. It is performed by bringing the steam up to 700°, in its passage through a worm, from which it enters the vessel containing the mercury, dipping a little way beneath its surface, and soon causing the metal to boil; after which the mercurial and aqueous vapors are carried off, and suitably condensed.

It may be here remarked that pure mercury is entirely volatilized in the heat; it dissolves completely in nitric acid, producing a nitrate of the metal, which, when the acid is employed in excess, is easily soluble in water. Poured into a narrow glass vessel, it presents a convex surface, owing to the mutual attraction of glass and mercury being at best but feeble; if, however, the

metal be amalgamated with as slight a quantity as the one four-thousandth part of lead, the convexity of the pure metal is destroyed, and the surface becomes even.

Physiological Effects.—It has long been a matter of doubt and discussion whether this metal exercises any physiological effects upon the human system, analogous to those of most of its saline compounds. It is generally admitted that, when taken in compact masses, the metal does not exert a poisonous action, although it may occasion injury mechanically; but when in a finely attenuated state, as in vapor, or *deadened* with innocuous substances, it possesses the power of manifesting all the symptoms of a mercurial poison.

All the effects of mercurial poisoning are very frequently observed among the miners and smelters of this metal, as also in those who work with water-gilders, looking-glass and barometer makers. For the most part they appear as the disease known as the *mercurial trembling*, or a kind of palsy, which first manifests itself by an unsteadiness in the arms, and which goes on till the movement becomes convulsive, and vertigo, loss of memory, and other cerebral disorders, which generally terminate fatally, follow. When the symptoms develop themselves in a mild form, and the individual perseveres in his labors, they proceed, and never fail to become more violent, and endanger the life of the person. This is well known in the mercurial mining and smelting districts, where if once a man becomes affected with trembling or salivation he is removed to a less dangerous department, or disbanded altogether. Some physiologists have remarked that the circulation is usually depressed and slow when the patient is undergoing salivation, and exhibits other symptoms of the effects of mercury; whilst others have observed an excited state of circulation, a fetid breath, with metallic taste in the mouth, increased flow of saliva, and a sponginess of the gums proceeding to ulceration, which sometimes extended to the throat.

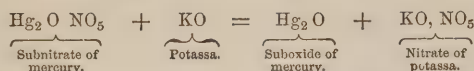
Vegetal physiologists state that mercurial vapor is destructive in a high degree to the life of plants.

MERCURIAL COMPOUNDS.—Mercury is capable of combining with most of the non-metallic elements, and many of the compounds thus formed are capable of constituting ingredients in further combinations; it has, therefore, a wide range of affinity, but in a manufacturing sense most of those compounds are unimportant, although in a strictly scientific point of view, and also on account of their medicinal qualities, they sometimes attract a great deal of attention. The principal compounds of mercury to be considered here are the sulphide—*cinnabar*, *vermilion*—the chlorides, oxides, iodides, *fulminating mercury*, and the ammonio-mercurial chloride known as *white precipitate*. The oxides, though not the most important, will be noticed first.

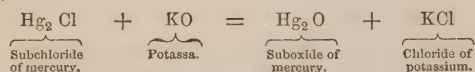
OXIDES OF MERCURY.—As stated already, there are two oxides of mercury, the *sub* and *prot*-oxide, which are capable of yielding well-defined salts of the respective bases. The first of these is not so stable as the second, nor is it so important in its applications.

Suboxide of mercury was first scientifically described in 1797; but was known, probably, long before that period as the *æthiops per se* of the pharmacæutists. There are several methods for preparing it; the

simplest and readiest being the precipitation of a dilute solution of a subnitrate of mercury by potassa; or it may be formed by disseminating calomel in water, and adding a proportionate quantity of potassa to the liquor, when suboxide of mercury falls. The change may be expressed thus:—



Or,



All the operations connected with this compound should be performed out of diffused daylight; and care must also be taken that the precipitation be complete, otherwise the substance thrown down will consist of a mixture of suboxide, protoxide, and metallic mercury.

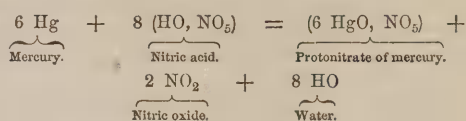
After being thoroughly washed, to remove alkalinity, and dried in the dark, suboxide of mercury is a black powder, having a disagreeable odor—GMELIN says it is devoid of taste and smell—it is insoluble in water and alkalies, soluble in nitric and acetic acids, and has a specific gravity of 10.6, HERAPATH; 8.95, KARSTEN. It is very rapidly decomposed, when exposed to the light of the sun, into protoxide and metallic mercury; but the same change, though slowly, is effected in the darkness. Heat resolves it into oxygen and metal. It is also decomposed by many compounds, the mercury being taken into other states of combination, and sometimes set free. Its composition is expressed centesimally by

	At. weight.	Donovan.	Guibourt.
2 Eqs. of mercury,....	200 ..	96.15 ..	96.04 ..
1 Eq. of oxygen,	8 ..	3.85 ..	3.96 ..
	208	100.00	100.00
1 Eq. suboxide of mercury,.....			

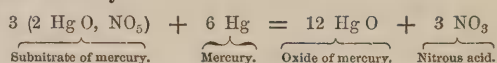
The suboxide of mercury is converted to no particular use in the arts.

Protoxide of Mercury.—This is the *precipitatum per se*, or calx of mercury, mentioned in old writings; it is analogous to the *hydrargyri oxidum rubrum* of modern pharmacy. Protoxide of mercury has an interest attached to it much greater than its application in the arts would merit, owing to the knowledge of its nature and composition being contemporary with the discovery of oxygen, the subversion of the old phlogiston theory, and the introduction and pursuit of a new and more enlightened system of chemical science. It was formerly prepared by submitting mercury to a high temperature in a narrow-necked flat-bottomed matrass, known as BOYLE'S *hell*, when, after a long period, the metal was slowly converted into oxide. This process is now, however, quite abandoned; salifying the metal, and subsequent precipitation of the oxide, being considered more effectual. One part of mercury is treated with three parts of nitric acid, specific gravity 1.20, in a flask on the sand bath, till perfect solution takes place, and the solution evaporated to dryness, the residue mixed up with another part of the metal, and the whole heated again as long as nitrous fumes are

observed to pass off. The residue, which now appears a dull grey mass, is removed from the heat, mixed with a tenth of its weight of pure crystallized carbonate of soda, and the whole boiled with water for a quarter of an hour, when impure protoxide of mercury settles to the bottom, and this by filtration and washing may be converted into pure protoxide—*red oxide of mercury*. The nitrate of mercury alone may be submitted to heat in this operation, but a loss of nitric acid would take place; besides, the degree of heat is critical, so that it is more productive and less troublesome to proceed as above stated. By the following formula the changes of the substances here alluded to are expressed:—



And secondly—



Oxide of mercury prepared by the action of heat upon a protosalt of the metal, forms a shining brick-red crystalline scaly powder, which, on being pulverized, acquires an orange tint. By the action of a moderate heat it changes to a vermilion color, which passes as the temperature rises to a darker hue, approaching to black, but as the substance cools the natural shade is regained. The specific gravity of the red powder has been variously estimated, the number arrived at by PLAYFAIR and JOULE being 11.136. It is but slightly soluble in water, only one part being taken up by seven thousand parts of this liquid; the solution, however, has a disagreeable metallic taste, and exhibits an alkaline reaction to delicate color tests; but alcohol fails to dissolve it. Between 700° and 900° it is resolved into its elements. Oxide of mercury obtained by precipitation is an amorphous yellow powder, and in this differs from that obtained by heat. There are also many other reactions wherein they behave differently.

The protoxide is readily decomposed by several substances; even light is capable of resolving it into mercury and oxygen gas; heat, and all organic substances, produce the same effect, only much more quickly. On this account it is frequently employed by the analyst to remove the last traces of carbon from a substance, and to oxidise sulphur into sulphuric acid. Phosphorus, sulphur, sulphurous acid, the alkali metals, protochloride of tin, and several other bodies, decompose it, many of them with evolution of light and heat. The protoxide of mercury may be distinguished from the suboxide, first by its color, and secondly by its solutions not giving a white flocculent precipitate with hydrochloric acid; it also produces, with solutions of hydriodic acid, or of alkaline iodides, a beautiful scarlet precipitate of iodide of mercury, and which is characteristic compared with the dull green color of the subiodide. Potassa gives a yellow, and ammonia a white precipitate, both of which are sufficiently distinct from the black deposit that they afford in solutions of the suboxide of this metal.

Protoxide of mercury is composed of—

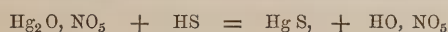
		Centesimally.			
	At. weight.	Theory.	Donovan.	Erdman and Marchand.	
1 Eq. of mercury,....	100 ..	92.59 ..	92.75 ..	92.596	
1 Eq. of oxygen,....	8 ..	7.41 ..	7.25 ..	7.404	
	108	100.00	100.00	100.000	

Its chemical symbol is Hg O.

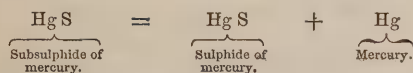
It is stated that protoxide of mercury is occasionally adulterated with minium or red lead, sesquioxide of iron, and powdered brick. Such substances are readily detected by heating the substance to a dull heat; the protoxide of mercury sublimes, and leaves the non-volatile matters in the crucible, or the mercurial compound may be treated with dilute nitric acid, to dissolve the mercurial oxide; and should minium be present, a puce-colored binocide of lead remains together with the other adulterants, if any be present. On adding dilute sulphuric acid to the clear liquor obtained in the foregoing, a white precipitate of sulphate of lead falls, corroborative of the existence of a lead compound.

SULPHIDES OF MERCURY.—Sulphur and mercury are capable of uniting artificially, and of forming compounds analogous to those produced from this metal with oxygen.

The *subsulphide* is the *æthiops mineral* of the older chemists, and was prepared by agitating a little water, sulphur, and mercury, in equal proportions, in a mortar, or at a slightly increased heat, till a black powder resulted. It can be obtained by transmitting a stream of sulphide of hydrogen gas through a dilute solution of subnitrate of mercury in the cold, when a subsulphide of a black color falls. The reaction is as follows:—



Heat must be guarded in this operation, since it would resolve the subsulphide into a protosulphide of mercury and metal, thus—



Prepared by either method, this compound appears as a black, tasteless, inodorous powder, which is insoluble in water, in hydrochloric, and dilute nitric acids. By heat it is resolved into mercury, and the red sulphide of the metal—cinnabar. Its chemical composition is—

	At. weight.	Centesimally.
2 Eq. of mercury,.....	200	92.59
1 Eq. of sulphur,.....	16	7.41
1 Eq. of subsulphide of mercury,	216	100.00

This compound is not prepared in any quantity, nor has it any application, excepting among veterinary surgeons, and even these are abandoning it for more appropriate agents.

Protosulphide of Mercury.—*Cinnabar, Vermilion.*—

This is a much more important compound, though, like the former, medicinally inert. The character and composition of the native ore have been already explained. Only a small quantity of that mineral, however, is of sufficiently fine quality to permit of its being employed as a pigment. Chemically, there is no difficulty in forming it;

but its value in the arts depends upon the richness of its color, the exact conditions to insure which are far from being generally understood. The following are some of the processes for its preparation:—

When sulphide of hydrogen gas is passed to saturation through a solution of protoxide of mercury, the white compound which appears at an early stage of the operation is destroyed, and the black precipitate then consists solely of mercuric sulphide, which, when collected, dried, and heated in a retort, yields a fine crystalline sublimate of cinnabar. These two bodies, therefore, the black and the red, are allotropic modifications of one substance, Hg S.

The process of LIEBIG consists in forming the *white precipitate* Hg Cl, Hg N H₂, and digesting it with sulphide of ammonium, obtained by saturating the common alkaline hydrosulphide with sulphur. The color of the product he afterwards improves by boiling with caustic potassa.

KIRCHOFF recommends triturating one hundred parts of mercury in a porcelain dish, with twenty-three parts of flowers of sulphur, chemical action being assisted from time to time by moistening the mixture with solution of caustic potassa. A potassa lie, containing fifty-three parts of solid hydrate in fifty-three of water, is next prepared, and in it the sulphurised mercury is warmed, and further triturated. The water must be replaced as it evaporates, and the operation continued for two hours. After this, and still with trituration, the red mass is evaporated to a thin paste, removing the heat at the moment when the red color has attained its finest shade; for a few seconds, either too soon or too late, deteriorates the quality of the product. Too little heat fails to bring up the red to its utmost degree of brightness, and a little too high, or even too long continuance of the proper temperature, changes the color to brown, and it can never be restored. The product, when cool, is *first* washed with a solution of potassa, and *afterwards* with water.

URE, in alluding to the process of KIRSCHOFF, remarks that of late it has been so much improved that the vermilion which it yields quite equals in tint that made in China. It appears also by the following table, that the quantity of vermilion which can be obtained, depends on the relative proportion of the substances employed:—

Mercury.	Sulphur.	Potassa.	Vermilion.
300	114	75	330
—	115	75	331
—	120	120	321
—	150	152	382
—	120	180	245
—	100	180	244
—	60	180	142

BRUNNER directs the trituration of one hundred parts of mercury with thirty-eight of sulphur. The *æthiops* so produced is next heated to 113° with twenty-five parts of potassa in one hundred and thirty-three to one hundred and fifty parts of water, and more liquid supplied as it becomes reduced by evaporation, the mixture being kept occasionally stirred. After a few hours the black substance begins to take a brown tint, and if the heat be maintained at 113° to 118°, this goes on brightening till it becomes a lively red. Whenever the mixture becomes

gelatinous, more water must be added, for it is absolutely necessary for the success of the process that it be kept in as pulverulent a state as possible, and also that the heat rise not above 120° to 122° . When the product has attained the fine red required, and which happens in the course of eight hours, the fire is removed, and the contents of the vessel are left to cool slowly. The cinnabar is then removed, washed with water, and further purified by levigation from any mercury or black sulphide which might still remain. BRUNNER states that one hundred parts of mercury, forty parts of sulphur, and forty of potassa, afford one hundred and seven parts of vermilion little inferior to the finest native substance, and much superior to any obtained by sublimation.

Dutch Method of Making Vermilion.—It is well known that the monopoly of preparing this pigment was long held by the Dutch, who alone, at one time, possessed in Europe the secret of giving to it a rich scarlet color. The particulars of the old method of its preparation at Amsterdam were many years ago described by M. TUCKERT in the *Annales de Chimie*. The process consisted of two parts; first, the production of what M. TUCKERT terms æthiops, but which is a mixture of cinnabar, black sulphide, uncombined metal, and sulphur; and, second, the conversion of this into the pure vermilion.

The first part of the operation was to effect the combination in a flat polished iron pot, two and a half feet in diameter, and one deep. Into this, one thousand and eighty pounds of mercury and one hundred and fifty pounds of sulphur—equivalent to 87.8 of mercury and 12.2 of sulphur, per cent.—were introduced, and the mixture stirred with an iron spatula very cautiously, because if the components were too briskly mingled, the combination would be too violent, and some of the substances would be lost. The black product of this operation, being reduced to powder, was next placed in hand jars capable of holding one pound and a half of water—thirty to forty of them being constantly kept full. The subliming pots, three in number, which were made of pure sand and clay, and well luted outside, were each covered with a smooth iron lid, and placed in a furnace secured with hoops of iron; the position of the pots being such that the flame could play over two-thirds of their height. In the evening the operation of heating the pots was begun, and as soon as they attained a red heat the iron covers were removed, and a pipkinfull of black sulphide thrown into each, and there left to crackle and burn. This emptying of the smaller pots into the larger was continued—sometimes two or more being emptied into the subliming pot at once, till, in the course of thirty-four hours, four hundred and ten pounds had been emptied into each of the three. As each fresh portion of black matter was thrown in, the mixture took fire, and the flame rose from three to six feet above the edge of the pot. During this period the cover was not replaced; but as it subsided the pot was again covered with the iron plate, until it was necessary to remove it for the introduction of more sulphide. For thirty-six hours after the last portion was added, the same steady heat was continued, and the contents of the pot occasionally

stirred by means of an iron rod which passed through the top of the lid. During this period, also, the workman tested from time to time the security of the process, by cautiously removing the pots, and observing to what height the flame then rose, and with what vigor it burnt. The proper temperature was indicated by a vigorous combustion, accompanied by a flame, which did not rise more than three or four inches over the edge of the pot.

When the thirty-six hours were expired, the whole was allowed to cool, after which the pots were removed and broken, and the vermilion which was incrustated within them, and chiefly in their upper parts, collected, ground with water between horizontal stones, then passed through sieves, and thereafter elutriated and dried. The usual loss in converting the black sulphide by this process into vermilion, was nearly three per cent.

Method adopted at Idria.—At Idria, as already stated, large quantities of the sulphide of mercury pigment are annually prepared. The method pursued is to introduce into a number of well-bound casks, contrived to turn on their axes, eight pounds of sulphur and forty-two of mercury, and then to put them in motion for three hours or more, till the ingredients combine to form a brownish powder. A number of cast-iron cylinders, placed upright in a furnace and heated to dull redness, are then charged with this product, one hundred pounds being portioned to each, the weighted cast-iron cover being immediately fixed on, and retained till all crackling noise subsides. When this happens, the iron top is removed, and another of stoneware, having the beak connected with a tube and receiver substituted; at the same time the fire is increased for the purpose of expelling the sulphide of mercury from the iron cylinder. After the sublimation of the charge, the capital and tube are removed, and when cold, the cake of cinnabar is separated. That which has the brightest tint is found caked on the outside of the cover; the portion collected in the tube and receiver is generally mixed with an excess of sulphur, which volatilizes with it, and for the most part is returned with a fresh charge of æthiops to be re-sublimed. The cakes of cinnabar are broken, and ground finely with water; then boiled with a solution of potassa, washed first with hot, and next with cold water, and finally dried.

Chinese Vermilion, which is so rich in color as to command five or six times the price of the European product, appears to be prepared in the ordinary way, leaving nothing to account for the superior brilliancy of shade except the sunnier climate. By careful selection, the finest portions are collected, and, if necessary, ground and washed several times. In making the artificial product, one part of sulphur and four of mercury are introduced into an earthen pot, to which an iron cover is luted and bound with wire; the pot with its contents is then placed in a fire of dried camel's dung. After sublimation, the cover is removed and the pot broken, and the purest of the sublimed picked out from the less-colored product, ground very fine, and the powder sifted into a large vessel of water. When the red product has subsided, the supernatant

water and scum are drawn off, and fresh liquid supplied, in which the sediment is stirred up, and after subsidence, the substance is collected and carefully dried in the sun.

By subliming one part of sulphide of antimony with sulphide of mercury, a greyish cinnabar is obtained. On boiling this with a solution of *liver of sulphur*—a compound of sulphur and potassium—and afterwards with hydrochloric acid, and washing thoroughly with water, a product is obtained which is quite as brilliant as the finest Chinese vermilion, and retains no antimonial sulphide. Sulphide of mercury prepared by saturating a solution of oxide of mercury, is a black substance, but when prepared by the other processes mentioned, it has a red color, more or less lively. It is a soft, heavy, colorless, and tasteless powder if prepared by the moist method, and is devoid of crystalline structure, but the sublimed product appears in masses composed of hexahedral needles. Exposed to the light of the sun it gradually acquires on the surface a grey tint, owing to a portion being decomposed into mercury and sulphur.

Properties.—Water or alcohol have no action upon cinnabar. Cold hydrochloric and nitric acid singly fail to dissolve it; but nitro-hydrochloric acid readily attacks it and converts it into chloride. Nitric acid, when heated, decomposes it, and produces a protosulphate of oxide of mercury and sulphur. Caustic potassa or soda in solution does not decompose cinnabar; but if the hydrate of the alkali be employed, and its action be assisted by increased temperature, decomposition takes place, which results in the production of metallic mercury, sulphate and sulphide of the alkali.

A temperature approaching a red heat volatilizes it without decomposition; if air be admitted the sulphide burns, the sulphur being converted into sulphurous and sulphuric acids, and the metal disseminated in the vapor. Charcoal, and other carbonaceous matters, iron filings, lime, or any of the fixed alkaline bases, also abstract the sulphur and set the metal free.

Cinnabar is composed centesimally, according to the analyses of PROUST and GUIBOURT compared with theory, as follows:—

	At Weight.	Theory.	Proust.	Guibourt.
1 Eq. of mercury,.....	100 ..	86.21 ..	85.0 ..	86.21
1 Eq. of sulphur,.....	16 ..	13.79 ..	15.0 ..	13.79
1 Eq. of sulphide of mercury, 116	100.00	100.0	100.0	100.00

These determinations lead to the formula Hg S.

Cinnabar or vermilion is principally employed for its hue, and is but rarely prescribed by the physician. Its high price exposes it to considerable sophistication in the hands of unprincipled traders. The adulterations which are most likely to be contained in it are minium or red lead, ferro-ferric oxide, Fe_3O_4 , red brick dust, and pentasulphide of arsenic. In searching for red lead in this case, the same directions as those given for the detection of the same adulterant in red oxide of mercury may be pursued; brickdust may likewise be detected in the way there directed; iron may be readily found by treating the residue, after the sublimation of the mercurial sulphide, with hydrochloric acid, and

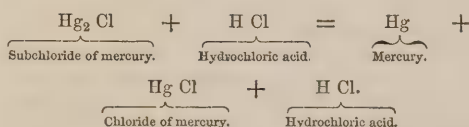
testing the filtered liquid with ferrocyanide of potassium—yellow prussiate—when a blue precipitate will appear if iron be present. Pentasulphide of arsenic may be found by treating the pigment repeatedly with strong solution of potassa, boiling, filtering off the liquid, adding to it hydrochloric acid, with a few fragments of zinc or iron, and, subsequently, transmitting sulphide of hydrogen gas through the solution, then boiling, filtering off the liquid, and adding hydrochloric acid to it to saturation. After some time sulphide of arsenic of a yellow color falls. In this case the alkali dissolves the quinesulphide from the mercury compound, and the hydrochloric acid again effects its precipitation.

The pigmentary uses of cinnabar are not confined to its external application in painting. It is largely consumed in the manufacture of red sealing wax, in which it is mixed up with venetian turpentine, shellac, and colophony. It is also employed in coloring wafers, and has been for the same purpose used in confectionary, and to improve the color of cayenne pepper; a practice greatly to be reprobated, for although Mr. TAYLOR states that he has not been able to find any instance of its having acted as a poison on man, yet thirty to seventy grains, even applied externally, have proved poisonous to the lower animals. It can scarcely be said to be used medicinally at the present time, though in 1769, Dr. DALBY wrote a book in praise of the virtues of cinnabar and musk in the cure of hydrophobia. BOLLEY proposes a solution of the ammonio-nitrate of silver as a test for cinnabar, for with whatever other matters it may be mixed up as a coloring matter, an instantaneous black color is produced, resulting from the formation of sulphide of silver along with basic nitrate, and also amide of mercury.

CHLORIDES OF MERCURY.—It may be safely stated that of all the compounds of mercury, none are of greater importance, in a medicinal point of view, than the two compounds produced by the union of chlorine and mercury, and which are well-known by the title of *calomel*—subchloride of mercury—and *corrosive sublimate*—protochloride of mercury. It is the growing opinion that in whatever state of combination mercury is administered by the medical practitioner, the active effects are the result of the chlorides of the metal, these being formed by the chlorides and free hydrochloric acid of the stomach. The experiments of MAILHE tend to corroborate this view, and hence the two compounds of mercury and chlorine are the principal mercurial combinations to which attention is directed in the several pharmacopœiæ of the medical colleges. For this reason, various methods are given for their preparation, and also for ascertaining their purity.

Subchloride of Mercury—Calomel.—As stated under the ores of mercury, this combination is met with in several mines in the form of incrustations—horn quick-silver—on other ores, or disseminated in the form of small transparent and translucent crystals. Those mines where it is particularly noticed, are the Almaden, Idria, Moschellandsberg; the mines of the Palatinate, Deux Ponts, and Bohemia. The quantity so found is, however, unimportant, and the native substance is never applied in medicine, that which is artificially prepared being preferred. There are several methods by which subchloride

of mercury may be obtained, as well by precipitation as by the dry way. When a solution of pure subnitrate of mercury is precipitated by another of a pure alkaline chloride, or with dilute hydrochloric acid, a white flocculent mass falls, which is the compound in question, and when washed well and dried it is chemically pure. It is necessary, however, to prolong the washings, otherwise some traces of the alkaline precipitant are retained, which react as a solvent upon a part of the precipitate by forming a double compound with it; and hence it is that calomel prepared in this way always leaves a mercurial taste. To guard against this, recourse is usually had to the dry method, in which the mercurial subsalt and chloride of sodium are mixed in the proper proportions, and then submitted to heat in a subliming pot, when the calomel is obtained in the form of a white incrustation on the cover of the vessel. Prepared in either way subchloride of mercury is a yellowish-white powder, which under the influence of solar light turns grey, being transformed into the protochloride and metallic mercury; it is but very slightly soluble, one part of the salt requiring twelve thousand of boiling water for perfect solution. Dilute hydrochloric acid has no action upon it, but when concentrated it changes the salt into metal and protochloride, thus—



Concentrated boiling solutions of the fixed alkaline chlorides, and of chloride of ammonium, react upon calomel in the same way. Hot strong nitric acid readily dissolves the subchloride of mercury, converting it into a protonitrate and protochloride of the metal. It is readily sublimed, and forms crystals on condensing. Its applications are chiefly medicinal, but it is employed in the laboratory as a test, though not frequently so used.

The symbol for this salt is $\text{Hg}_2 \text{Cl}$, corresponding with the suboxide Hg_2O ; its atomic weight, $100 + 35.5 = 135.5$; its density, 59.77 .

The formula given above agrees with the following composition:—

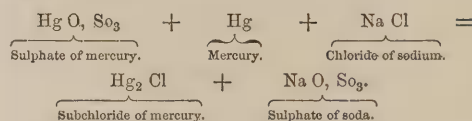
Centesimally.				
	At. weight.	Theory.	Klaproth.	
2 Eqs. of mercury,....	200	84.96	85.10	
1 Eq. of chlorine,....	35.5	15.04	14.90	
	235.5	100.00	100.00	
Volume.				
Mercurial vapor.....	1	=	6.9300	
Chlorine.....	$\frac{1}{2}$	=	1.2271	
Vapor of calomel.....	1	=	8.1571	

Although CHRISTISON and other authorities assert, that the calomel prepared by precipitating a dilute solution of a subsalt of mercury with one of chloride of sodium in the manner already stated, or by agitating a solution of sesquichloride of iron with metallic mercury, does not differ in therapeutic properties from that formed by sublimation, still the latter method

is adopted in the manufacture. Various recipes are known for obtaining it; thus, by mixing four parts of corrosive sublimate—protochloride of mercury—with three parts of the metal, and subliming, calomel is obtained; likewise, when sulphate of the protoxide of this metal is heated with an equivalent proportion of common salt and mercury, corrosive sublimate is produced. In the first instance the reaction may be symbolized thus—



and in the second,



When operating according to the first equation, it is required to have the metal in slight excess, in order to insure the complete reduction of the protochloride. MOHR states that this method is frequently adopted in the German pharmaceutical laboratories. The materials are ground up with a little water, or spirit, to prevent the escape of dust or powder, and when the metal is *deadened* the material is placed in glass vials and heated; after sublimation the product is collected by breaking off the neck of the bottles, and detaching the crust of salt.

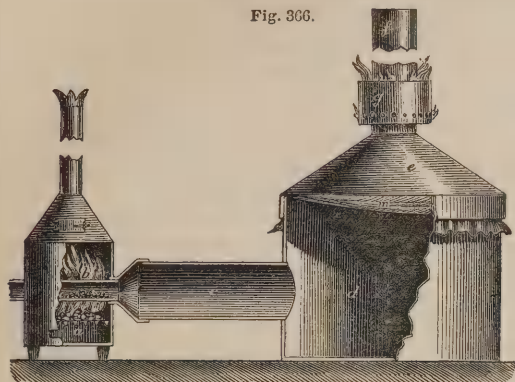
When preparing it by the second method, which is much the better of the two, two parts of mercury are dissolved in three of strong sulphuric acid, or better still, four ounces of the metal are acted upon with two ounces two drachms, liquid measure, of strong sulphuric acid, to which half a fluid drachm of strong nitric acid is added.

When sulphuric acid only is employed, the sulphate of mercury obtained by evaporation is mixed with two parts of metal, and afterwards with one part and a half of common salt, the whole being triturated in a mortar till the metal disappears. The mass is then sublimed in the usual way. In this operation the whole of the mercury is, however, never reduced to calomel, and on this account the sublimed mass requires purification from corrosive sublimate by repeated washings with boiling water, in which the latter is freely soluble. As soon as the washings give but faint indications of precipitates with a solution of nitrate of silver or sulphide of hydrogen gas, the calomel may be considered pure.

Fig. 366 is a drawing of a subliming apparatus described by MOHR. It consists of an earthenware tube, *b*, one foot long and a little more than two inches wide. This tube passes through a small furnace, and is connected on the left with a small bellows, and on the right with the wider pipe, *e*, that enters the box or chamber, *d*, where the sublimed calomel collects. This box is lined interiorly with glazed paper, the top being secured by a cloth, *m*, which is retained in its place by the funnel-cap, *e*, terminating in the chimney, *f*. At *g* is shown a small iron gallery for retaining hot charcoal, by which means a continuous draught is maintained.

The fire having been laid on at *a* and *g*, and as soon as the temperature rises to the subliming degree, air is urged through the apparatus by working the bellows, and this forces the calomel vapors, as fast as they rise,

Fig. 366.



into the chamber, *d*; as soon, however, as the chimney has become sufficiently hot by the chauffer in it, the blowing apparatus may be detached, as there will then be sufficient draught to carry the sublimed vapors into the receiver without mechanical aid. As the charge already in the tube, *b*, becomes exhausted, a further quantity may be introduced at the open side, and as long as the fire in *g* remains, the current of air drawn through will be sufficient to prevent any mercurial vapor escaping by the open end.

Under ordinary circumstances the incrustated calomel requires to be finely ground before it is fit for use. This operation is generally performed under lead rollers, unless the salt be minutely subdivided at the moment of condensation. Mr. JEWELL, patented a process for effecting this, which has since been improved by M. O. HENRY and SOUBEIRAN, and consisted in allowing the mercurial vapor to pass into a vessel charged with steam, having water in the bottom. By this arrangement the substance becomes reduced to the finest state of division.

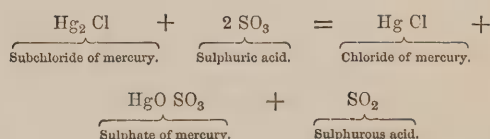
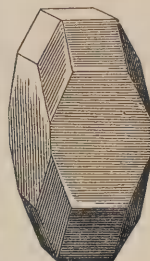
Thomson's Gaseous Method.—A patent was sealed on the 8th March, 1841, by Dr. ANTHONY TODD THOMSON, for manufacturing the chlorides of mercury by the direct union of the elements. It has long been known that even at common temperatures mercury and chlorine gas combine, though slowly, and that when heated the combination is effected rapidly with the development of heat and light. In Dr. THOMSON'S process the proportion in which the gas is admitted determines the nature of the product. The process is as follows:—A glass, earthenware, or other suitable vessel, provided with openings at both ends, is mounted in brickwork, or in any other convenient manner, and exposed to the action of an open fire beneath. A certain quantity of mercury is placed in this vessel, and the temperature raised to between 350° and 660°. One end of the glass communicates with an alembic, such as is generally used for generating chlorine gas, and the other end is connected with a large chamber made perfectly air-tight, to prevent the escape of any of the gases. In order to procure the chlorine, the alembic is charged

with a mixture of common salt, binocide of manganese, and sulphuric acid. The chlorine gas, as it is generated, passes from the alembic through the bent tube into the glass or earthenware vessel which contains the mercury, when it combines with its vapors, generated by raising it to 350° and above. The combination of the two gases forms either calomel or corrosive sublimate according to the quantity of chlorine gas employed. The product is found at the bottom of the air-tight vessel, from whence it may be taken after the operation is completed.

The patentee claimed the direct combination of the gas, not only with the mercurial vapor, but with the metal in any form.

Properties of Calomel.—The form in which calomel sublimes is modified by the dimensions of the apparatus employed, and the temperature at which it is produced. Prepared in small vessels it usually takes the shape of a fibro-crystalline cake, which when powdered is yellow or buff, whereas if the apparatus is large, and the receiver cold, it falls as a white impalpable powder. The crystals of calomel are square prisms, Fig. 367, with a specific gravity of 7.150; 7.156, PELOUZE and FREMY; 6.9920, KARSTEN. Calomel is not volatile at ordinary temperatures. Below a red heat it sublimes without fusing. It has neither taste nor smell, and is insoluble in pure water at 60° Fahr. Boiling muriatic acid quickly changes calomel into corrosive sublimate and metallic mercury. In hot nitric acid it dissolves, evolving nitric oxide. In the cold, sulphuric acid neither dissolves nor decomposes it, but the action of hot sulphuric acid is to produce the higher chloride, a sulphate of mercuric oxide, and sulphurous acid gas, thus—

Fig. 367.



Solutions of the fixed alkalis convert it into black oxide, and by ammonia it is changed into the double salt, 2 (Mg NH₂), Hg₂ Cl, which is also black. This amide compound is different from that which is formed when calomel and dry ammonia are brought in contact; the last has, according to KANE, the formula 2 Hg₂ Cl, H NH₂.

The trade adulterations of calomel are chalk, sulphate of baryta, carbonate of lead, common salt, sal ammoniac, and sometimes a little corrosive sublimate. For the detection of all impurities, the Edinburgh college directs that heat, sulphuric ether, and solution of caustic potassa should be employed. Calomel, if pure, is entirely volatilized by heat, all fixed impurities will therefore be found in the residue, whilst the sublimate may contain, besides calomel, the mercuric chloride and sal ammoniac. These impurities being soluble in water,

a solution is readily obtained containing both, and this liquid, when acted on by aqua potassæ, gives a yellow precipitate or cloud; after which, if gently heated, fumes of ammonia will be given off, producing, in contact with muriatic acid, the white vapors of muriate of ammonia. Or the liquid may be gently evaporated, and the solid residue treated with solution of caustic potassa, after which the volatile ammonia may also be brought in contact with the hydrochloric acid vapor.

The fixed residue supposed to contain barytic, sulphate, white lead, and chalk, may now be treated with pure and dilute nitric acid; any insoluble matter still remaining is set aside for examination, and the solution in nitric acid, which, if it was attended with effervescence, showed the presence of carbonic acid, may be, if necessary, diluted with water. Solution of sulphide of hydrogen gas is then added, and a black precipitate obtained, if lead be present. The clear liquid filtered from the plumbic sulphide is next neutralized by ammonia, and oxalate of ammonia added. A white precipitate proves the presence of lime.

Returning now to the insoluble residue from the nitric solution, which may still contain sulphate of lead and sulphate of baryta—the solid matter may at once be tested with a drop of sulphide of ammonium. If lead be present, it will be immediately blackened. If otherwise, then having been well washed with water, it may be boiled with pure carbonate of potassa, the solution filtered, excess of alkaline carbonate in the liquid expelled by pure hydrochloric acid, and afterwards chloride of barium added to detect the presence of sulphuric acid. If a white precipitate is observed, then the white matter left on the filter is carefully washed and dissolved in a small portion of pure hydrochloric acid; to this liquid dilute sulphuric acid is next added, and a precipitate of sulphate of baryta is obtained.

It is well known that calomel boiled with water, very slightly acidulated with hydrochloric acid, and containing a slip of clean copper, gives a deposit on that metal of metallic mercury. In the case of a solution of corrosive sublimate, the same test may be employed, or the following neat arrangement may be adopted:—A drop of the liquid is placed on a sovereign, and an iron key is placed so that one part is immersed in the liquid whilst another touches the gold of the coin. At the former point a brilliant mercurial stain is immediately produced by the galvanic current. A copper coin may take the place of the gold, in which case a strip of clean zinc, slightly arched, must be substituted for the iron key.

Finally, it being established that the solution contains mercury, the identification of it, as the bichloride, may be easily effected by solutions of nitrate of silver, caustic ammonia, iodide of potassium, and protochloride of tin.

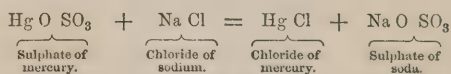
Medicinally, calomel is the mildest and most generally employed of all mercurials. It is irritant, however, in large doses, and to some constitutions, violently so. In small doses, and especially when combined with opium, it is sedative and antiphlogistic. Even alone, it possesses a cathartic action; but this, like the pre-

ceding, is rendered more certain by combining it with evacuants, as jalap and colocynth. Combined with digitalis or squills it is an effective diuretic, and its diaphoretic, like its sedative properties, are best developed in combination with opium. Its alterative properties are most generally produced by the use of small doses daily, or it may be given along with the golden sulphide of antimony, as *Plummer's pill*.

The Editor trusts, however, that before many years are over, medical men will have abolished the administration of all hydrargyric compounds, which can only have a baneful effect upon the system.

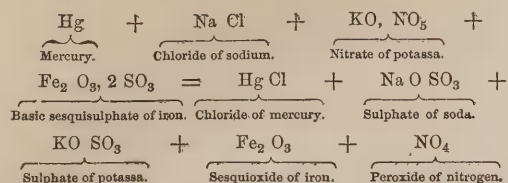
Protochloride of Mercury.—Corrosive Sublimate.—This combination of mercury, though containing the same elements as the last described compound, has very different properties, and, in a medical point of view, is much more active. It has been known from time immemorial, though the first description of it was given by GEBER of Thus, in Persia, who lived in the ninth century; and it has occupied ever since a prominent place in the *materia medica* of succeeding physicians. It may be prepared by acting upon the sulphate of protoxide of mercury by various metallic chlorides in solution—chloride of barium for instance—when a chloride of mercury is produced, together with a sulphate of the base of the precipitant. If the latter be insoluble, as in the case of baryta, the mercurial chloride may be obtained by evaporating the filtered liquor to dryness. Alkaline chlorides, chloride of magnesium, and other similar salts, effect the same changes, but slowly. By bringing together the vapor of mercury and chlorine gas, in the equivalent proportions, it is likewise produced.

None of these methods are, however, followed in its manufacture, recourse being always had to the dry process of subliming a mixture of chloride of sodium and sulphate of mercury, when a chloride of the latter and sulphate of soda are formed, the mercurial compound being expelled by the heat. Thus:—

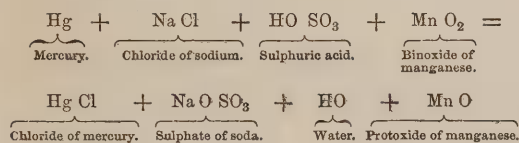


Considerable quantities of this compound were prepared by the Dutch manufacturers before the knowledge of its formation became more general. Their mode of procedure was to mix equal parts of nitrate of mercury, decrepitated salt—chloride of sodium—and calcined or white martial vitriol—subsulphate of the sesquioxide of iron—and introduce the composition into a matrass, filling only one-third its capacity. The vessel was then imbedded in the sand bath, and heat applied till its bottom assumed a dull red, when a series of decompositions took place, by which chloride of mercury was produced and sublimed, whilst sulphate of soda and sesquioxide of iron remained in the matrass, and the nitric acid, after suffering decomposition, was evolved as nitrous acid, quadroxide of nitrogen— NO_2 —and oxygen. Another process was to cause metallic mercury, chloride of sodium, saltpetre, nitrate of potassa, and martial vitriol to react upon one another in the matrass by heat, when corrosive sublimate resulted.

GMELIN gives the rationale of this operation in the formula—



KUNKEL improved upon the process by producing first a sulphate of the protoxide of mercury, by acting on the metal with oil of vitriol, and heating in a matrass equal parts of this and common salt. Subsequently, FOURCROY, in order to dispense with the first operation, directed to employ sulphuric acid, mercury, and common salt, to submit the mass to heat, and finally to sublime it. In practice, the proportions taken were ten parts of mercury, eight of common salt, eleven of sulphuric acid, six of peroxide of manganese, and three of water. The decomposition in this case may be represented thus—



That is, there is formed, in the first instance, a sulphate of mercury by the concurrent oxidation of the binixide of manganese and the action of the sulphuric acid, and this sulphate is afterwards decomposed in the heat by the salt chloride of mercury being formed and expelled to the upper part of the matrass; sulphate of soda and protoxide of manganese being left in the bottom of the vessel.

The London college directs that one pound of mercury be boiled with thirty-one fluid ounces of sulphuric acid, and that the dry bipersulphate is to be mixed with half a pound of salt, and sublimed.

In the receipt of the Edinburgh college, the process for preparing calomel and corrosive sublimate is the same, with the exception that only half the quantity of mercury is taken for the latter.

The Dublin college at first prepares the sulphate of mercury, and intimately mixes this in fine powder with dried common salt, likewise ground, in the proportion of two of the former to one of the latter, subjecting the mixture to heat in an iron pot lined with clay, to which an earthen head is adapted. In either of these operations the temperature at which the salt is sublimed should not be too elevated, as in this case the chloride would fuse and fall back into the vessel, and thus occasion a loss.

In the formation of the sulphate of mercury, preparatory to subliming it with common salt, the materials are introduced into a cast-iron boiler, placed in brick-work, having a fire beneath it, and surmounted by a hood, to carry off the noxious gas evolved into the chimney. The heat required to effect the union of the mercury with the acid is moderate. In the course of the action, one portion of the acid is decomposed

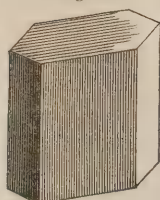
into oxygen, and sulphurous acid, which escapes; the oxygen unites with the metal, and the oxide so formed, is salified by a second equivalent of sulphuric acid; the mass forms a thick magma, and continues to evolve sulphurous acid as long as any metal remains unoxidised. Some subsulphate is apt to be produced; but as it is necessary for the purity of the chloride which is intended to be obtained from this, to have the whole of the metal in the state of protosulphate, a quantity of acid should be employed at the end of the process, before the drying of the salt. The better to insure this, several tests may be made with a portion of the sulphate from time to time, by suspending it in water saturated with chloride of sodium; when the whole dissolves, it is evident that all the mercury is in the form of protosulphate; but should a white deposit be formed, it indicates that a sulphate of the suboxide still remains. When the sulphate is prepared, it is mixed with the requisite quantity of alkaline chloride, and a little binixide of manganese—one part to ten of the mercuric sulphate operated upon—and allowed to remain during two or three days, with the view of effecting a thorough decomposition. At the expiration of this period the fire is lighted, and a gentle heat maintained till all moisture has evaporated; after which, the mass is put into the sublimers, which may be of green glass, resting on cast-iron plates, and imbedded in sand up to the neck. In large factories, the subliming furnace is usually an oblong, capable of holding about one hundred matrasses, and heated by fires symmetrically disposed along the longer side. These are generally covered by a prismatic conical hood, from which a pipe leads into the chimney, with the view of carrying off any escaping vapors of the mercurial compound, and for which use, to be effectual, the chimney should have a good draught. The most important part of the business is the regulation of the heat, which, in the first instance, disengages moisture, and after this the mercurial salt begins to be volatilized. At this stage a small glazed conical vase is inverted on the neck of each matrass, in order to arrest any vapors which may make their escape. When white vapors are observed, it is a certain sign that the heat is too strong, in which case the vessel must be cooled by removing a portion of the sand from its upper part. Towards the end of the sublimation the blast must be increased, with the view of bringing the sullimed chloride nearly to its fusing point, for the purpose of causing it to adhere together in a compact cake; but for reasons already assigned, the temperature must not be carried too far, since this would occasion a loss. After the sublimation the fire is withdrawn; and as soon as the sand has sufficiently cooled, the matrasses are taken out and broken in the middle as gently as possible, so as not to detach the crust of salt upon the upper part. Finally, the fragments of glass and discolored parts are removed, and the pure cakes set aside to be ground and packed.

Any subchloride of mercury which may happen to be formed during the sublimation, owing to its not being so volatile as corrosive sublimate, forms a whitish ring on the lower part of the sullimed crust, and thus admits of being removed. Such portions may be added

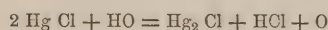
in the succeeding charge which is being converted into sulphate, and afterwards re-sublimed.

Properties.—Ordinary sublimed chloride of mercury is a white satiny substance having a crystalline appearance, although often no distinct order can be distinguished. If, however, the sublimation be effected at a low heat, and as slowly as possible, crystals appear, having the shape of flattened tetrahedral prisms, Fig.

Fig. 368.



368, with a specific gravity of 5.4. The sublimed salt appears more or less translucent, and when in thin fragments often transparent. In the heat it is very volatile, entering first into fusion before it is disseminated. According to FARADAY, the salt volatilizes at ordinary temperatures, but REIGEL found this not to be the case. Water dissolves it very readily; sixteen parts are required in the cold, but three parts at 212° are sufficient to dissolve one part of it, and the liquid reacts acid to test-paper. A hot, concentrated, aqueous solution of mercurial chloride deposits crystals on cooling, which slightly differ in appearance from those obtained by sublimation: they are anhydrous. Alcohol and ether also take it up very freely; seven parts of cold alcohol dissolve three of corrosive sublimate, but the same quantity at a boiling temperature takes up six parts of the salt. When sulphuric ether is added to a solution of corrosive sublimate in water, the mobile liquid abstracts the salt, and an ethereal solution of chloride of mercury floats on the water, which is more or less reduced of its saline constituent. Acids aid in the solution of this body in water, without, however, causing any decomposition or alteration of it. Hydrochloric acid converts it, however, into a hydrochloride of chloride of mercury; sulphide of hydrogen in excess gives rise to a black protosulphide of mercury, but if this agent be sparingly added, a compound of sulphide and chloride of mercury is produced. Potassa in excess throws down the protoxide, but if the solution be not saturated with the alkali, a white oxychloride separates. Ammonia gives rise, also, to an amidochloride of mercury, which an excess of ammonia dissolves. A solution of iodide of potassium throws down a scarlet precipitate of iodide of mercury. Protochloride of tin causes at first a reduction to the subchloride of mercury, which precipitates; but this also becomes reduced to the metallic state, hydrochloric acid being set free in the liquid. By exposure to sunlight an aqueous solution of the salt suffers decomposition into calomel, hydrochloric acid, and oxygen, thus:—



It is likewise decomposed by various substances, metallic, non-metallic, and organic; the latter usually converting it to the state of subchloride. It forms insoluble, or at least but very partially soluble precipitates with albumen and fibrin.

The centesimal composition of protochloride of mercury corresponds with the chemical formula Hg Cl , as shown in the annexed:—

	At Weight.	Centesimally. Theory.
1 Eq. of mercury,.....	100	73.86
1 Eq. of chloride,.....	35.5	26.14
1 Eq. of chloride of mercury, ..	135.5	100.00
	Vol.	Specific Gravity.
Vapour of mercury,	1	6.9300
Chlorine gas,	1	2.4543
Vapour of chloride of mercury,...	1	6.3843

On all animals the effects of chloride of mercury are, as its technical name implies, those of a corrosive poison, and by its external application even, it has proved fatal to man. When swallowed in any quantity, the symptoms come on almost immediately. Indeed, the rapidity of their appearance and the strong metallic taste which is experienced, are among the phenomena which strongly distinguish cases of poisoning by this agent from those occasioned by arsenic. According to WRIGHT, the best antidote against its poisonous action is the white of egg suspended in water and milk—one egg is said to be required for every *four grains* of the poison; hydrated sesquioxide of iron has also been recommended, and likewise, on account of the gluten it contains, wheat-flour and water. In this country it is little employed internally for allaying human maladies; and even its external application is not free from danger. In veterinary practice, however, it is frequently used, especially in the form of ointment or wash.

The salt has been extensively employed for the preservation of subjects of natural history, and likewise for preserving wood against the dry rot.

Compound Chlorides of Mercury.—Corrosive sublimate is capable of entering into combination with hydrochloric acid and most of the metallic chlorides, forming well-defined crystallizable salts. Thus, with hydrochloric acid it produces a compound, expressed by Hg Cl , HCl or Hg Cl_2 , HO ; with chloride of potassium, Hg Cl , KCl , 2 HO , 2 Hg Cl , KCl , 4 HO , and 4 Hg Cl , KCl , 8 HO_2 . Soda, lithia, baryta, strontia, calcia, and magnesia salts react in the same way, as also the chlorides of manganese, iron, nickel, and cobalt, all of which produce with the mercurial salt well-defined crystalline compounds.

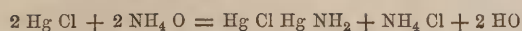
The same compound, when cautiously treated with a dilute solution of a fixed caustic alkali, or with one of the carbonates of the alkalies, gives rise to a compound of chloride and oxide of mercury, having the composition Hg Cl , 3 Hg O —a chloride of the alkali in the first case, and a bicarbonate in the second instance, being formed. All these, however, though interesting to the theoretical chemist, are as yet of no practical utility, and therefore will not be discussed here at greater length. At the same time there is one combination which arises from the addition of ammonia to a solution of chloride of mercury, that has many valuable properties in medicine, and on that account merits a short description, namely:—

Amido-Chloride of Mercury—White Precipitate.—

This compound is obtained by adding to a solution of two equivalents of the chloride of mercury—271 parts—in a large quantity of water, a solution of ammonia

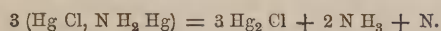
as long as a precipitate is formed, collecting the separated substance, washing with cold water, and drying.

For a long time this body was thought to be identical with calomel, till RAMMELSBURG showed it to be different, and KANE demonstrated its true composition, in his researches on the *Amides*. The reactions in its formation may be expressed thus:—



That is to say, one equivalent of the volatile alkali suffers decomposition into amidogen— NH_2 —water and hydrogen; the amidogen takes an equivalent of the mercury from the corrosive sublimate and sets free chlorine, which seizes on the ammonium of the second equivalent of the alkali, and forms chloride of ammonium, thus liberating its oxygen to the hydrogen set free in the first change.

Amido-chloride of mercury forms a snow-white mass, without odor, but possessing a nauseous metallic taste. It requires for solution about six hundred parts of water, but the mineral acids readily dissolve it. When heated it volatilizes without fusing, but WITTSTEIN states that the same compound, when obtained from chloride of mercury, chloride of ammonium, and a fixed alkaline carbonate, melts in the heat before dissipation. In either case the compound is completely broken up into corrosive sublimate, ammoniacal gas, and nitrogen, as shown by the equation:—



When the precipitate is boiled in water, chloride of ammonium is produced, and a heavy yellow powder composed of two equivalents of protoxide of mercury, one of protochloride, and one of amide of mercury falls. Potassa likewise changes it into oxide and chloride of the metal, ammonia being evolved. Caustic ammonia has no apparent action, and hence this alkali serves to distinguish it from calomel, which is turned grey or blackish by it. Its composition is given:—

	At weight.	Centesimally.	
		Theory.	Kane.
2 Eqs. of mercury,	200.0	79.522	78.60
1 Eq. of chlorine,	35.5	14.115	13.85
1 Eq. of nitrogen,	14.0	5.566	6.37
2 Eqs. of hydrogen,	2.0	0.795	
Water,	—	—	0.58
	251.5	99.998	99.40

Or,

	At. weight.	Centesimally.
		Theory.
1 Eq. of chloride of mercury,	135.5	53.876
1 Eq. of amide of mercury,	116.0	46.124
	251.5	100.000

This compound, in a physiological point of view, has been but imperfectly studied. It is, however, regarded as an energetic poison, in this exhibiting a similarity with corrosive sublimate. It is never administered internally, but may be used externally in the form of an ointment, and is efficacious in various skin diseases. In cases of poisoning with this substance, albuminous antidotes, such as are given to reduce the action of corrosive sublimate, serve best. It is said that white precipitate is much adulterated with sulphate of lime,

carbonate of lime, and carbonate of lead. The extent of the adulteration may readily be found by heating a weighed quantity, and weighing the residue should any be left.

Iodide of Mercury.—Iodine and mercury are capable of entering into several states of combination; and some of the compounds so formed are capable of constituting binary salts with the alkaline iodides. Thus, there is the green iodide of mercury, $\text{Hg}_2 \text{ I}$; the yellow iodide, $\text{Hg}_2 \text{ I}_2 = \text{Hg}_2 \text{ I, Hg I}$, and the red iodide, Hg I . The latter compound produces, with iodide of potassium, a mono- bi- and tri-iodargyrate of potassium, the composition of which respectively is Hg I, KI ; 2 Hg I, KI , 6 H O , and 3 Hg I, KI . There are formed similar compounds from the iodide of mercury and the soluble chlorides, but as objects of manufacture, they are of no interest. Respecting the manufacture of the scarlet iodide of mercury, the reader will find particulars under iodine at page 398.

FULMINATE OF MERCURY.—*Fulminating Mercury*; *Mercur fulminante*, French; *knallquecksilber*, German.—This very explosive compound was first described by HOWARD in the Philosophical Transactions for 1800. BRANDE gives the following method for its preparation:—One hundred grains of mercury are treated with an ounce and a half by measure of nitric acid, aided by heat in a porcelain basin, till the whole is dissolved. As soon as the liquid is cold, two ounces by measure of alcohol, specific gravity .85, are added, and a gentle heat applied. Brisk action takes place, ethereal vapors being copiously evolved, and a yellow-grey precipitate deposited, which is the compound in question. If the effervescence be too brisk, the vessel should be withdrawn from the heat, and its contents cooled by the addition of more alcohol. As soon as the precipitate has formed, it is to be well washed by decantation and filtration, only a small quantity of distilled water being used in the latter process. The temperature at which the compound is dried should not exceed 100° , and only small quantities ought to be operated upon at a time to guard against an explosion. One hundred and twenty grains of the fulminate are obtained from the above quantity of mercury when the operations are successfully conducted. It happens that on the addition of the alcohol, a portion of the mercuric salt is reduced to the state of metal, but this can be separated from the yellowish salt after the spirit is decanted by treating with boiling water, in which the fulminate is soluble; and by filtering off the liquor and setting it aside to cool, the salt separates in silky acicular crystals. When it is required to prepare it in large quantities, the course followed is to dissolve one part of mercury in twelve of nitric acid of 1.36 specific gravity, and to add eleven parts of alcohol, specific gravity .850, when the solution is cold. On slightly heating the vessel, brisk action takes place as above stated, and similar effects are produced. The separated metal is removed from the explosive compound by boiling water, from which the fulminate is deposited on cooling in silky crystals. CREMASCOLI directs, as the safest method, to treat half an ounce of the metal with six ounces of nitric acid of 1.30 in a flask, which should be held in boiling water for a minute or so, and as

soon as solution takes place, and the temperature is reduced to 55° , to pour in four ounces of alcohol of $\cdot 833$ specific gravity, and again to immerse the flask in boiling water for two or three minutes, till dense white vapors begin to fill the upper part of the vessel, at which period it should be removed from the heat. The reaction is said to be very moderate in this instance, and the whole of the fulminate falls down in the course of a few hours, when it may be purified by decantation and washing.

Fulminate of mercury forms an extremely dangerous substance to operate upon, owing to the readiness with which it explodes, the violence of which has repeatedly been the cause of serious injury, and even of loss of life. It detonates strongly when struck with a hard body; but sometimes trifling friction may serve to produce this effect, even when in a moist state. Heated to 300° it explodes, and at the same time evolves a bright flame; the electric spark, and contact with strong nitric and sulphuric acids, also induce its decomposition, which is invariably accompanied with explosion. The products resulting from it, when detonated, are carbonic acid, nitrogen, and vapor of mercury. Its chemical formula is expressed by 2HgO , $\text{C}_4 \text{N}_2 \text{O}_2$, or 2HgO , $\text{Cy}_2 \text{O}_2$, that is, two equivalents of protoxide of mercury and one of fulminic acid.

Fulminating mercury has been much used since its discovery for the manufacture of percussion caps for guns, and latterly has been employed in the construction of destructive machines, such as grenades and the like. HOWARD endeavoured to substitute it for gunpowder, but was unsuccessful, owing to the nature of its explosion, which is such as to destroy the gun by its suddenness and force without expelling the shot. When used for priming percussion caps it may be moistened with a little resinous tincture, and dropped into the little capsule, but the universal practice is to mix it with about six per cent. of nitrate of potassa and water, sufficient to reduce the whole to a thin paste. A small quantity of this is dropped into each cap, and carefully dried at a low heat.

Analysis of Mercurial Matters.—Already a short description of the method of analysis pursued in determining the richness of mercurial ores has been given, and although the system of analysis to which reference will now be made is analogous to that described, still, since it is more applicable to mercurial compounds in general, it deserves a short space here. It is known as MILLON'S method, and is conducted as follows:—

A hard German glass tube, such as is generally employed in organic analysis, is taken and drawn out in the form represented by *a*, *b*, *e*, in Fig. 369.

The part *a* is intended for the retention of the reduced mercury, and the rest, from *b* to *e*, for the reduction of the ore or salt of mercury. A plug of asbestos is introduced into the end, *b*, and then fragments of quicklime as far as *d*; the compound to be analysed, in quantities varying from fifteen to twenty grains, is then carefully put in, and fills from *c* to *d*, and fragments of quicklime are made to occupy the rest of the tube to *e*. When nitric acid exists in the compound to be analysed, copper turnings are substituted for the quicklime in the part *b d*. The extremity, *e*, is connected by perforated

corks, quill tubes, and flexible connectors, with the apparatus, *g*, for generating a current of pure dry hydrogen gas. The charged tube being placed in the combustion furnace, *f*, and connected with the apparatus, *g*, and filled with gas, ignited charcoal is placed

Fig. 369.



round the part from *b* to *c*, and as soon as this is red-hot the remainder is gradually heated to redness to the end, the current of gas being still maintained. During this operation the mercury is disengaged, and collects in the part, *a*, the water which is generated or contained in the substance being carried off by the current of hydrogen. When the operation is over, the narrow neck near *b* is cut off, and the part containing the reduced metal weighed; after this, the metal is taken out, and any portions remaining dissolved with nitric acid, then washed with distilled water, dried and reweighed. The difference of the two results will be the weight of metal in the sample operated upon.

Provided no easily reduced metal be contained in the substance to be assayed, a quicker method may be resorted to. It consists in adding to the solution of the compound, as free from nitric acid as possible, protochloride of tin, acidulated with hydrochloric acid, and collecting the precipitated mercury on a weighed filter, washing and drying under the exhausted receiver, over sulphuric acid, and weighing.

To Dr. DALZELL, of Edinburgh, the Editor feels indebted for much of the valuable matter contained in this article, and kindly supplied gratuitously and unsolicited.

NICKEL.—English, French, and German.—It was CRONSTEDT who, in 1751, showed that nickel was a distinct body. MILLER remarks that it always occurs in nature associated with iron, both as a constituent of meteoric iron, and in the ores of that metal, which present a composition analogous to those of cobalt. Nickel may be obtained pure upon a small scale by dissolving the roasted ore in aqua regia, evaporating to expel the excess of acid, redissolving in water, and transmitting through the menstruum a current of sulphide of hydrogen. The filtrate is boiled with nitric acid, to sesquioxidize the iron; the solution is precipitated by an excess of ammonia, filtered from the ferruginous oxide, and to the blue liquid potassa is added until the azure tint entirely disappears. A pale-green precipitate, consisting of hydrated oxide of nickel and potassa, is thus obtained, which must be well washed with hot water to remove the alkali, and then reduced by ignition in a current of hydrogen gas. If heated for an hour by means of a blacksmith's forge, in a crucible lined with charcoal, a well-fused button of carbide of nickel is produced; a globule of the pure metal may,

however, be procured by heating the oxalate of nickel intensely in a crucible with a luted cover, without any other reducing agent than the carbonic oxide furnished by the decomposition of the vegetal acid.

Pure nickel is a brilliant, silver white, ductile metal, little more fusible than iron. At ordinary temperatures it is susceptible of magnetism, but it loses this property almost entirely if heated to a point exceeding 630°, though it recovers its magnetic power on cooling. Nickel becomes oxidized by exposure to a current of air at an elevated heat. The metal is easily attacked by nitric acid and aqua regia, and is dissolved slowly, with evolution of hydrogen, in sulphuric or in hydrochloric acid. Its specific gravity is 8·82; its symbol Ni; and its equivalent 29·5.

SOURCES.—Native nickel occurs at Westerwald in the Erzgebirge, in Bohemia, combined with arsenic, under the significant name of *kupfernickel*; with cobalt, iron, and copper, as *arsenic-nickel*, in the Hartz; at Riechelsdorf in Hesse, as an oxide, in *nickelschwartze*; as a sulphide in *haarkies*; as a sulphide and arseniate of nickel in *nickelglanz*; and with sulphur and antimony in *nickelspeisglanz*, at Siegen, and near Freussberg, in the principality of Nassau. Nickel is always present in meteoric stones. Kupfernickel occurs in numerous external shapes; as uniform, globular, botryoidal, arborescent, massive, and disseminated; fracture, coarse or fine grey; in silver and cobalt veins, in gneiss, sienite, mica-slate, kupfer-schiefer, accompanied by speiss cobalt, native silver, quartz, *et cetera*. It is found in Westphalia near Ospe, in Hesse at Riechelsdorf, and Biber in Baden; in the Saxon Erzgebirge, near Schneeberg and Freiberg; in Bohemia, at Joachimsthal; in Thuringia, at Saalfeld; in Steyermark, near Schladming; in Hungary, France, and England.—*Ure*.

Subjoined are the analyses and characteristic properties of a few of the more important of these minerals:—

Kupfernickel.—The composition of this mineral, as stated by STROMEYER and PFAFF, is as follows:—

Centesimally.		Riechelsdorf.	
Nickel,	44·20	.....	48·90
Arsenic,	54·70	.....	48·70
Iron,	0·33	.....	0·44
Lead,	0·32	.....	0·96
Sulphur,	0·45	.....	0·90
Loss, .....	—	.....	0·10
	100·00		100·00

It is of a copper or yellowish-red hue, but acquires a grey or blackish tarnish by exposure. The specific gravity is 6·6—7·6. It occurs reticulated, dendritic, and botryoidal, but more commonly massive; never crystallized; streak, pale brownish-black. The fracture is imperfectly conchoidal, or fine-grained and uneven, with a glistening or shining metallic lustre; it yields to the knife with difficulty, and is brittle. Before the blowpipe it gives out an arsenical vapor, and then fuses, though not very easily, into a white metallic globule. After roasting, it usually tinges a bead of borax blue, indicating the presence of a certain quantity of cobalt. In nitric acid it assumes a green coating, and in aqua regia is dissolved.

Haarkies—Sulphide of Nickel.—The following is ARFEDSON'S analysis:—

Centesimally.	
Nickel,	64·76
Sulphur,	35·24
	100·00

With traces of cobalt and arsenic. Its specific gravity is 6·45.

It occurs in capillary and sometimes diverging filaments of a yellowish color, inclining to steel-grey. Primary form the cube; flexible; opaque, with a metallic lustre; not magnetic. Before the blowpipe on charcoal, with a good heat, it fuses into a globule which is metallic, malleable, and magnetic, and consists wholly of nickel; but in the open tube it exhales the smell of sulphurous acid. With nitric acid it forms a greenish solution.

Nickelspeisglanz.—This mineral is generally a combination of nickel, sulphur, and antimony, in the following proportions:—

Centesimally.	
Nickel,	27·36
Sulphur,	16·98
Antimony,	55·66
	100·00

Its specific gravity is 6·45—6·5, and its primary form a cube. It occurs in masses, which have a granular composition, and possess a steel-grey or silver-white color; lustre, metallic; cleavage, perfect parallel to the faces of the cube; brittle. Before the blowpipe it is partly volatilized, disengaging vapors of antimony and sometimes of arsenic, and ultimately melts into a metallic globule, which communicates a blue tinge to glass of borax. It is acted upon by nitric acid, forming an immediate precipitate, and imparting to the solution a greenish tinge.

Meteoric Stones.—A natural alloy of nickel and iron, forms a principal metallic ingredient in most *aérolites*, or *meteoric stones*. Though nothing is really known of the source or origin of these bodies, remarks BRANDE, it has been ascertained upon satisfactory evidence, that they are not of terrestrial formation; and, consequently, their visits to the surface of this planet have awakened much speculation, and some experimental research. The first tolerably accurate narration of the fall of a meteoric stone relates to that of Ensisheim, near Basle, upon the Rhine, which fell in 1492, and weighed two hundred and fifty-five pounds. The account which is deposited in the church, runs thus:—Anno Domini 1492, Wednesday, November seventh, there was a loud clap of thunder, and a child saw a stone fall from heaven; it stuck into a field of wheat and did no harm, but made a hole there. The noise it made was heard at Lucerne, Villing, and other places. On the Monday, King MAXIMILIAN ordered the stone to be brought to the castle, and having conversed about it with the noblemen, said the people of Ensisheim should hang it up in their church, and his Royal Excellency strictly forbade anybody to take anything from it. His Excellency, however, took two pieces himself, and sent another to Duke SIGISMUND of Austria.

In 1627, November twenty-seventh, GASSENDI saw a burning stone fall on Mount Vaisir, in Provence; he found it to weigh fifty-nine pounds. In 1672 a stone fell near Verona weighing three hundred pounds. LUCAS, when in Larissa in 1706, describes the falling of a stone with a loud hissing noise, and smelling of sulphur. In September, 1753, DE SALANDE witnessed this phenomenon near Pont de Vesle. In 1768 no less than three stones fell in different parts of France. In 1790 there was a shower of stones near Agen, witnessed by DARCET and several other persons. On the thirteenth December, 1795, a stone fell near Major TOPHAM's house in Yorkshire; it was seen by a ploughman and two other persons, who immediately dug it out of the hole it had buried itself in; it weighed fifty-six pounds.

Various other and equally satisfactory accounts of the same kind are narrated. All concur in describing a luminous meteor, moving through the air in a more or less oblique direction, attended by a hissing noise, and the fall of stony or semimetallic masses in a heated state. There exists, however, evidence of another kind, proving the peculiar origin of these bodies. It is, that although they have fallen in very different countries and at distant periods, when submitted to chemical analysis they agree in component parts; the metallic particles being composed chiefly of iron and nickel, with magnesia and silica.

Large masses of native iron have been found in different parts of the world, of the history and origin of which nothing very accurate is known. Such are the great block of iron formerly at Elbogen in Bohemia; the large mass discovered by PALLAS, weighing sixteen hundred pounds, near Krasnojark in Siberia; that found by GOLDBERRY in the great desert of Zara in Africa; probably, also, that mentioned by BARROW, on the banks of the great Fish-river in Southern Africa; and those noticed by CELIS, HUMBOLDT, and others, in America, of enormous magnitude, some exceeding thirty tons in weight. That these should be of the same source as the other meteoric stones, seems at first incredible; but when they are submitted to analysis,

and the iron they contain found alloyed with nickel, it no longer seems credulous to regard them as of meteoric origin. Nothing of the kind is found in the earth. Two blocks of such iron were, in fact, observed to fall from a meteor at Hradschina, near Agram, in Croatia, in 1751.

To account for these remarkable visitations of metallic and lapideous bodies, a variety of hypotheses have been suggested. Are they merely earthy matter, fused by lightning? Are they the offspring of any terrestrial volcano? These were once favorite notions; there is no instance recorded in which similar bodies have in that way been produced, nor do the lavas of known volcanoes in the least resemble them; to say nothing of the inexplicable projectile force that would be here wanted.—*Brande*.

The notion that these bodies come from volcanoes in the moon is no longer received. The most plausible hypothesis is that of HUMBOLDT, who supposes that meteoric stones are, in fact, small planets continually wandering in myriads through the celestial spaces, but which occasionally come within the earth's attraction, and fall to the ground.

In meteoric iron the proportion of nickel varies considerably. In a specimen from the Arctic region, BRANDE found 3·2 per cent. In that from Siberia, CHILDREN obtained nearly ten per cent. The analysis may be performed by solution in nitro-hydrochloric acid; the iron is thrown down by excess of ammonia in the state of sesquioxide; it is separated by filtration, washed, and dried; and on evaporating the filtrate, and heating its dry residue red-hot, the oxide of nickel is obtained, which should be redissolved in nitric acid, and precipitated by pure potassa, the mixture being boiled for a few seconds; or the nitro-hydrochloric solution may be precipitated by excess of ammonia, and filtered: the sesquioxide of iron remains upon the filter, and the filtrate is an ammoniacal solution of nickel, from which the metal may be precipitated by ferrocyanide of potassium. The following are some further analyses of meteoric iron:—

	Klaproth.		M. de Rivers and Boussingault.			
	Sclavonia.	Siberia.	From the Andes.			
Iron,	96·5	98·5	91·51	91·23	91·76	90·76
Nickel,	3·5	1·5	8·49	8·21	6·36	7·87
Loss,	—	—	—	0·56	1·88	1·37
	100·0	100·0	100·00	100·00	100·00	100·00

MANUFACTURE.—The nickel of commerce is chiefly obtained from kupfernickel, nickeliferous pyrites, and from the speiss obtained as a secondary product in the treatment of nickeliferous ores of cobalt. The most productive mines of this metal are those of Saxony, Germany, and Norway. The preparation of pure nickel from speiss is conducted in accordance with a method first proposed by WÖHLER. The powdered speiss is roasted, first alone, and afterwards with the addition of powdered charcoal, to effect the separation of its arsenic. The residue obtained by this process is at present mixed with three parts of sulphur, and one part of carbonate of potassa, and then fused in a large earthen

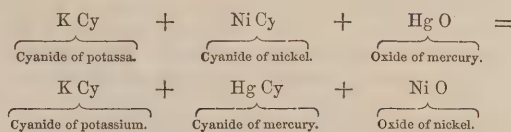
crucible. This product is nowedulcorated with warm water, by which the arsenic and sulphur associated with potassium are dissolved, while the nickel, in the form of sulphide, remains at the bottom of the vessel in which the operation has been conducted. When, as sometimes happens, from the employment of too high a temperature at the commencement of the roasting, the whole of its arsenic has not been expelled, the operation must be repeated on the residual sulphide thus obtained. As soon as entirely freed from arsenic, the sulphides are well washed with warm water, and then dissolved in sulphuric, to which a small quantity of nitric acid has been added; the precipitation of the

lead, copper, and bismuth, which may be present, is determined by a current of sulphide of hydrogen gas, and the metals which still remain in solution are afterwards precipitated by an alkaline carbonate. This deposit, after being well washed, is then treated with an excess of oxalic acid, which forms an insoluble oxalate of iron, and leaves behind an insoluble oxalate of the oxides of cobalt and nickel. These are then dissolved in ammonia, and treated as already described. The oxalate of nickel deposited from this solution is, after being carefully washed to remove any traces of the ammoniacal liquor, ignited in a close crucible, having an aperture in the lid for the escape of the evolved gases.

As the metal itself is now extensively used in alloys, of which German silver is one of the most important, great pains have been taken to procure it in a state of comparative purity, and several processes have been proposed. According to LOUYER, the process by which nickel is extracted from speiss at Birmingham, on the large scale, is as follows:—The speiss is first fused with chalk and fluorspar, the metallic mass obtained is reduced to powder, and roasted for twelve hours to expel the arsenic; the residue is then dissolved in hydrochloric acid; the solution is diluted, and the iron sesquioxidized by the cautious addition of chloroxide of calcium—bleaching powder—milk of lime is then carefully added so long as sesquioxide of iron falls, which carries down with it the last portions of arsenic. This precipitate is well washed, and the liquid, which contains all the cobalt and nickel, is treated with a current of sulphide of hydrogen; the sulphides of copper, bismuth, and lead are thus precipitated, and are thoroughly washed. The whole of the nickel and cobalt still remain in the liquid, which is again treated with chloroxide of calcium: the cobalt is thus thrown down as sesquioxide; after which the total quantity of the nickel is separated from the solution in the form of hydrated oxide, by adding milk of lime as long as any precipitate is produced.

For the separation of nickel and cobalt, the method recommended by LIEBIG is the best. The cobalt and nickel having been freed from all other substances except salts of potassa or soda, are precipitated in the form of hydrated oxides, which, after partial washing from the adhering alkaline salts, are mixed with caustic potassa and a decided excess of hydrocyanic acid; the mixture is then boiled for ten minutes in order to expel the greater part of the excess of hydrocyanic acid, and to convert the oxides into double cyanides of cobalt and nickel. A cobaltcyanide of potassium— $K_3 Co_2 Cy_6$ —is produced at the same time. The formation of the cobaltcyanide may be traced as follows:—cyanide of cobalt is first formed, $H Cy + Co O = Co Cy + HO$, and this cyanide of cobalt, by boiling with an excess of cyanide of potassium and hydrocyanic acid, yields cobaltcyanide of potassium and free hydrogen, $2 Co Cy + 3 K Cy + H Cy = K_3 Co_2 Cy_6 + H$. The double cyanide of nickel and potassium is very simply formed, as with nickel no compound corresponding to the cobaltcyanide is obtained; $2 K Cy + Ni O = K Cy + Ni Cy + HO$. If the solution be now boiled with very-finely levigated

oxide of mercury, the nickel salt is decomposed, hydrated oxide of nickel is precipitated, and cyanide of mercury is produced:—



The cobaltcyanide of potassium is not decomposed by the oxide of mercury, but remains in solution, and may be filtered from the oxide of nickel, which requires to be carefully ignited in a platinum crucible till it ceases to lose weight. The cobalt may then be precipitated from the filtrate as a white subcobaltcyanide of mercury, by the addition of solution of subnitrate of mercury; the precipitate is collected, dried, and ignited, when pure oxide of cobalt is left, which may be reduced to the metallic state in a current of hydrogen.

The solution of the oxides, which must be free from nitric acid, is, after previous neutralization of the free acid which may be present, by ammonia, precipitated with sulphide of ammonium, and highly dilute hydrochloric acid, according to ROSÉ, or acetic acid—WACKENRODER—is then added. This serves to dissolve the sulphide of manganese and the sulphide of iron, whilst the sulphide of cobalt and the sulphide of nickel remain undissolved, though the latter less completely. The sulphides of the metals are re-precipitated from the filtrate by the addition of ammonia and sulphide of ammonium, and the precipitate is treated once more with dilute hydrochloric acid. The results are nearly accurate. The cobalt and nickel can be determined by LIEBIG's method, as given above.

Nickel is separated from manganese and zinc by the annexed process of EBELMEN. Put the weighed mixture of the oxides in a small platinum vessel, insert this into a tube, heat the mixture to dull redness, conducting all the time sulphide of hydrogen gas over it. Let the sulphides formed cool in the gaseous stream, and then digest them for several hours with cold dilute hydrochloric acid, which dissolves only the sulphides of manganese and zinc. The sulphides of cobalt and nickel are left behind in a perfectly pure state, and may be separated, if desired, as above, by dissolving in aqua regia, *et cetera*. The reader will find much valuable information with respect to nickel under COBALT, Vol. I., page 492.

ALLOYS OF NICKEL.—FARADAY states that meteoric iron has been imitated by fusing iron with nickel. The alloy of ninety iron with ten nickel is of a whitish-yellow cast, and not so malleable as pure iron. The alloy with three per cent. of nickel is perfectly malleable and whiter than iron. These alloys are less disposed to rust than pure iron, but nickel alloyed with steel increases the tendency to rust.

BRANDE remarks that nothing is known of the alloys of nickel with *potassium, sodium, manganese, zinc, or tin*. With *copper* it forms a hard white alloy; the *white copper* of the Chinese, or *Pakfong*, consists, according to the analysis of Dr. FYFE, of 40.4 parts of copper, 31.6 of nickel, 25.4 of zinc, and 2.6 of iron.

German Silver.—A similar alloy is often used as a

substitute for silver, or for plated articles, under the name of *German silver*. It should consist of one part of nickel, one of zinc, and two of copper; or, when intended for rolling, of twenty-five parts of nickel, twenty of zinc, and sixty of copper; to which, if for casting, three of lead may be added. The following details respecting the alloys of nickel, are from a pamphlet on the subject by Messrs. TOPPING. The metals referred to should be as pure as possible. *Common German Silver*.—Copper 8, nickel 2, zinc 3.5. This is the commonest that can be made with any regard to the quality of the article produced, and may be used for ware for ordinary purposes. If the quantity of the nickel be reduced much below this, the alloy will be little better than pale brass, and tarnish rapidly. *Good German Silver*.—Copper 8 nickel 3, zinc 3.5. This is a very beautiful compound. It has the appearance of silver a little below standard; by some persons it is even preferred to the more expensive compounds. *Electrum*.—Copper 8, nickel, 4, zinc 3.5. This is the compound first introduced by Messrs. TOPPING, and they still prefer it to any of the others. It has a shade of blue like very highly-polished silver: it tarnishes less easily than silver.—Copper 8, nickel 6, zinc 3.5. This is the richest in nickel that can be made, without injuring the mechanical properties of the metal. It is a very beautiful compound, but requires a higher heat for fusion than the preceding, and will be found rather more difficult to work. *Tutenag*.—Copper 8, nickel 3, zinc 6.5. The proportions were originally obtained by analyzing a piece of Chinese tutenag of the best ordinary quality; but some rare specimens of Chinese tutenag, equal to electrum, have been seen. This alloy is very fusible, but very hard, and not easily rolled: it is best adapted for casting. A variety of articles are now plated with nickel by electrolytic precipitation from a solution of sulphate of nickel, the process being in all respects similar to that in which copper is used. SMEE recommends chloride of nickel as the solution, when electroplating with this metal, with a nickel positive pole and single battery; the nickel thus deposited, he says, is very brilliant, but rather brittle.

CHEMICAL COMBINATIONS.—Nickel forms two oxides: a protoxide, NiO —and a sesquioxide, Ni_2O_3 .

Protoxide of Nickel may be procured in the anhydrous form by igniting the carbonate in a covered crucible, when it is left of an olive-green color. It may be precipitated from its salts by potassa, as a bulky light-green hydrate— NiO, HO —and may be obtained crystallized by boiling carbonate of nickel in ammonia. Oxide of nickel forms insoluble compounds with potassa or soda, which, however, may be decomposed with frequent affusions with boiling water. Baryta, strontia, and several other bases, also yield with it insoluble compounds; ammonia dissolves it, forming a deep-blue solution. When fused with borax, the oxide tinges the glass of a hyacinth yellow, which becomes less intense on cooling.

Sesquioxide— Ni_2O_3 —is a black powder, which may be procured by treating the hydrated protoxide with a solution of chloroxide of sodium. It is singular that it does not combine with acids, but gives off a portion of its oxygen by ignition, or by heating with

nitric or sulphuric acids, which form with it salts of the *protoxide*.

Sulphide of Nickel— NiS —occurs native in greyish or yellowish capillary crystals; it may be produced artificially by fusion, and can be obtained as a black hydrate, when a salt of nickel is precipitated by sulphide of ammonium.

Chloride of Nickel— $\text{NiCl} + 9\text{HO}$ —is formed by dissolving the oxide in hydrochloric acid.

Sulphate of Nickel— $\text{NiO}, \text{SO}_3 + 6\text{HO}$ —which results from the action of sulphuric acid on the metal, or its oxide, crystallizes in green rhombic prisms; these, when exposed to light, are converted, without loss of water, into small regular octohedra, aggregated together in the form of the original crystal, which becomes opaque.

CHARACTERS OF THE SALTS OF NICKEL.—The salts of this metal are of a delicate green hue, both when in the solid state and in solution. They have a sweetish astringent metallic taste.

Before the blowpipe, salts of nickel give, in the oxidating flame, with biborate of soda, a reddish-yellow glass, which becomes much paler as it cools. In the reducing flame, greyish particles of reduced nickel are disseminated through the bead.

In solution *sulphide of hydrogen* gives no precipitate, if the liquid be acidulated with sulphuric acid. *Sulphide of ammonium* gives a black sulphide. *Ammonia* gives a pale-green deposit, soluble in excess of ammonia, forming a bright blue solution. *Potassa* and *soda* throw down a pale-green bulky hydrated oxide of nickel. The *carbonates of the alkalies* give a pale apple-green precipitate of basic carbonate of nickel, which is readily soluble in carbonate of ammonia. *Ferrocyanide of potassium* affords a greenish white, and *ferridcyanide of potassium* a yellowish-green precipitate.

ANALYSIS.—Protoxide of nickel is always weighed as such. Mix the acid solution of the oxide in a beaker glass with pure potassa, or soda in excess, heat for some time to near boiling, filter, wash the precipitate thoroughly with hot water, dry, and ignite. The presence of ammoniacal salts, or of free ammonia, does not interfere with the precipitation. This method, if carefully executed, gives exceedingly accurate results, which the Editor has often confirmed.

USES.—The nickel obtained in this country, is chiefly employed for the manufacture of Argentane or German silver, which, as stated above, is an alloy of this metal with zinc and copper. Nickel likewise forms one of the constituents of the tutenag of China, and the *Pakfong* of the East Indies. Being exclusively used as an alloy, the nickel of commerce comes into the market in the form of finely-divided grains, or granulations, of the size of small beans. The best German silver consists of eight parts of copper, three of nickel, and three and a half parts of zinc; but an inferior and more common variety is sometimes manufactured from eight parts of copper, two of nickel, and four of zinc. From its magnetic property, a patent has been taken to substitute nickel for the magnetised steel needles employed in COOKE and WHEATSTONE's Electric Telegraph; but it has not been practically applied to this purpose.

NITRIC ACID.—*Acide nitrique*, French; *Salpetersäure*, German; *Acidum nitricum*, Latin.—An interesting paper appeared some time ago, by Mr. THORNTON J. HERAPATH, intended to show that this acid was known to the ancient Egyptians. In his *brochure* Mr. HERAPATH gave a short account of some experiments he had made on certain hieroglyphical marks or letters that had been discovered on the wrappers of a mummy which was unrolled by Mr. NASH at the Bristol Microscopical Society, and, as the result of these, he stated his belief that the ancient Egyptians were acquainted with a marking fluid containing nitrate of silver for its basis, and were also familiar with the use of nitric acid. A short time afterwards, Mr. DENHAM SMITH, in replying to this paper, took exception to these views; and whilst admitting the interesting nature of the discovery that had been made of an argentine solution having been employed some three thousand years ago, as *marking ink*, totally dissented from the conclusions that had been founded on it, inasmuch, he said, as there was no evidence to prove that the Egyptians were even versed in the art of distillation. He also hazarded the opinion, unsupported, however, by direct evidence, that the marking fluid in question was prepared by dissolving either the chloride or oxide of silver in an ammoniacal solution, and, consequently, without the intervention of any acid whatever. As the question in dispute is one of great interest, in a scientific point of view, Mr. HERAPATH pursued the subject, and submitted the marks to a fresh examination. After making several preliminary experiments, he found that no results of any value could be obtained by the ordinary modes of analysis, and was therefore compelled, as a last resource, to call in the aid of the microscope.

On examining with this instrument some of the fibres of the bandages that were stained by the argentine ink, he found them to present a very singular appearance. The ends near the corroded parts of the fabric, were stained of a deep brown or black; but for some little distance beyond the blackened portion, the fabric had a pale yellow hue, as if, during the decomposition of the silver salt that had been employed as *marking ink*, the nitrogenous constituents of the tissue had been partially acted upon, and converted into xanthoproteic acid.

Between several of the fibres, and, in many places, adhering to their external surfaces, were found small particles of some organic tissue, which were tinged of a still deeper yellow than the fibres themselves. On subjecting some of the latter to the action of strong liquor ammonia, the yellow portions, particularly the altered intercellular substance, acquired a still darker hue, whilst those, on the contrary, which were stained by the reduced silver, became slightly paler, as if a part of the argentine film was soluble in that menstruum; though it should be observed that no further effect was produced on the stain, even by a lengthened digestion in ammonia. Now, upon making comparative experiments with a piece of the linen wrapper that had been previously marked in the ordinary manner with solution of nitrate of silver, the fibres were found to present an appearance very similar to that above

described; the only difference being that the yellow coloration was not quite so palpable, and more of the silver stain was eradicated by the solution of ammonia; whereas, on the other hand, fibres that had been stained by solutions of chloride and oxide of silver in ammonia, were uniformly colored of a dark-brown or black, and exhibited no remnant of the yellow coloration.

On the whole, the results of Mr. HERAPATH's microscopic examination appear to justify the conclusion that the ancient Egyptians were really familiar with nitric acid and its uses; and actually employed the nitrate of silver as a marking fluid. In what way, however, they prepared the acid, whether by distillation of the nitrate of soda or of nitrate of potassa with sulphuric acid, may for ever remain a mystery.

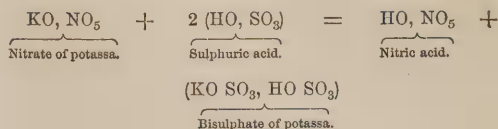
Liquid or hydrated nitric acid was known in the seventh century to GEBER, who termed it *solutive water*. It is sometimes called *azotic acid*, and in the time of the alchemists, it was known as *aqua fortis*—a name still retained. The nature of its constituents was shown by CAVENDISH in 1785, and their proportions were subsequently determined by DAVY, GAY-LUSSAC, and THOMSON. When nitrogen is mixed with twelve or fourteen times its bulk of hydrogen, and a jet of the gas is allowed to burn in air or in oxygen, water is formed, which has a sour taste and an acid reaction, from the simultaneous formation of a small quantity of nitric acid. In this case, the nitrogen burns by the aid of the heat developed during the combustion of the hydrogen, and the nitric acid combines at once with the water formed, which much increases its chemical stability. It was, indeed, owing to the accidental production of nitric acid in the course of his experiments on the formation of water by the combustion of hydrogen, that CAVENDISH was induced to institute the train of research which resulted in his important discovery.

If two volumes of nitrogen be mixed with five volumes of oxygen in an inverted siphon containing a few drops of an infusion of litmus, each limb plunging into a separate glass of mercury, and a series of electric sparks be passed through the mixture, the two gases will slowly combine, and the litmus will be reddened. The heat of the spark determines combination of the gases just at the spot through which it passes, but the action does not extend further. In like manner, if a number of sparks be passed from the electrical machine, between two metallic points, over moistened litmus paper in air, a red spot will be produced upon the paper, owing to the formation of nitric acid in minute quantity by the combination of oxygen with nitrogen. During stormy weather, and, indeed, whenever a flash of lightning passes through a humid atmosphere, the same compound results in appreciable quantity. Indeed, rain water always contains traces of nitrate of ammonia, which may be detected, if the experiment is made with sufficient attention to accuracy.

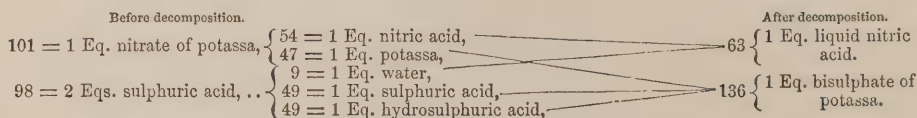
Nitric acid also occurs in combination with potassa or soda, in the form of an efflorescence in the soil, especially in tropical climates, as in some parts of India and Peru. The compound formed with soda constitutes the *nitre*, and with potassa, the *saltpetre* of commerce.

Preparation.—It is either from nitrate of potassa or nitrate of soda that this acid is always obtained for chemical purposes. When saltpetre is heated with sulphuric acid, it is decomposed; an alkaline sulphate remains in the retort, whilst the more volatile nitric acid distils over, and may be condensed in the usual manner. In preparing nitric acid on the small scale, equal weights of nitre and concentrated sulphuric acid are placed in a glass retort, and carefully dis-

tilled. The result of the reaction may be traced as follows:—



or, as it may be illustrated more in detail:—

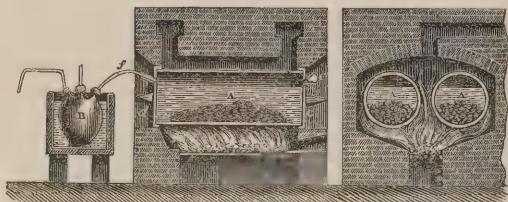


Red vapors appear in the retort during the distillation, arising from partial decomposition of the acid, and a formation of some of the lower oxides of nitrogen. A yellowish corrosive liquid condenses in the receiver, fuming strongly on exposure to the air, and emitting a powerful, irritating odor.

On the large scale, iron retorts, Fig. 370, coated with fire-clay on the inside of the upper part, where they are exposed to the acid vapors, are employed for the distillation, and nitrate of soda is substituted for the potassa salt, being cheaper, and likewise containing considerably more nitric acid.

The cylinders or retorts are arranged in pairs in a furnace, so that each fire heats two cylinders, as shown in the transverse section. They are furnished with a movable lid, *c, d*, at each end. The nitrate is intro-

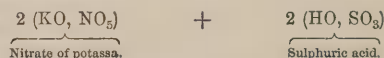
Fig 370.



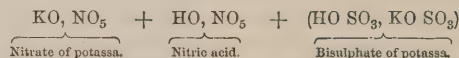
duced into the retort, *A*, through the aperture at *c*, which is closed during the distillation, by a stone lid that fits accurately; the sulphuric acid being introduced by a funnel at *e*, after the retort is closed. As soon as the acid is added, the funnel is withdrawn, and the opening closed with a plug. The acid, as it distils over, passes through the pipe, *f*, and is condensed in a series of stoneware bottles, the first of which is seen at *B*. The acid which condenses in the first receiver, is always contaminated with sulphuric acid, and that in the last is rather dilute, as water is placed in it to condense the nitrous fumes.

It is usual upon the large scale to employ a smaller proportion of sulphuric acid than when the distillation is performed in glass vessels, as it is quite possible to effect a complete decomposition of the nitrate by heating it with one-half its weight of sulphuric acid. Under these circumstances, however, a higher temperature is needed to expel the last portions of acid, and a considerable quantity of the nitric acid is thereby decomposed and wasted. The residue in the retort, when the smaller

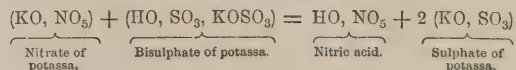
quantity of sulphuric acid is used, is much less soluble in water, and consequently is much more difficult of removal; in the iron cylinder of the manufacturer, this is of no moment, as the saline mass can easily be detached by the use of iron tools, when the distillation is at an end. The cause of these differences lies in the fact that sulphuric acid forms with potassa two different compounds, one of which contains twice as much acid as the other. When saltpetre and sulphuric acid are mixed in the proportion of two equivalents of each, half the salt only is decomposed, so long as a gentle heat is employed, and the acid sulphate of potassa is formed. The nitric acid, thus liberated, distils over readily. Annexed is represented the form of this reaction:—



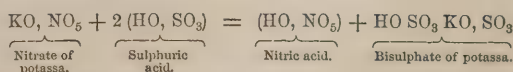
yielding



As soon as the first half of the nitric acid has passed over, the temperature begins to rise, and the bisulphate of potassa then reacts on the undecomposed saltpetre; the second half of the nitric acid is liberated, but at the same time is partially decomposed towards the end of the operation, and the whole of the potassa remains in combination with sulphuric acid in the form of the sparingly soluble neutral sulphate. This second stage of the decomposition is exhibited in the subjoined equation, which will be easily understood from the foregoing:—



When, on the other hand, two equivalents of sulphuric acid are used to one of nitrate of potassa, the whole of the potassa is at once converted into the acid sulphate, so that the total quantity of the nitric acid is liberated immediately, and distils readily:—



The result is, therefore, one equivalent of the bisul-

phate of potassa, and one of nitric acid. These changes will perhaps be better understood by the following tabulation :—

Before decomposition.	After decomposition.
202 = 2 Eqs. of saltpetre, 2 (KO, NO ₅)	101 = 1 Eq. saltpetre.
101 = 1 Eq. nitre (KO, NO ₅)	63 { 1 Eq. liquid nitric acid (HO, NO ₅).
54 = 1 Eq. nitric acid (NO ₅)	{ 1 Eq. of bisulphate
47 = 1 Eq. potassa (KO)	{ of potassa (KO
9 = 1 Eq. water (HO)	{ (SO ₃ , HO SO ₃ .)
98 = 2 Eqs. of sulphuric acid, 2 (HO, SO ₃)	136
49 = 1 Eq. sulphuric acid (HO, SO ₃)	
49 = 1 Eq. sulphuric acid (HO, SO ₃)	

PROPERTIES.—In the most concentrated state in which it can be obtained by the preceding process, nitric acid is, when pure, a colorless, limpid, fuming, powerfully-corrosive liquid, having a specific gravity of 1.520. It is the highest oxide of nitrogen known to exist, and contains one equivalent of nitrogen with five of oxygen, associated with one equivalent of water—HO, NO₅. One hundred parts contain 85.71 of the anhydrous nitric acid. Exposure to the light of the sun produces its partial decomposition; mere distillation, in fact, has invariably the same effect. At 184° it begins to boil, and congelation occurs about 40° below zero. It very readily parts with a portion of its oxygen to the metals, and to combustible bodies. If it be dropped into hot, finely-powdered charcoal, the charcoal burns vividly; if mixed with a little sulphuric acid and poured into oil of turpentine, the mixture bursts into flame. Nitric acid has a pungent, rather disagreeable smell, is very acid and corrosive, and stains the skin, and organic matter in general, yellow.

It has a strong attraction for water, and becomes hot when mixed with it. Acid of medium strength, mixed with snow, causes it to liquefy instantly, producing intense cold. Nitric acid acts violently upon tin or iron filings, especially if they be previously moistened with a few drops of water: this acid is, indeed, constantly employed by the chemist as an oxidising agent. In order to produce a rapid oxidation of the metals, it is best to dilute the acid until it has a specific gravity between 1.25 and 1.35.

The action of nitric acid upon the metals is instructive, and it is well remarked by MILLER, from whose excellent work the Editor has largely drawn in the present article, that this action may serve to illustrate the manner in which metallic bodies combine with the acids generally. The metals, he observes, will enter into direct combination with many of the simple non-metallic bodies: thus, antimony will unite directly with chlorine, and will even take fire if allowed to fall in fine powder into the gas. Iron will burn in oxygen; and copper turnings, if mixed with powdered sulphur, will combine with the sulphur on the application of heat, emitting a vivid flash of light. But no metal will unite directly with an acid; in order that the combination between them should occur, it is necessary that the metal should be in the form of oxide. This oxidation, may, however, be effected at the same time that the acid is presented to the metal, and the formation of the oxide and its solution may appear to occur simultaneously. Zinc, for example, does not unite as zinc with sulphuric acid: when this metal is placed in dilute sulphuric acid, the oxygen is supplied from the water which is decomposed, oxide of zinc is produced, and is immediately dissolved by the acid, whilst the hydrogen escapes in the gaseous form. When a metal,

such as copper or silver, is dissolved by nitric acid, a preliminary oxidation is equally necessary; but owing to the facility with which nitric acid is deprived of a part of its oxygen, this oxidation is usually effected at the expense of the nitric acid, which is more readily decomposed than water; some of the lower oxides of nitrogen are liberated in the form of ruddy fumes, whilst the compound of the metal with oxygen dissolves in another portion of the acid which has remained intact. The exact nature of the decomposition which the nitric acid experiences varies in different cases. Silver, when allowed to dissolve slowly in the cold in dilute nitric acid, produces nitrous acid—NO₂—which remains in solution: thus, 2 Ag + 3 NO₅ becomes 2 (AgO, NO₅) + NO₂, and the metal dissolves without evolution of gas; and a similar effect is produced by palladium. With metals which, like copper and mercury, have a somewhat stronger affinity for oxygen, binoxide of nitrogen—NO₂—is disengaged in large quantity; for example, 3 Cu + 4 NO₅ = NO₂ + 3 (CuN, NO₅); and if the metal have a still more powerful tendency to combine with oxygen, as is the case with zinc, the protoxide of nitrogen—NO—is, if the acid be dilute, amongst the vapors disengaged: 4 Zn + 5 NO₅ would produce NO + 4 (Zn O, NO₅). Zinc and tin also decompose water as well as nitric acid when dissolved in the acid, eliminating hydrogen, which, as soon as it is evolved, completely deprives a portion of nitric acid of its oxygen, and forms ammonia by entering into combination with the liberated nitrogen; for instance, 8 Zn + 8 HO + 8 NO₅ = 8 (ZnO, NO₅) + 8 H, and NO₅ + 8 H yield 5 HO + NH₃.

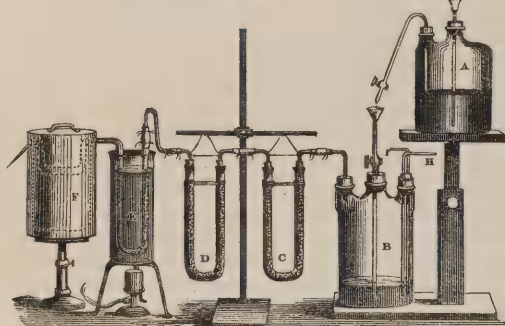
When the concentrated acid is exposed to the air it imbibes moisture; and if mixed with water it absorbs a sensible amount of heat, owing to the formation of another hydrate of much greater persistency. This stable hydrate contains four equivalents of water, and one of nitric acid (HO, NO₅ + 3 Aq.); it has a specific gravity of 1.424, and is composed of sixty per cent. of anhydrous acid, and forty of water. This hydrate has a higher boiling point than the protohydrate, and distils at 250° unaltered.

Anhydrous Nitric Acid.—Nitric acid, says MILLER, may be obtained anhydrous by DEVILLE's method, in which state it forms perfectly transparent, brilliant, colorless crystals, derived from the right rhombic prism; they melt at 85°, and boil at 113°; at about this temperature the compound begins to be metamorphosed. Sometimes the crystals, even if kept in sealed tubes, undergo decomposition at the ordinary atmospheric temperature, and the tube bursts with a dangerous explosion from the pressure exerted by the liberated gases. The crystals dissolve rapidly in water, emitting much heat, and producing ordinary nitric acid.

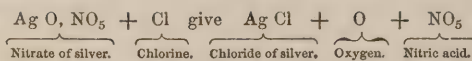
The process consists in passing a uniform current of

perfectly exsiccated chlorine gas very slowly over crystals of well-dried nitrate of silver; the salt is heated to about 200° at first, till the decomposition has commenced, and the temperature is then lowered to about 150° . The operation is one of considerable delicacy, and requires attention to a number of minute precautions, for the details of which the reader is referred to M. DEVILLE's paper. The apparatus required is shown in Fig. 371. A is a vessel of concentrated sulphuric acid; the acid is drawn off from it by the siphon, and allowed to flow into the vessel B, in a very

Fig. 371.



slender stream, which can be regulated by the glass stopcock; B has also been filled with sulphuric acid, and subsequently charged with pure dry chlorine, by means of the bent tube, H. C is a tube filled with dry chloride of calcium; D a tube filled with pumice moistened with sulphuric acid; E a tube filled with nitrate of silver in crystals, immersed in a bath of oil; F the receiver for the anhydrous nitric acid, which is kept cool by a mixture of ice and salt. The tubes E and F are made of one continuous piece of glass, as the acid immediately attacks and destroys cork or caoutchouc joints; a portion of one of the lower oxides of nitrogen is liquefied and collected in the tube in F, and is then separated. The chlorine displaces the nitric acid and oxygen from the nitrate of silver; chloride of silver is formed, and the nitric acid and oxygen escape. By surrounding the receiver, F, with a freezing mixture, the nitric acid is condensed in crystals. The decomposition is of the following simple character:—



The composition of anhydrous nitric acid was determined by DEVILLE, by estimating the quantity of nitrogen which a given weight of the acid furnished after the oxygen had been removed from it by heating it in contact with copper, which rapidly combines with oxygen at a higher temperature. M. DEVILLE found in one of his experiments, that five hundred and forty-seven milligrammes of acid, gave one hundred and sixteen cubic centimetres of nitrogen, at a temperature of 41° , whilst moist, and under a barometric pressure of seven hundred and fifty-seven millimetres. This, when corrected, gives in one hundred parts of the acid by weight, 25.9 of nitrogen; the deficiency, 74.1, is

oxygen; or fourteen parts of nitrogen are united with forty of oxygen.—Miller.

The subjoined is an abridgment of a table, giving the per-centage of anhydrous nitric acid contained in aqueous solutions of various specific gravities, as determined by Dr. URE:—

Specific gravity.	NO ₅ in one hundred parts by weight.	Specific gravity.	NO ₅ in one hundred parts by weight.
1.5000	79.700	1.2887	39.053
1.4940	77.303	1.2705	36.662
1.4850	74.918	1.2523	34.271
1.4760	72.527	1.2341	31.880
1.4670	70.136	1.2148	29.489
1.4570	67.745	1.1958	27.098
1.4460	65.354	1.1770	24.707
1.4346	62.963	1.1587	22.316
1.4228	60.572	1.1403	19.925
1.4107	58.181	1.1227	17.534
1.3978	55.790	1.1051	15.143
1.3833	53.399	1.0878	12.752
1.3681	51.068	1.0708	10.361
1.3529	48.617	1.0540	7.970
1.3376	46.226	1.0375	5.579
1.3216	43.835	1.0212	3.188
1.3056	41.444	1.0053	0.797

Tests for Nitric Acid.—No ready method is known of precipitating nitric acid from its solutions, since all its compounds dissolve more or less freely in water. Various indirect methods have been recommended for discovering its presence. One of the best consists in neutralizing the solution, if acid, with potassa, and evaporating nearly to dryness; then adding a few copper filings, and heating the mixture with a little sulphuric acid. The copper combines with a portion of the oxygen of the nitric acid, and decomposes it, while characteristic red fumes of binoxide of nitrogen show themselves, if nitric acid be present. A still smaller quantity of the acid may be detected by substituting a crystal of protosulphate of iron for the copper, before adding the sulphuric acid; on the application of a gentle heat in this case, the characteristic action consists in the formation of an olive-green solution, the color of which disappears on boiling. The nitrous acid gas, formed by the deoxidising action of one portion of the ferruginous salt, dissolves, with the distinctive green color, in the solution of the unoxidised part of the salt. If a few drops of hydrochloric acid be added to a solution which contains free nitric acid, or a nitrate dissolved, the liquid acquires the power of dissolving gold leaf. This effect, however, is produced by hydrochloric acid in solutions of the iodates, chlorates, and bromates, but the presence of these salts may be detected by other characters. PRICE's test for the detection of iodine, and which is described at page 403, is equally applicable for the detection of nitric acid.

QUANTITATIVE ESTIMATION.—MARTIN separates the ammonia present in the substance to be examined from the nitric acid, by boiling it with potassa. He then introduces the resulting solution into a vessel, with metallic zinc, and a sufficient quantity of water, and adds by degrees hydrochloric or sulphuric acid. By these means the nitric acid is completely converted into ammonia, and its amount may now be arrived at by the usual methods for estimating that alkali, Vol. I., page 198. Seventeen of ammonia, NH₃, represent fifty-four of nitric acid, NO₅.

Nitrates.—Nitric acid combines with one equivalent of the various bases to form the class of salts termed nitrates. No acid nitrates exist or have been produced, but several subnitrates may be formed; that is to say, salts may be obtained containing more than one base for each equivalent of acid; such, for instance, as the subnitrate of copper, $3 \text{ Cu O, NO}_2, \text{HO}$. When heated, most of the nitrates fuse readily; at an elevated temperature they are all decomposed, and in most cases the pure oxide remains. When thrown on glowing coals, the nitrates are decomposed with scintillation; if dissolved in water, and paper be moistened with the solution, allowed to dry, and then burned, the smouldering combustion characteristic of touch-paper will be produced. This property, however, is also exhibited by the salts of some other acids, of which the chloric is the most important.

Adulterations.—The specific gravity of nitric acid is very often artificially augmented by dissolving in it nitrate of potassa; this sophistication, however, is very easily detected by evaporating the acid, when the nitrate so added will be left behind. But the best way of determining the real value of nitric acid is by ascertaining its saturating capability, that is, finding how much pure carbonate of soda it will neutralize.

The nitric acid of commerce is ordinarily contaminated by *sulphuric* and *hydrochloric acids*, or by *chlorine* or *chlorides*.

The presence of sulphuric acid is discovered by diluting a portion of the nitric acid with pure water, and adding a solution of nitrate of baryta; if this produces a white precipitate, insoluble in water, in acids, and likewise in ammonia, it is sulphate of baryta, and it indicates, of course, the presence of *sulphuric acid*. If the precipitate is in ponderable quantities, it should be first boiled with the acid liquor in which it has been produced, allowed to settle, filtered, washed, dried, ignited, and weighed: 116.5 grains represent forty of dry sulphuric acid.

The presence of *chlorine* or of *chlorides*, or of *hydrochloric acid*, is detected by diluting the nitric acid with pure water, and adding a solution of nitrate of silver. If a white curdy precipitate, or an opaline tinge or turbidity is produced, insoluble in nitric acid, but which instantly disappears by pouring an excess of ammonia, and reappears by adding an excess of acid, it is chloride of silver; in which case the acid liquor should be moderately heated, in order to promote the settling of the precipitate, which may then be collected on a filter as small as possible, washed, and carefully exsiccated. It should then be introduced into a counterpoised porcelain crucible; the filter, being scraped clean, is afterwards burnt upon the cover of the crucible, and the ashes are added to the precipitate in the crucible; the mass is then fused, and on cooling, it is weighed; 143.5 grains of chloride of silver represent 35.5 grains of chlorine, or 36.5 grains of hydrochloric acid.

Before testing the acid, as just said, it must not be forgotten to dilute it with three or four times its bulk of distilled water, for otherwise a precipitate would be produced, but which is nothing else than nitrate of baryta and nitrate of silver, which might simulate the presence of sulphuric acid and of chlorine. Such pre-

cipitates, however, immediately disappear by an addition of water.

When nitric acid contains fixed substances, they are easily detected by evaporating a small quantity of the acid in a watch-glass or small capsule, in which case a fixed residuum will be left. Pure nitric acid is entirely volatilizable by heat.

Impure nitric acid can always be easily purified by adding to it a sufficient quantity of nitrate of silver, in order to precipitate the chlorine and sulphuric acid, decanting the acid from the precipitates produced, and distilling it in a glass retort and glass receiver, taking care not to use either lute or cork. If done with care, and at a moderate heat, the acid which passes is pure and colorless.

Physiological Effects.—The action of this acid varies with its degree of concentration or dilution. In the concentrated form, the acid acts as a powerfully corrosive poison, which property it partly derives from its affinity for water, but more especially from the facility with which it gives out oxygen; so that the appearances caused by its action on some of the tissues are different from those produced by sulphuric acid. The permanent yellow stain—xanthoproteic acid—which it communicates to the cuticle, is peculiar to it. Iodine stains the skin yellow or brown, but a little caustic potassa quickly removes the color, when recent; whereas the yellowish stain caused by nitric acid becomes orange, on the addition of an alkaline soap. Bromine also stains the skin yellow; but, when recently produced, the color may likewise be removed by potassa. The yellow or citron tint communicated to the lining membrane of the tongue, pharynx, *et cetera*, by nitric acid, has been lucidly illustrated by Dr. ROUPELL. A preparation presenting appearances in every way identical, is preserved in the anatomical museum of the metropolitan hospital. Nitric, like sulphuric acid, also chars the animal tissues; and thus, after the ingestion of it, the stomach is sometimes found blackened, as if sulphuric acid had been swallowed. The symptoms are the same as those produced by sulphuric acid. The yellow, citron, or orange spots sometimes seen on the lips, chin, or face, will, when present, at once indicate the kind of acid swallowed. Sometimes the binocide of nitrogen is evolved by the mouth.

Properly diluted, nitric acid produces effects similar to those of the other mineral acids. It is said, however, to act less evidently as a tonic, and to be more apt to disagree with the stomach, so that it cannot be used for so long a time. In some instances it has excited pyalism, and from this circumstance, as well as from the occasional benefit derived from its use in the venereal disease, it has by some writers been compared in its operation to mercury—a comparison founded on theoretical rather than practical considerations.—*Pereira*.

OIL.—*Huile*, French; *Oel*, German; *Oleum*, Latin. —Oils are a very interesting class of natural substances, inflammable, and greasy to the touch. Oily bodies are generally divided into two classes, fixed or fat oils, and essential or volatile oils. The two are, however, entirely dissimilar, both in properties and composition;

indeed, except in the one common property of greasiness, they are not at all allied to each other. The oils belonging to one classification may readily be distinguished from those of the other; the essential oils emitting at ordinary temperatures a distinctive, intensely odorous, and penetrating vapor, and when dropped on paper, not producing a permanent greasy spot, while the stain of a fixed fatty oil does not disappear by exposure, nor even when the paper is subjected to a gentle heat. For the present, to avoid confusion, only the fixed and fat oils will be considered.

Fats and fixed oils are most indispensable requisites of domestic economy, equally important as nourishment, as material for the manufacture of soap, and as sources of light. They contain a very large proportion of carbon, as compared with that of the other constituents—a character that distinguishes this class of substances from the greater number of compounds of organic origin. In many instances the amount of carbon is from seventy to eighty per cent., and upon this property depends their great value as food, and as sources of light. As regards the former, they must always be most useful; those fats only which are unfit for food are valuable as sources of light, or for the production of soap.

HISTORICAL NOTICE.—Oils have been known from the earliest ages of the world, and were, even at that remote period, applied to a variety of purposes, but principally as a means of illumination. In the writings of MOSES olive oil is frequently mentioned; and it appears probable that the candlesticks so frequently referred to in Holy Writ were intended as a support for lamps, and not candles. In Genesis MOSES speaks of a *burning lamp*, and in the two following books it is clearly stated that olive oil was the material used as the source of light. The introduction of oils into Europe dates also from a very remote age. According to HERODOTUS, the Greeks were the first European people acquainted with them. They derived their knowledge of oil, and the means of procuring it, from the Cecrops, who brought olive oil from Sais, a province of lower Egypt. No record can be found showing the method of extracting it at this early date, nor even the purposes for which it was used. The Greeks of that period appear to have been ignorant of the mode of applying it as a source of light, for HOMER mentions wood torches as a means of illumination in use at the time of the Trojan war. EUSEBIUS, however, relates that, at the commencement of the fourth century, the city of Constantinople was annually illuminated on Easter eve by means of *lamps* and wax candles. Afterwards, until the introduction of tallow and animal fats, wax and pitch were the combustible materials most commonly employed.

SOURCES.—Oils are found abundantly in the vegetal and animal kingdoms. In the former, they occur in various parts of the plant, principally in the cellular structure of, and in the fleshy pulp surrounding the seeds, and very rarely in the roots. They are contained in that part of the seed which gives birth to the cotyledons, and not in the plumula or radicle. In the olive tree only the oil is contained in the fleshy integuments of the fruit. The seeds richest

in oil are those belonging to the genus *cruciferae*, and next to that are the *drupaceae*, *aomentaceae*, and *solanee*. Linseed contains twenty per cent. of oil, rape seed from thirty-five to forty, castor seed sixty per cent., and nuts about half their weight. The quantity of oil furnished by seeds varies, not only with the species, but in the same seed, with climate and method of cultivation. The seeds should be ripe, fresh, and of good quality. The yield of oil is always less than that actually contained in the seed, and the quantity remaining in the *marc* or pressed cake is greater in proportion as the starchy, ligneous, and albuminous principles predominate. The exact quantity of oil contained in seeds is easily estimated by taking a given quantity and bruising and treating repeatedly with ether, until the oil is completely extracted. The solution is then evaporated by means of a water bath, and the oily residue remaining is washed with water, to remove soluble matters, then dried and weighed, and the result is the exact proportion of oil present in the seed.

The part of the plant in which fats and oils are originally produced, is, according to DUMAS, the green leaves only, whence they are removed by a process of circulation, and deposited in the seeds and fruits. The essential ultimate constituents of oils are carbon, hydrogen, and oxygen, and consequently they may be produced by a process of deoxidation from carbonic acid and water, which are of course imbibed for the most part by the green leaves. It is, therefore, extremely probable that the theory of DUMAS, which attributes the assimilation or process of formation of oils to the verdant foliage of the plant, is the correct one; certainly it is the only plausible one yet adduced to explain this very peculiar action. The living plant breathes, feeds, and digests, exactly as is the case with the animal, though in the plant the organs of digestion and respiration exist almost entirely in the leaves; and here the vital force, under the influence of light, effects the transmutation of the food into the several substances of which the plant is constructed, while the whole, or at least the greater portion of the oxygen of the absorbed carbonic acid, is returned by respiration to the atmosphere. The formation of vegetal oils is, therefore, owing to absorption and transformation of food containing the elements under the form of gases, which by the vital force, and the peculiar organic structure of the plant, are secreted and arranged into entirely new products.

In animals, fats are contained chiefly in the cellular membrane, and, for the most part, immediately beneath the skin; also interiorly, particularly in the omentum, and in the region of the kidneys. This substance exists in the form of globules or small drops, and swims in the animal fluid with which the cells are filled. In the species of whale, the bony cavity of the head is the depository of the secreted spermaceti, and in the case of butter, the fat is mixed in a liquid state in milk. Oils and fats, both in plants and animals, are always associated with an albuminous principle; in vegetals, with *diastase*, *synaptase*, or an analogous body, which, from its peculiar liability to change, exercises an important influence upon the oils when kept for any length of time.

Two distinct theories concerning the production of animal fats have been promulgated, and each of them has had a large number of supporters, eminent for their extensive chemical knowledge.

DUMAS is of opinion that fatty matters are not generated in the animal body, but that they are derived, already formed, solely from the vegetable kingdom, the manifold products of which serve as food for the *herbivora*, while the *carnivora* also derive them indirectly from the same source, through the plant-eating animal. This opinion has for its supporters, BOUSSINGAULT, PAYEN, and others. Undoubtedly the fat of the *herbivora* is, to a certain extent, conveyed to them in the plants which serve them as food; while, at the same time, it is indisputable that fat may also be produced by a process of deoxidation of the amylaceous constituents of food. This latter theory was advanced by LIEBIG, and is now almost universally acknowledged to be the true explanation of the formation of animal fats. A powerful argument in favor of the latter supposition is, that the *carnivora*, which, as their name implies, are flesh-eating animals, have much less fat, but more muscle, than the *herbivora*. The latter derive the substance of their bodies from plants, to the amylaceous, or saccharine, starchy, and gummy components of which are due the production of fat; the comparatively small nitrogenized portion being taken up to form muscle, and the other albuminous or nitrogenous parts of the structure. The absence of the non-nitrogenous or amylaceous ingredients in the food of animals occasions a leanness of flesh, while at the same time, it is well known that the proportion of fat in the animal body may be increased by an augmentation in the quantity of non-nitrogenous food. A curious fact in support of LIEBIG'S theory was adduced by HUBER and by GUNDELACH, who fed bees *solely on pure sugar*, and found an abundant secretion of wax,—a true fat. No doubt, therefore, these insects produce wax by a process of assimilation of the sugar contained in honey: indeed, this has since been admitted by DUMAS. Animal fat may, therefore, be considered to be a product of the deoxidation of the non-nitrogenous constituents of vegetal food, and consequent upon a deficient supply of oxygen to the body, this element being absolutely indispensable to the dissipation of these components of food. It follows, therefore, that farinaceous food, and abstinence from exertion, are promotive of the formation of fat, rest being a necessary condition, as during locomotion or other exertion, respiration is more frequent, and the supply of oxygen consequently more abundant, and by its agency the formation of fat is prevented: the amylaceous constituents of the food, undergoing a species of slow combustion, are entirely broken up, and expelled from the system in the form of carbonic acid and water,—the components of the atmosphere from which they were originally produced in the plant. The above exposition is an admirable illustration of the dependence of the animal upon the vegetal kingdom, and a very important instance of the economy of nature.

PROPERTIES.—The consistence of fatty matters is very variable—from that of extreme fluidity, as in the oil of almonds, to that of solid masses, as suet or butter.

Those obtained from warm-blooded animals are usually solid at ordinary temperatures; whilst fish oils, and those procured from cold-blooded animals, remain liquid; sometimes, however, the same plant as well as animal yields both varieties. The concrete vegetal oils, as that of cocoa-nut, are sometimes designated vegetal butters.

The value of oils as combustibles is greatly affected by their degree of fluidity. This is determined by the period required for a given quantity to flow through a funnel of known dimensions. With an apparatus similar to that represented in Fig. 387, Vol. I., page 704, SCHUBLER and URE obtained the following results:—

Fluid.	Time required to flow through a given aperture. Seconds.	Fluidity. Water = 100.
Water,.....	90	100.0
Olive oil,.....	195	46.1
Colza oil,.....	162	55.5
Oil of brassica napus,.....	159	56.6
Oil of brassica præcox,.....	148	60.8
Oil of brassica napo-brass,.....	142	63.3
Oil of brassica rapa,.....	136	66.1
Train oil,.....	450	20.0 Ure.

The specific gravity of oils and fats is always below that of water, and varies from 0.91 to 0.94 at 60°. The oils, of all fluids, expand the most by heat, and, indeed, in some cases to such a degree as to render it necessary, for the purposes of commerce, to know exactly the extent of this expansion. The following table, given by SAUSSURE, shows the density of several oils at different temperatures:—

	At 53°.	At 75°.	At 122°.	At 200°.
Nut oil,.....	0.928	0.919	—	0.871
Almond oil,.....	0.920	—	—	0.863
Linseed oil,.....	0.939	0.930	0.921	0.881
Castor oil,.....	0.970	0.957	—	0.908
Olive oil,.....	0.919	0.911	0.893	0.862

For every degree of Celsius the volume of olive oil increases, according to PREISSER, one twelve-hundredth, of rape oil one eleven hundred and twentieth, and of train oil one one-thousandth, so that one hundred measures of train oil at 32° Fahrenheit will become in summer at 68° Fahrenheit one hundred and two measures.

Common hog's lard at 60° has a specific gravity of 0.938 in its fluid state; at 122°, it is 0.892; at 155°, it is 0.881; and at 200°, 0.863. The specific gravity of oil increases also with its age; indeed, it may be remarked, that no accurate determination of the degree of purity of an oil can be deduced from its density, as there are frequent discrepancies in the same kind of oil, according to the locality where the plant was cultivated, and the varied modes of extracting the oil.

Fats and oils may be exposed to a considerably high temperature without suffering any important change; but at a heat of between 500° and 600° they are rapidly decomposed, and, therefore, will not admit of distillation. This property especially distinguishes the fixed from the essential or volatile oils, which may be distilled without alteration. The continued action of heat upon fat oils has a very remarkable effect. A little above 500° they assume a darker color, and evolve acrid and offensive vapors; and when further heated to about 600°, eliminate carbonic acid, and carbide of

hydrogen gases, accompanied by a peculiarly irritating substance termed *acrolein*, and also margaric and sebacic acids, and a variety of solid and liquid carbides of hydrogen. The result of the action of heat, however, is not always the same, but varies with the nature of the oil. The period at which these alterations occur has been improperly said to be the boiling point, the phenomena of apparent ebullition arising from the escape of the gases produced by the decomposition of the oil. When introduced in small portions into red-hot vessels, or what is the same thing, when the vapor of oils is made to pass slowly through a red-hot tube, they are almost entirely converted into volatile products, consisting principally of carbonic oxide, and gaseous, liquid, and vaporous hydrocarbons. This mixture constitutes *oil gas*, which in illuminating power is far superior to that of the best coal gas, and exceeds in this property three and a half times that of ordinary coal gas. For a detailed notice of this highly interesting and important subject—the manufacture of oil gas, and its application to lighting purposes—the reader is referred to the article *GAS*.

Olein, Stearin, Margarin, and Glycerin.—CHEVREUL, in the course of an extended examination of fixed oils, which he concluded about the year 1813, discovered them to consist of, for the most part, always two, and frequently three distinct compounds, united in the most variable proportions. These bodies are combinations of *oxide of glyceryl* with stearic, margaric, and oleic acids. For the sake of brevity, these compounds are named *stearin*, *margarin*, and *olein*, and it is upon the prevalence of one or other of these ingredients that the consistence of fat depends. When stearin predominates, the fat is firm and solid; if margarin be most abundant, the fat is less hard; while if olein is the chief principle, the oil is liquid at ordinary temperatures.

BRACONNOT, who investigated this subject about the same period, gives the following table of the results of his experiments, showing the centesimal proportion of solid matter contained in the oils and fatty bodies therein mentioned:—

	Solid matter in one hundred parts.	Degrees.
Cow's butter in summer, . . .	40 fusible at	134.5
Cow's butter in winter, . . .	65 —	134.5
Lard,	30 —	110.0
Ox fat,	76 —	141.0
Mutton suet,	26 —	123.8
Goose's fat,	32 —	111.2
Duck's fat,	28 —	125.5
Fat of turkeys,	26 —	113.0
Olive oil,	28 —	68.0
Oil of almonds,	24 —	42.8
Colza oil,	46 —	45.5

Fats, therefore, as taken from vegetal or animal bodies, are not homogeneous chemical combinations, but mixtures of such, which, taken singly, have all the properties of the fats themselves. By congelation at low temperatures, and pressure of the concrete mass, a separation of the oil ensues into a liquid and a solid portion. The former consists of olein, and the latter of stearin or margarin, or both. By pressure between folds of blotting paper, or in linen bags, a nearly complete separation of the olein is effected, and the solid stearin

or margarin remains. By heating the paper in water, the liquid olein may be obtained separate. Tolerably pure stearin may also be procured by boiling the natural oil with alcohol, in which stearin is nearly insoluble. Besides the above process for procuring olein by refrigeration, it may be obtained by boiling oil for some time with a small proportion of caustic soda or potassa, and treating the mixture with dilute alcohol, when the olein collects as an oily layer upon the surface of the liquid. For the preparation of olein, almond oil should be employed, as it contains a greater quantity of this principle than other oils. Stearin constitutes by far the greatest proportion of the solid components of fats and fixed oils. The properties of these ingredients vary with the nature of the respective oils, so that the sole difference does not consist in the variable proportions of the three bodies, but also in peculiarities of the principles themselves; as it has been found that, according to their source, they solidify at very different temperatures.

When oily seeds, such as almonds, walnuts, or poppy seeds, are crushed or pulverized, so as to break up the cellular tissue, and bring its various ingredients into intimate admixture with each other, the fatty bodies, which the seeds naturally contain as neutral compounds, are gradually resolved into fatty acids, with simultaneous liberation of a colorless, inodorous, and sirupy liquid. The latter is *glycerin*, and was called by SCHEELÉ, its discoverer, the sweet principle of oils. The change is owing to the presence of a peculiar albuminous body, previously mentioned as being always associated with oils. This nitrogenous matter, gradually decomposing, acts as a ferment, and produces the above alteration in the constitution of the oils, and, as PELOUZE has shown, is independent of any absorption of oxygen. When heated with the hydrates of the fixed alkalies, with the alkaline earths and other metallic oxides, in presence of water, decomposition also ensues, the oily acids combine with the alkali or metallic oxide used, yielding oleates, margarates, and stearates; the oxide of glyceryl with which these acids were united separating in chemical combination with a certain proportion of water, the product being *glycerin*. This peculiar principle—the base of oils—in consequence of its growing importance in the arts and manufactures, and particularly as an article of the *materia medica*, has been made the subject of a separate article, to which the reader is referred. The three substances constituting the proximate principles of fats and oils, have also been noticed under the article *CANDLE*, where full information as to the mode of preparation, properties, and uses, will be found, together with a description of the respective acids entering into their constitution. It may be mentioned, that although the three components of oils—olein, stearin, and margarin—are respectively compounds of oleic, stearic, and margaric acids with the basis of glycerin, simple mixture of the fatty acids with the glycerin does not reproduce the oil from which they were obtained, in consequence of the metallic base, in displacing the oxide of glyceryl, having given up a portion of its water to it, while the fatty acids, in the process of separation from the metallic oxide, have also

united with a portion of water. In fact, the united weight of the fatty acids and glycerin always exceeds by three or four per cent. that of the oil originally employed. The water absorbed so modifies the constitution of the acid and base as to prevent the re-formation of the fatty bodies, of which they are the essential constituents.

BERTHOLLET has, however, recently succeeded in reproducing the natural fats by a direct union of their acids with the base of glycerin. According to this chemist, stearic, margaric, and oleic acids, each form three compounds, by uniting with oxide of glyceryl; during combination, water is separated in each case, but there appears to be a doubt as to the accuracy of his determinations of the precise quantity of water liberated. BERTHOLLET's researches on this subject have been noticed at some length in the article on GLYCERIN.

Other Constituents.—In addition to the three neutral principles, stearin, olein, and margarin, of which at least two are always contained in oil, many oils and fatty bodies contain another or more substances analogous in composition to these bodies, but essentially different in their properties. Some, like those above named, are, by the action of suitable reagents—for example, when treated with hydrates of the fixed alkalies—resolved into a fixed fatty acid and glycerin; others, when similarly treated, yield glycerin and a volatile fatty acid, and it is to the presence of the latter that the peculiar and characteristic flavor and smell of the various fatty bodies are to be attributed. In the appended table are given the names of these peculiar principles, with the acids yielded by each, and, so far as they are known, the melting points of the fat and of the acid:—

FATS YIELDING FIXED ACIDS.

Melts at		Melts at
Laurostearin, . . . 113°	Laurostearic acid, $C_{24}H_{48}O_4$ —109°·4	
Cocosin, 716	Cocinic acid, . . . $C_{26}H_{52}O_4$ —95	
Myristin, 87·8	Myristic acid, . . . $C_{28}H_{56}O_4$ —120·2	
Benin, —	Benic acid, . . . $C_{30}H_{60}O_4$ —109·4	
Moringin, —	Moringic acid, . . . $C_{30}H_{58}O_4$ —32	
Linolein, —	Linoleic acid, . . . $C_{30}H_{54}O_4$ —	
Palmitin, 118·4	Palmitic acid, . . . $C_{32}H_{64}O_4$ —140	
Butyrolein, —	Butyroleic acid, . . . —	
Ricinolein, —	Ricinoleic acid, . . . —	
Elaidin, 96·8	Elaidic acid, . . . $C_{36}H_{72}O_4$ —111·2	
Margaritin, —	Margaritic acid, . . $C_{22}H_{44}O_4$ —185	

FATS YIELDING VOLATILE ACIDS.

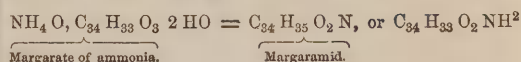
Butyrin,	Butyric acid, . . . $C_8H_{16}O_4$
Valerin, or Delphinin, . . .	Valerianic acid, . . $C_{10}H_{20}O_4$
Caproin,	Caproic acid, . . . $C_{12}H_{24}O_4$
Caprylin,	Caprylic acid, . . . $C_{16}H_{32}O_4$
Caprin,	Capric acid, . . . $C_{20}H_{40}O_4$
Hircin,	Hircic acid, . . . —
Sabadillin,	Sabadillic acid, . . . —
Crotonin,	Crotonic acid, . . . —
Ricinin,	Ricinic acid, . . . $C_{22}H_{42}O_4$ —70°

Of the above principles, many are unknown in the separate state, and are supposed to exist merely from the liberation of their fatty acids by the saponification of the natural fats, and subsequent treatment with acid.

Action of Alkalies on Oils—Soaps—Margaramid.—The combination of the fatty acids with alkaline and other bases gives rise to the production of soap, which

will be discussed in a separate article. It may suffice here to observe, that the compounds of the fatty acids with the fixed alkalies constitute soluble soaps; and, with the earthy and metallic bases, insoluble soaps. In the cases of oxide of lead and of zinc, they are termed *plasters*.

The action of ammonia upon the fixed oils differs from that of the other alkalies and metallic bases. If the emulsion obtained by agitating solution of ammonia with a fatty oil be, soon after being prepared, mixed with sufficient dilute acid to neutralize the ammonia, or if the mixture of oil with ammonia be exposed to the air, the volatile alkali after some time is completely dissipated, and the oil is reproduced in its original state. As already observed, simple admixture of glycerin with the fatty acids does not reproduce the oil yielding them; and, therefore, the reproduction of the oil unaltered, after expulsion of ammonia, is a proof that no combination of ammonia with the fatty acids had been formed. Prolonged contact of ammonia with oils in a closed vessel, however, gives rise to the formation of true salts of ammonia with the fatty acids, or ammoniacal soaps; but in addition to these, there is produced also a peculiar substance to which its discoverer, BOULLAY, has given the name of *margaramid*. It is an amide of the fatty acid, and may be obtained by treating the soap of ammonia with boiling water, by which means it is thinned out, but not dissolved, and on cooling, the greater portion congeals at the surface. The congealed mass is dissolved in boiling alcohol, and on cooling, margaramid is thrown down as a white, crystalline, perfectly neutral substance. The composition of margaramid is margarate of ammonia, *minus* two equivalents of water:—



Margaramid is unalterable in the air, insoluble in water, but readily dissolved by alcohol or ether. It fuses at 140°, burns with a sooty flame, is decomposed by boiling concentrated solutions of the fixed alkalies, and also by acids when at a certain degree of concentration. The transformation of oils into margaramid by the action of ammonia is especially rapid and characteristic in the case of castor oil.

Action of Acids on Oils—Sulphuric Acid.—The action of acids upon oils has been the subject of many recent critical examinations. The changes produced vary with the kind of acid employed. Sulphuric acid, when added to many oils to the amount of one per cent., has no action upon the oil itself, but it instantly develops a dark green or brownish coloration. After some time, a chemical combination of the acid with mucilage and other parenchymatous matter is deposited, and the oil is thus rendered brighter and more limpid. When sulphuric acid is added in larger quantities, very remarkable changes occur. In moderate proportion, its action appears to be limited to the abstraction of the oxide of glyceryl, with which it combines and forms bisulphate of oxide of glyceryl, or sulphoglyceric acid— $C_6H_7O_6 \cdot 2SO_3$, whilst the oily acids are set at liberty. When applied in larger quantities,

the result is the conversion of the fatty acids into various modifications, sulpho-glyceric acid being a simultaneous product. If sulphuric acid be gradually added in the cold to twice its volume of olive oil, the mixture becomes tough in appearance, and if, after standing twenty-four hours, two volumes of water be added, sulpholeic, sulpho-margaric, and sulpho-stearic acids separate and rise to the surface; for, though soluble in pure water, these acids are quite insoluble in the acid liquid. When the solution of these acids in water is kept for some time at ordinary temperatures, the sulphuric acid separates, and there are produced three new acids—metamargaric, metoleic, and hydromargaric acids. The two former rise to the surface, and the latter remains dissolved in the water along with sulphuric acid. On heating the original solution, there is formed a fourth, hydroleic acid, which rises to the surface in admixture with the acids above mentioned; and if this mixture is boiled with alcohol, still another acid is produced—the hydromargaric, which is deposited from the solution on cooling. FREMY was the first to notice these peculiar reactions; the subject has, however, since been investigated by others, and especially by MILLER and VARRENTTRAPP, but is still to a great extent involved in mystery. The sulpho-acids have an oily, bitter taste. Of the three, sulpholeic is by far the most permanent.

The action of sulphuric acid upon oils or fats at a high temperature, differs from the above; a separation of the fatty acids and oxide of glyceryl is immediately effected, and the glycerin and sulphuric acid mutually decompose, yielding sulphurous and carbonic acids. The application of this reaction to the separation of the fatty acids, for manufacturing purposes, has already been discussed in connection with the article CANDLE.

Action of Nitrous Acid—Elaidin.—The action of nitrous acid upon fixed oils varies with the kind on which it operates. According to their behavior under the influence of this acid, they are divided into two distinct classes or divisions—the *drying* and the *non-drying* oils. The latter by this treatment are converted into solid masses, a change of which those of the first division are not susceptible. The reaction appears to be confined to one of the principles of the greasy oils—olein; and its effect is to convert this, the most liquid of the components of oil, into a concrete fatty matter, termed *elaidin*, which by analysis is found to consist of a peculiar acid—elaïdic acid—in combination with oxide of glyceryl. This action was first observed by POUTET, a French apothecary, in the course of experiments on olive and other oils. BOUDET showed nitrous acid to be the true agent of decomposition. According to the quantity employed, the change is effected in a longer or shorter period of time. Thus, a mixture of three parts of nitric acid, with one of nitrous acid, gave the following results:—

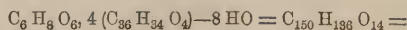
1 part of the acid with 33 of olive oil solidified in 70 minutes.	
1 50	78
1 75	84
1 100	130
1 200	435
1 400	remained unchanged.

The annexed table indicates the time required, at

the temperature of 60°, for the congelation of one hundred grains of oil, when treated with three grains of nitric acid, and three of pure nitrous acid:—

	Color immediately developed.	Number of minutes before congelation.
Olive oil,.....	Bluish green,	73
Sweet almond oil, ..	Dirty white,	160
Bitter almond oil, ..	Deep green,	160
Nut oil,	Bluish green,	103
Castor oil,.....	Bright yellow,	603
Colza oil,	Brown yellow,	2400

The very small quantity required to produce the effect, and the remarkable fact, that in some cases a similar solidification is produced by a deoxidising agent—sulphurous acid—render this action a problem as yet unexplained. Protonitrate of mercury also induces a similar change on the greasy oils, and in all cases, with the exception of castor oil, the product of the action is the same. Pure elaidin is best obtained by agitating olive oil with a mixture of nitrous and nitric acid. To procure this mixed acid, one part of nitrate of lead is heated in a retort connected with a receiver, in which is contained one part of nitric acid, of specific gravity 1.35. To one hundred parts of olive oil are added ten parts of this mixture of acids, and the whole is agitated till it begins to solidify. It is then allowed to stand at rest, and gradually a yellowish semi-solid mass is formed. This, when washed with alcohol, becomes white, and after pressing strongly between folds of bibulous paper, and subsequent crystallization from ether, yields pure elaidin. As thus procured, elaidin is solid at ordinary temperatures, and when heated with alkalis or metallic oxides, is saponified. It fuses at a temperature between 90° and 100°, is almost insoluble in alcohol, but is readily dissolved by ether, and in all proportions. Its specific gravity is 0.8978, and by distillation it yields, among other products, acrolein, and elaïdic and sebatic acids. The stearin and margaric of fats are not transformed into elaidin, though this change is stated to occur by some chemists. According to GOTTLIEB, the production of elaidin is due solely to the conversion of oleic acid into an isomeric modification, but how the acids effect the transformation is still a matter for further research. A small quantity of ammonia is formed during the reaction—a proof of the decomposition of a portion of the acid. The drying oils, as those of linseed, poppy seed, and hemp, undergo no metamorphosis by the action of nitrous acid, except that they are slightly tinged brown. The composition of elaidin is exactly the same as the olein from which it is produced— $C_{150}H_{136}O_{14}$ —and consists of one equivalent of glycerin, and four of elaïdic acid, minus eight equivalents of water—



one equivalent of elaidin.

Elaïdic acid is prepared by saponifying elaidin, by heating it with a fourth of its weight of caustic soda or potassa, and half its weight of water. The resulting soap is a mixture of margarate and elaidate of potassa or soda, and when treated with hydrochloric acid, chloride of the metal of the alkali is formed, and a mixture of elaïdic and margaric acids liberated. According to MEYER, it may be obtained pure by passing

a current of nitrous acid, as disengaged by the deoxidation of nitric acid when heated in contact with starch, through pure oleic acid at a low temperature, and avoiding the use of an excess of acid. The liquid after a short time congeals into a crystalline mass. This is washed with hot water to remove nitric acid, and then dissolved in its own volume of hot alcohol. On cooling, elaidic acid is deposited as a mass of crystalline scales, which may be purified by pressure, re-solution, and recrystallization, from alcohol.

MORFIT gives a method for preparing this acid on the large scale. Oleic acid is to be treated with steam at a high temperature, and afterwards there is added exactly sufficient solution of carbonate of potassa to neutralize any sulphuric acid it may contain. After standing some time, the oil rises to the surface of the condensed steam, and must be siphoned off into a wooden tub. To every two thousand pounds is then added an intimate mixture of eighty-one pounds of nitric acid, of specific gravity 1.35, and thirteen and a half pounds of molasses, and the whole is very gently heated by steam passed in through a worm of copper, having its terminus above the kettle, as it is not desirable that any water should get into the oily matter at this stage of the operation. When red fumes begin to appear, the action must be checked by drenching with four or five hundred gallons of water, after which an aqueous solution containing forty to fifty pounds of acetate of ammonia is added. During all these operations, the mass should be constantly agitated, and, after the addition of water, very briskly for two or three hours. The water and agitation withdraw all acid matters, and leave the elaidic acid in a condition to be drawn off, after repose, into small tubs, and cooled. Neutral oils by the same treatment yield elaidin, and this latter, as well as elaidic acid, is an excellent material for the manufacture of soap and candles. Elaidic acid is a pearly crystalline solid, resembling in appearance the silvery scales of sublimed benzoic acid. It fuses at about 112° , is readily soluble in alcohol, less so in ether, and quite insoluble in water. When distilled, a great portion passes over unaltered, the remainder is decomposed into carbides of hydrogen, but no sebacic acid.

As already observed, GOTTLIEB has shown that elaidic acid is isomeric with oleic acid. Its composition is, therefore, $C_{36}H_{38}O_2$, $HO = C_{36}H_{34}O_2$. This chemist proved likewise, that a small quantity of freshly-prepared elaidic acid, when mixed with a large proportion of oleic acid, gradually converts the whole mass into elaidic acid; and also that when exposed to the air, elaidic acid gradually becomes oxidised to oxyelaidic acid $= C_{36}H_{34}O_3$, whilst oleic acid submitted to the same influence, gradually passes into $C_{36}H_{34}O_2$.

Action of Chlorine, Bromine, et cetera.—The fixed oils are decomposed by chlorine and bromine, yielding hydrochloric and hydrobromic acids. Compounds of the oil are also at the same time formed with those radicals, in which it frequently happens, that each equivalent of hydrogen abstracted is replaced by one of the halogen. Iodine is generally dissolved, forming a brown solution. Sulphur is also soluble in oils, and, if heated, rather largely; the greater portion, however, is deposited on cooling; but if the tempera-

ture of the mixture be increased to the point at which the oil begins to be decomposed, sulphide of hydrogen is evolved, and a permanent solution formed. This compound is not saponifiable, it mixes with the fat and volatile oils, and, when long exposed to the air, dries into an elastic substance, insoluble in ether. When distilled, among other products sulphide of hydrogen is evolved, and a black porous mass remains, containing centesimally forty-five of sulphur, and fifty-five of carbon, and is expressed by the formula— SC_3 . Phosphorus and selenium are also sparingly soluble in the fixed oils.

The action of steam at a high temperature upon fatty oils was investigated by TILGHMAN. He observed that when a mixture of fat and water is forced, under strong pressure, through tubes heated nearly to redness, so as to raise the temperature of the mixture to between 400° and 500° , the fatty matter is entirely decomposed into glycerin and fatty acids; the elements of water enter into combination with those of the fat, and by this means a result is obtained exactly the reverse of that produced by BERTHOLLET at lower temperatures, when the acid and base are caused to reunite, again producing the natural fat. The application of TILGHMAN'S discovery to the preparation of the pure fatty acids, has been treated of at length in connection with the article CANDLE.

Sebacic Acid.—It has already been observed that the fixed oils, when submitted to distillation *per se*, are decomposed, yielding, besides carbonic acid, inflammable gas, and various hydrocarbons—*margaric* and *sebacic* acids, and a substance termed *acrolein*. A portion of oleic acid also passes over unchanged. Sebacic acid, with the exception of castor oil, is yielded by all oils, whether animal or vegetable, drying or non-drying oils. It is formed exclusively from the decomposition of oleic acid. Stearic and margaric acids, as well as pure margarin and stearin, do not yield a trace of it. The detection of sebacic acid amongst the products of this decomposition is, therefore, a certain test of the presence of an oil, and especially of olein or oleic acid. As produced from oleic acid, it is accompanied by a considerable quantity of capric and caprylic acids, with traces of valerianic and butyric acids. To obtain it pure, the whole liquid and solid products of the distillation of oils or fats, or better, of pure olein or oleic acid, are boiled with water, until the soluble portion is extracted. The aqueous liquid deposits sebacic acid on cooling. The crystals are purified by washing with cold water, and recrystallizing from the hot solution, till they become colorless, and free from empyreumatic smell. Or the watery solution is precipitated by adding acetate of lead, which throws down sebate of lead. This, after washing, is dried; and, decomposed by dilute sulphuric acid, yields a solution which, on evaporation, deposits pure crystals of sebacic acid. According to DUMAS and PELIGOT, its ultimate composition is as annexed:—

	At weight.	Centesimally.
10 Eqs. of carbon,.....	60	59.4
9 Eqs. of hydrogen,.....	9	8.9
4 Eqs. of oxygen,.....	32	31.7
1 Eq. of sebacic acid,.....	101	100.0

As thus obtained, the acid is combined with one equivalent of water, and is, therefore, expressed by the formula, $C_{10}H_8O_3, HO$. Hydrated sebacic acid forms light, white, pearly scales, resembling benzoic acid in appearance; indeed, it was considered by BERZELIUS to be identical with this acid. It has a very slightly acid taste, but reddens litmus. It fuses at 260° to an oily liquid, and, at a higher temperature, sublimes unchanged. It is much more soluble in hot than in cold water, and is readily dissolved by alcohol or ether. With the alkalies it forms soluble sebrates, but its salts, with other metallic oxides, are for the most part insoluble. LIEBIG and REDTENBACHER were the first to notice this acid as a certain and delicate test of the presence of oleic acid.

Acrolein.—Acrolein is another highly characteristic product of the decomposition of oils by the application of a high temperature. When the volatile products arising from the destructive distillation of oils or fats, are passed through a series of bottles, half filled with water, the second and third bottles retain the greater portion of the acrolein, partly in solution in the water, and partly in the form of an oil floating on the surface of the liquid. When this floating oil is agitated with twenty times its bulk of water, the greater part of it is dissolved; and when this solution is distilled in a water bath, an oily matter—nearly pure acrolein—passes over at about 125° . According to REDTENBACHER, it is most readily obtained in a state of purity by distilling, in a capacious retort, a mixture of glycerin with anhydrous phosphoric acid, or bisulphate of potassa; the vapors are condensed in a receiver placed in a freezing mixture. The receiver is luted on to the retort, and is provided with a tube conducting into a chimney with a good draught, so as to carry off any uncondensed acrolein. To exclude atmospheric air, the oxygen of which rapidly combines with acrolein, the whole apparatus must be charged with carbonic acid, and the current be continued to the end of the process. The distillate separates into two layers, of which the upper one consists of acrolein, and the lower one of an aqueous solution of the same substance, and containing also another body resulting from the oxidation of acrolein. The latter is acrylic acid, very analogous to acetic acid, and is produced during the distillation, even in the presence of carbonic acid. The distillate, with the addition of a quantity of powdered litharge, to retain acrylic acid, is rectified by the heat of a water bath, and the acrolein thus obtained is submitted to another rectification from chloride of calcium, and is then as pure as it has yet been obtained. Acrolein is especially remarkable for the peculiarly pungent and acrid nature of its vapor, intensely disagreeable and irritating to the eyes and nose, the evaporation of even a few drops, in a large room, causing a copious flow of tears in the eyes of all present, and with severe pain. It is a colorless, limpid, and volatile oily liquid, possessing a high refracting power, is very soluble in ether, and sparingly so in water. It boils at 125° . It is assumed to be the hydrated oxide of a radical termed, *acryl*— C_6H_3 , and its formula is C_6H_3O, HO . When long kept, it changes spontaneously into a white, flocculent, inodorous substance,

which REDTENBACHER named *disacryl*. The latter body is insoluble in ether, oils, acids, and alkalies. As it is formed even when acrolein is excluded from air, it is in all probability an isomeric modification of this body. The aqueous solution of acrolein also gradually undergoes a similar change. Sometimes acrolein, under the same circumstances, becomes transformed into a resinoid mass, which fuses at 212° , and forms a brittle transparent mass, on cooling. This substance is insoluble in water, but soluble in alcohol and in solutions of the alkalies. Acrolein owes its formation solely to the decomposition of glycerin, and its production is, therefore, an extremely sensitive test of the presence of the latter body. It appears to be produced by a dehydration of glycerin, since this substance contains the elements of acrolein, *plus* four equivalents of water.



Acrolein and its products of oxidation are remarkably analogous to aldehyde and its products, as will be observed by a comparison of the subjoined tables:—

Acryl,.....	C_6H_3 —unknown.
Hydrated oxide of acryl—acrolein—	C_6H_3O, HO .
Acrylous acid,.....	$C_6H_3O_2, HO$.
Acrylic acid,.....	$C_6H_3O_3, HO$.
Acetyl,.....	C_4H_3 —unknown.
Hydrated oxide of acetyl—aldehyd—	C_4H_3O, HO .
Acetous acid,.....	$C_4H_3O_2, HO$.
Acetic acid,.....	$C_4H_3O_3, HO$.

It may be observed that STENHOUSE found in palm oil, and PLAYFAIR in butter of nutmegs, a base having the same formula as acrolein— $C_6H_4O_2$. This substance, however, when separated from the oily acid, always appears as ordinary glycerin.

Elementary Composition of Oils.—From what has been detailed as to the proximate constituents of oils, it will hardly be thought necessary to notice their elementary composition. Indeed, a knowledge of the ultimate analysis of any organic body, is only a very slight assistance to the chemist in the determination of the true composition of these substances. This can only be arrived at, to any degree of certainty, by a thorough investigation of the changes induced by the action of reagents, and an accurate determination of the quantities of the several products, as well as their composition. It is owing to the application of this principle, first laid down by the illustrious CHEVREUL, that, in the hands of such philosophers as LIEBIG, DUMAS, BOUSSINGAULT, BUNSEN, WÖHLER, and others, organic chemistry has made such rapid strides during the last half century. The Editor has, however, annexed a table, showing the relative centesimal proportions of carbon, hydrogen, and oxygen, in each of the following oils, together with the name of the authority:

	Carbon.	Hydrogen.	Oxygen.	Authority.
Olive oil,.....	77.21	13.36	9.43	{ Gay-Lussac and Thenard.
Almond oil,.....	77.40	11.48	10.82	Saussure.
Linseed oil,.....	76.01	11.35	12.62	Do.
Nut oil,.....	79.77	10.57	9.12	Do.
Castor oil,.....	74.17	11.03	14.78	Do.
Whale oil,.....	76.13	12.40	11.50	Bérard.
Spermaceti oil,.....	78.91	10.97	10.12	Ure.
Hog's lard,.....	79.09	11.14	9.75	Chevreur.
Suet,.....	78.99	11.70	9.30	Do.
Butter,.....	65.60	17.60	16.80	Bérard.

All fixed oils consist essentially of these three elements only, some, however, yield minute traces of nitrogen, referable to adhering impurities.

Drying and Non-Drying Oils.—Excluded from air, oils may be preserved unchanged for a lengthened period; but when exposed to the air, some oils, through the absorption of oxygen, become converted into a thick and viscid mass; others are changed into a transparent resinous body or varnish, especially when they are in thin strata. This reaction constitutes another well-marked distinction of the oils into the two classes, *non-drying* or *greasy* oils, and *siccative* or *drying*. The former class, though they may acquire more color and solidity, never lose their property of communicating a greasy stain, and the latter, as already mentioned, do not solidify when mixed with nitrous acid, or protonitrate of mercury. Oleic acid, as obtained from drying oils by absorption of oxygen, dries to a resinous mass, like the oil from which it is derived, and appears to be a distinct substance from the oleic acid of non-drying or greasy oils. The most important drying oils are those of linseed, poppy seed, grape seed, and nuts; and all are much more susceptible of the change after having been heated with the addition of a small quantity of oxide of lead. The principal non-drying oils are those of olive, colza, sweet almonds, rape seed, and palm oil. These, under the same circumstances, acquire rancidity, become thick and less combustible, and assume an offensive smell, more especially when they contain much impurity, such as albumen or mucilage.

SAUSSURE has particularly investigated this action of air or oxygen on oils, and has announced the phenomena occurring during exposure as follows:—He found that the recently-expressed fixed oils are scarcely affected by the oxygen of the atmosphere, but that after a variable period, sometimes of several months, but dependent upon temperature and exposure to light, they begin rapidly to absorb oxygen, and evolve hydrogen and carbonic acid gases. SAUSSURE's experiment to prove the absorption of oxygen by oil was the following:—A layer of nut oil, one quarter of an

inch thick, and three inches in diameter, was inclosed in oxygen gas standing over quicksilver. During eight months, from December to August, the oil absorbed only three times its bulk of gas, but in the course of ten days in the latter month, it absorbed sixty additional volumes. This absorption of oxygen diminished progressively, and at the end of three months, entirely ceased, and the oil had taken up one hundred and fifty-five times its bulk of the gas. No water was generated, but twenty-two volumes of carbonic acid were disengaged, and the result was a transparent jelly, which did not produce a stain on paper. Linseed oil, in undergoing this metamorphosis, does not evolve any gas. Under certain circumstances, the alteration by the action of oxygen may become so energetic as to lead to a considerable elevation of temperature, and ultimate inflammation, and particularly if the surface of the oil is greatly extended, as in the case of oily wool or hemp, or greasy cloth, which, when left in a heap, has frequently taken fire spontaneously, and caused the destruction of mills, warehouses, and ships; indeed, so frequently has spontaneous combustion arisen from this circumstance, causing lately the almost total destruction of one of the noblest of British merchantmen, as to render precaution necessary in all cases where danger can arise from such causes. In illustration of these occurrences, it may be proved experimentally that if paper, linen, tow, wool, cotton, or bodies of a like nature, be slightly imbued with linseed or hempseed oil, and placed in contact with sun and air, especially when in heaps or piles, they will quickly inflame. This spontaneous combustion is owing to rapid absorption of oxygen by the oil, the hydrogen of which is inflamed by the caloric eliminated from the gas at the moment of its absorption, until then existing as latent heat, and serving to retain the oxygen in its gaseous condition.

Enumeration of Vegetal Greasy Oils.—The subjoined is a list of the principal greasy oils of commerce, with the plants that yield them, their specific gravity, and the per centage amount of oil that may be extracted from some of the seeds mentioned:—

	Plants.	Specific gravity.	Yield of oil per cent. From olives.
Olive oil,.....	Olea Europea,.....	0.9176	32
			From seeds.
Rape seed oil,.....	Brassica campestris et napus,.....	0.9136	30 to 36
Colza oil,.....	Brassica campestris oleifera,.....	0.9136	36 to 40
Summer rape seed oil,.....	Brassica præcox,.....	0.9390	36 to 40
Almond oil,.....	Amygdalus communis,.....	0.9180	28 to 54
Cocoa-nut oil,.....	Cocos nucifera,.....	.....	—
Palm oil,.....	Cocos butyracea vel avoira elais,.....	0.9680	—
Teel oil,.....	Sesamum orientale,.....	—	40
Oil of behen or ben,.....	Guilandina mohringa,.....	—	—
Beech oil,.....	Fagus sylvatica,.....	0.9225	15 to 17
Oil of mustard,.....	Sinapis nigra et arvensis,.....	0.9160	15 to 38
Plum kernel oil,.....	Prunus domestica,.....	0.9127	33.3
Butter of cacao,.....	Theobroma cacao,.....	0.8920	—
Laurel oil,.....	Laurus nobilis,.....	—	—
Ground nut oil,.....	Arachis hypogæa,.....	0.9242	60
Pincy tallow,.....	Vateria Indica,.....	0.9260	—
Oil of radish seed,.....	Raphanus sativus oleifera,.....	0.9187	50
Cherry-stone oil,.....	Prunus cerastus,.....	0.9239	—
Apple seed oil,.....	Pyrus malus,.....	—	—
Spindle-tree oil,.....	Euonymus Europeus,.....	0.9380	—
Cornel-berry-tree oil,.....	Cornus sanguinea,.....	—	—
Oil of the roots of cyper grass,.....	Cyperus esculenta,.....	0.9180	—
Henbane seed oil,.....	Hyoscyamus niger,.....	0.9130	—
Horse-chestnut oil,.....	Æsculus hippocastanus,.....	0.9270	2 to 8

Characters of the Drying Oils.—The drying oils vary from those just enumerated, by becoming gradually converted into solid masses by exposure to the atmosphere, and also by not being solidified by contact with nitrous acid or protonitrate of mercury. Their principal use is in the preparation of varnishes and painters' colors, and the more quickly they become hard by exposure, the more valuable are they for these purposes. Their siccative properties may be much increased by heating them with about seven or eight per cent. of their weight of litharge, which, in this proportion, is, for the most part, dissolved by the oil. The heat is continued until the oil acquires a reddish hue. Oxide of manganese, oxide and sulphate of zinc, and magnesia, have also been used to produce a similar effect; what is technically known as *boiled* oil, being linseed oil which has been thus treated. According to CHEVREUL, the common practice of heating the oil to a very high degree, and for a considerable length of time, is not essential to the production of a good drying oil; linseed oil heated to 140°, with the addition of ten per cent. of its weight of oxide of manganese, having acquired powerful siccative properties. LIEBIG is of opinion that the increased rapidity with which oils thus treated become hard on exposure, is owing to the separation of the mucilaginous and other matters, by the oxide of lead, and that the atmospheric oxygen is thus brought more closely into contact with each particle of oil. DUMAS and others consider the effect to be due, in a great measure, to the presence of oleate and stearate of lead dissolved in the oil. Another view, which the Editor, however, considers fallacious, supposes the conversion of the oil into varnish to be the result of the saponification of the fatty acid by means of oxide of lead, and the simultaneous destruction of the oxide of glyceryl by the agency of heat. But if linseed oil be saponified in the ordinary manner, and the soap produced be afterwards decomposed by means of an acid, so as to separate the whole of the glycerin, and as much oxide of lead be then dissolved in the fatty acid as will allow the mass to remain fluid on cooling, no varnish is obtained, and this is positive proof that the destruction of the oxide of glyceryl is not the object of the manufacture of quick drying oils. If a previous remark be borne in mind, that the drying oils, as shown in the experiments of SAUSSURE, absorb oxygen from the air with much greater rapidity at a later period, than when first exposed, it will appear probable that one or other of the foreign matters present retard the absorption, and this being dissipated after a

long resistance, the oil is brought more freely into contact with oxygen. The formation of varnish is thus reduced to a simple purification of the oil, by removing all those substances which prevent the immediate contact of the oil with atmospheric oxygen. Adopting this highly probable assumption, LIEBIG devised a method for removing the mucilaginous impurities by precipitation at the ordinary temperature. He recommends for the production of a superior and less colored drying oil, that the oil be agitated for some time with a mixture of water, litharge, and subacetate of lead, without the application of heat. In prosecuting this method, the basic acetate of lead is first prepared as follows:—One part of neutral acetate of lead is dissolved in five parts of water, and to the solution is added one part of finely reduced litharge. The whole is allowed to digest until the red of the litharge has been replaced by a white color. The clear solution of basic acetate is then decanted, and mixed with an equal quantity of water, and added to twenty parts of linseed oil, which has previously been triturated with one part of finely powdered litharge. The mixture now requires to be shaken at intervals, and subsequently allowed to remain at rest for some hours, when the impurities subside with the water, and the supernatant oil is so pure that it dries into a varnish in twenty-four hours. In this case, a small quantity—four to five per cent.—of oxide of lead is retained in solution by the oil; but contrary to its effect, after being boiled with the oil, it improves, rather than deteriorates, the varnish produced. Should it, however, in any way interfere with the uses to which the oil is to be applied, it may easily be removed by agitation with dilute sulphuric acid. The solution of acetate of lead employed in the above method of purification, and which collects below the stratum of oil, may be again used in the preparation of the subacetate, by the addition of litharge as before.

The oil or varnish taken for the preparation of printers' ink, is procured by boiling drying oils in an earthenware vessel. After ebullition for a sufficient length of time, the vessel is removed from the fire, and uncovered, when the vapors inflame. It is allowed to burn for about half an hour, then extinguished by replacing the cover, and again seethed until it acquires the proper consistence, and the tendency to dry quickly.

Enumeration of Drying Oils.—The following is a list of the principal drying oils, with their sources, specific gravity, and the per-centage yield of some of the seeds:—

	Plants.	Specific gravity.	Centesimal yield.
Linseed oil,	<i>Linum usitatissimum et perenne</i> ,	0.9347	11 to 22
Nut oil,	<i>Corylus avellana et juglans regia</i> ,	0.9260	60
Poppy oil,	<i>Papaver somniferum</i> ,	0.9243	56 to 63
Hempseed oil,	<i>Cannabis sativa</i> ,	0.9276	14 to 25
Castor oil,	<i>Ricinus communis</i> ,	0.9611	25
Grape seed oil,	<i>Vitis vinifera</i> ,	0.9202	—
Cucumber oil,	<i>Cucurbita pepo et melapepo</i> ,	0.9231	—
Sunflower oil,	<i>Helianthus annuus et perennis</i> ,	0.9262	15
Tobacco seed oil,	<i>Nicotiana tabacum et rustica</i> ,	0.9232	—
Oil of julienne,	<i>Hesperis matronalis</i> ,	0.9281	18
Oil of camelina,	<i>Myagrum sativa</i> ,	0.9252	28
Oil of weld seed,	<i>Reseda luteola</i> ,	0.9358	—
Oil of cress seed,	<i>Lepidium sativum</i> ,	0.9240	56 to 58
Oil of deadly nightshade,	<i>Atropa belladonna</i> ,	0.950	—
Oil of cotton seed,	<i>Gossypium barbadense</i>, .....	.....	—
Pinetop oil,	<i>Pinus abies</i> ,	0.9285	—

Extraction of Oils from Seeds.—The vegetal oils are for the most part obtained by expression, the seeds being previously ground or bruised. Some seeds after this treatment readily yield to pressure, and give what is known as virgin oil, possessing an agreeable taste; others, especially those containing a large proportion of mucilaginous matters, give up their oil with great difficulty, and it becomes necessary to submit the bruised seeds to torrefaction, previous to pressure. The albumen is thus coagulated, and the oil, rendered less viscous, becomes more easy of separation. The latter process, however, requires careful management, or the oils are greatly impaired, both in color and taste.

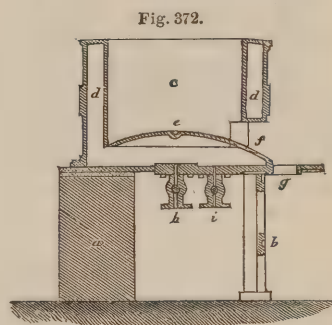
Until a comparatively recent date, the treatment of oleiferous seeds for the extraction of their oil was by pounding in hard wooden mortars, with pestles shod with iron, and set in motion by cams driven by a shaft turned with horse or water-power. The bruised seed was then transferred to woollen bags, which were wrapped in horse-hair cloth, and squeezed between upright wedges in press-boxes. This arrangement, known as the Dutch mill, has been almost entirely superseded by the hydraulic oil mill and press. In some districts, however, both in this country and on the continent, the old method is still obstinately adhered to, and supposed to be preferable to the hydraulic mills and presses. Some varieties of seed, such as linseed, rape, and other hard seeds, require, before the final crushing, to be passed between iron rollers, in order to crack the shells. The seeds are first introduced into a hopper, through which, by means of a fluted roller, lying across it, they are caused to descend equably between the crushing rollers. These rollers revolve in opposite directions, and are sometimes of different sizes, so that different velocities may be given to their surfaces, enabling them also to draw in different sizes of seed, and to perform their work more quickly. Two scraper blades, are pressed by means of two weights, hanging upon levers, against the surface of the rollers, and remove any seed-cake that may adhere to them. The crushed seeds fall through a slit in the case, and are received into a chest placed upon a board beneath.

The seed broken by the rollers is passed under two vertical granite millstones or runners—Fig. 375—revolving on a horizontal bed. For accelerating the pulverization, a blade should be attached, and revolve with the stones, for turning up the mass and detaching that which adheres, and returning it constantly into the track of the runners. The two stones, travelling round their circular path, grind the seeds, not merely by their weight, but also by a rubbing motion or attrition; for their periphery being not conical, but cylindrical, they cannot roll on a plane surface without at every instant turning round with a certain amount of friction upon their resting points. Some manufacturers employ stones hooped with iron; but the rough granite surface is much the best. It may be dressed from time to time with hammers as it becomes irregular.

In some cases, and especially when operating upon old seeds, a small quantity of water is added previous to the final crushing, which, taking the place of the oil in the seed, renders the process of extraction much

more easy of execution; sometimes, however, this addition would be injurious. Occasionally, also, the seeds are subjected at once to the runners, dispensing entirely with the previous crushing. When the seed is sufficiently bruised by either or both of these operations, the pasty mass is generally heated in iron pans over an open fire, although the practice is by no means judicious. The object of doing so is principally to coagulate the albumen, which otherwise either retains a large quantity of oil, or itself exudes in admixture with the expressed oil. By heating the bruised seed, the oil is also rendered more limpid, and therefore more easily expressed. The heat of boiling water, however, is sufficient, and either this or steam may be advantageously applied to effect the above purposes; the uniform action of the latter upon the heated pan obviating completely the evils arising from partial and overheating, which always occur at the top and bottom of the common pans.

Fig. 372 is an apparatus designed for this purpose, shown in vertical section. It is known as the steam-kettle of HALLETTE. *a* is the wall of masonry, upon

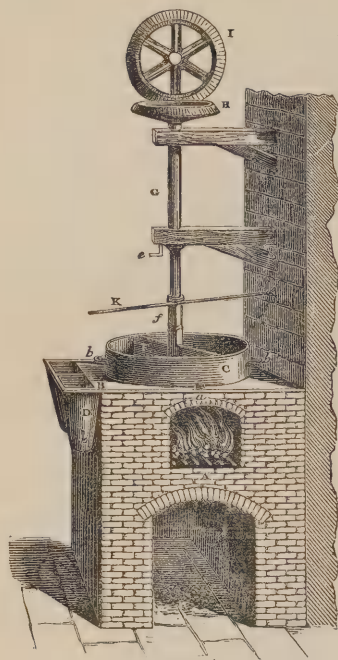


which and the iron pillar, *b*, the pan is supported. It is inclosed in a jacket for admitting steam into the intermediate space, *ddd*, at its sides and bottom. *c* is the middle of the pan, in which the shaft of the seed-stirrer, not shown in the figure, is planted upright, resting by its lower end in the step, *e*. *f* is an opening, by which the contents of the pan may be emptied; *g* is an orifice into which the mouth of the sack or woollen bag is inserted, so as to receive the heated seed when it is expelled by the rotation of the agitator, after the plug, *f*, is withdrawn; *h* is the steam induction pipe; and *i* the eduction pipe, which serves also to run off any condensed water that may collect.

Fig. 373 represents the heating apparatus attached to MAUDSLEY'S seed-crushing mills. In this the seed is heated in an iron pan over the open fire with constant agitation. A cast-iron plate, *b*, called the fireplate, rests immediately over the fireplace, and upon this is placed the ring-pan, *c*, also of iron, for containing the seeds, and which is held immovable by the pins or bolts, *a a*. The agitator, *f*, is employed to prevent the scorching of the seeds by continued contact with the iron plate. It is appended by a turning joint to the collar, *j*, which revolves with the shaft, *g*, and slides up and down upon it. The shaft, *g*, is turned by the

action of the bevel-wheel, *i*, upon the bevel-wheel, *h*, at the upper end of the shaft. The lever, *k*, is for raising the agitator; and *e*, a catch for holding it in its

Fig. 373.



place when it has been raised to the proper height. The heated seed is removed from the ring-pan by the funnels, *d d*, into which it is caused to fall by pulling the case, *c*, by means of the handles, *b b*, and the bags are suspended to the funnels by means of hooks, *e*.

If fine cold-drawn oil is required, the seed-flour is subjected at once to pressure, without previously heating; but the method most commonly pursued is that given above. The crushed cake is inclosed in a press-cloth or bag previous to its introduction into the case. The bags and cloths used for this purpose are made of different materials, the object being to have them sufficiently strong to bear the force exerted; while, at the same time, they are not so thick or porous as to retain any great quantity of liquid. Woollen cloth is especially manufactured with a view to its application to this process of expression, and is the material usually employed, either wrapped in horse-hair cloth or otherwise.

Several different kinds of presses are used in the extraction of oil, as the screw-press, the wedge-press, and the hydraulic press. Of these the wedge-press is the most frequently employed. It consists of a large press-box, either hollowed out of a strong block of stone or timber, or otherwise constructed of sufficient strength to bear the enormous pressure of the wedges. The bags of seed are placed between iron plates, which are united at bottom in the form of a book cover. These plates are each provided with three side ribs; the immovable ones press against the sides of the case, and the movable against the intermediate wedges; and they are pierced

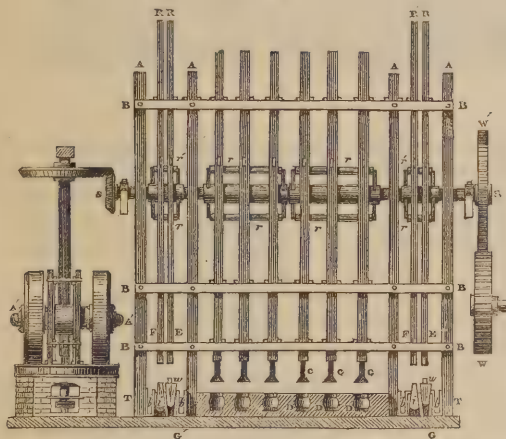
with numerous apertures to allow the oil to percolate more easily.

As the product of oil is, to a certain extent, proportional to the intensity of the pressure, it is more economical to employ that kind of apparatus which gives the most power. The use of either vertical or horizontal hydraulic presses is, therefore, to be preferred to the form of press above described. An important improvement in this press, as used for the expression of oil, has been introduced some time ago, and consists in the employment of double-sided presses, and into the division between the two walls steam is introduced. The press thus heated renders more easy the extraction of the oil. Each hydraulic oil press is usually double—that is, it has two vertical rams placed parallel to each other, so that while the pressure is exerted on one side, the other is being emptied of its contents. The first pump has usually about two and a half inches diameter for a ram of ten inches, and the second pump one inch; both are worked by steam-power, and the pressure exerted is from three to four hundred tons. Many advantages, however, are attached to the use of the old form of press; for it is necessary, in order to accomplish the object efficiently, that the press should be capable of maintaining unrelaxed the degree of compression which has been produced at each successive effort, and that it should not allow the particles, by their elastic force, to regain to any extent their original condition. This quality is possessed to a greater extent by the wedge than by the hydraulic press. The former will maintain for an indefinite length of time any degree of compression which may have been applied to the substance placed in it; but not so the latter. The pressure in the hydraulic press is communicated through a liquid, and maintained by the action of valves, and it is found impossible in practice to prevent a slight leakage, which necessarily diminishes or relaxes the force of the pressure when the pump is not in action. It is necessary, therefore, more frequently to renew the force when conducting the process of expression with the hydraulic press, than is the case with the wedge press.

The oil obtained by the first expression is of the finest quality, and is kept apart from that yielded by subsequent processes. After removal of the flattened seed-cakes from the press and bags, they are returned to the millstones, and crushed and finely pulverized. The fine meal thus produced is submitted to a second compression, sometimes with the addition of a little water, and with the assistance of heat. The temperature to which it is raised is about 155°, and it is constantly agitated by a stirrer moved by machinery. The oil resulting from the compression after this process is of the second quality. In some countries, and particularly in Holland, a still further quantity of oil is extracted, otherwise the soft and fat cakes are sold as food for cattle. The last process of extraction is merely a repetition of the second, except that the pulverized cake is kept for some time at the heat of boiling water, and that a greater pressure is applied than before. The oil obtained is of the lowest quality, and the hard and dry oil-cakes cannot be applied otherwise than as manure.

Fig. 374 is a representation of a mill that may be worked by water-power, wind, steam, or other available means, acting directly on the wheel, *W*, which engages with another wheel, *W'*, mounted on the shaft, *s s*. The stamping or crushing of the seeds is effected by the pestles, *c c*, and mortars, *D D*. The framework, *A A*, supporting the pestles, consists of four strong uprights, bolted firmly together by means of the cross pieces, *B B*. The pestles work in notches attached to the rails, for the purpose of guiding their motion. The raising of the pestles is effected by means of wipers, *r r*, attached to the shaft, *s s*, and so arranged that each revolution raises the pestle twice. The wipers consist of a square socket affixed to the shaft, with arms and rollers at their extremities, so as by avoiding friction to confer greater durability upon the apparatus. When not at work, the pestles are raised by levers, so

Fig. 374.



that the lifts are quite clear of the wipers. The press boxes are similarly constructed to the wedge-presses before alluded to. *E E* are the drivers that strike the wedges, *w w*; and the stampers, *F F*, strike the relieving wedges, *i i*, and serve to disconnect the apparatus. These rams are worked by wipers, *r' r'* affixed to the horizontal shaft. The grinding apparatus, shown in the same figure, is also attached to the machine, and is worked by the same motive power. The running granite stones revolve in a powerful frame-work attached to a vertical axis, which also slowly revolves by the action of a cog-wheel at the extremity of the horizontal shaft upon a similar wheel attached to it. A double motion is thus communicated to the stones—one by which they are carried round upon the bed or floor of the mill, and the other on their own axis. The horizontal axis, *A' A'*, passes through the vertical axis; and to give greater freedom of motion, and to allow the stones to pass over any heaps of seed without straining, the hole for the axle is vertically oval, and of sufficient width. The vertical shaft revolves in a brass bush, laid in the centre of a block of wood; and the horizontal shaft passes through to such an extent, that one of the runners is two-thirds of its own thickness nearer the vertical shaft than the other, and the stones are thus caused to pass over a greater extent of surface than they would, were the

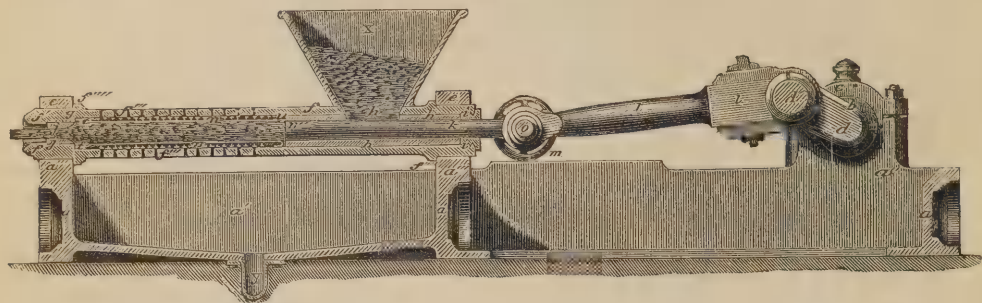
vertical shaft equidistant from each. The seed, spread and dispersed by the motion of the stones, is again brought into their path by means of rakes or sweepers attached to the framework, and revolving on the surface of the bedstone. The inner rake collects the seeds under the outer stone in the form of a ridge, over which the stone passes and flattens it, when the outer rake collects it again into a ridge in the line of motion of the inner stone. The outer rake consists of two parts, one of which presses closely on the wooden hoop of the raised border, and pushes the seed obliquely inwards, while the other part gathers up the grain which has spread towards the centre. The inner rake has a joint near the middle of its length, by which the outer half of it can be raised from the nether stone, while the inner half remains in contact with it, and continues to remove the moist paste. When the seed is sufficiently bruised, the outer end of the rake is lowered and gathers up the paste, and carries it obliquely outwards to the raised border, whence, by an open part of the rim, it falls out into troughs placed to receive it. The latter are perforated at bottom, and a quantity of very pure oil oozes out and is conducted to a cistern apart.

A machine for expressing oils was invented by BESSEMER and HEYWOOD of London, and secured by patent, sealed in May, 1849, in which the materials to be operated upon are forced, by means of a plunger or piston, into and through a pervious vessel which, while allowing the oil to percolate, prevents the passage of other matters through its pores. This oil-press is shown in longitudinal section in Fig. 375. The bedplate or framing, *a a*, which should be cast in one piece, forms at *a'* a cistern for the reception of the oily matters as expressed from the seed or other substance, and at the opposite end of this plate there are projections, *a''*, in which brasses, *b*, provided with caps, *c*, are fitted, and form bearings in which the crank-shaft, *d*, revolves. Two other projections, *a'''*, are also cast on to the bedplate, and are provided with caps, *e*, so as to retain the pressing cylinder firmly in its place. The latter must be of sufficient strength and thickness to withstand the amount of internal pressure exerted. The *lining*, fitted within the cylinder, *f*, consists of a tube of gun-metal, having a spiral groove cut on the outside of it, and having the appearance of an ordinary square threaded screw. At very short intervals all along the spiral groove there are conical holes drilled through the tube, *n*, and communicating with the interior of it. At *t t* the inside of the tube is enlarged, and is provided with a steel collar, beyond which the tube is reduced in diameter. A plain cylindrical bag, with open ends formed of fustian, or other similarly pervious material, is made to fit closely to the inside of the tube, *n*, and within this bag is placed a cylinder of wire-gauze, or finely perforated metal. The steel collar, *t*, is forced into the end of the wire-gauze, by which it becomes driven into the narrow part, and is securely held there by the pressure of the collar, *t*. The bag and wire-gauze are then stretched over the end, *n''*, of the tube, and the collar, *u*, driven tightly on, by which means the bag and wire-gauze are securely held in their places.

The lining tube, *n*, is then put into the pressing cylinder as far as the shoulder, *g*. A tubular piece, *h*, is next put in, and brought into contact with the collar, *u*, and then the gland, *i*, is screwed home, whereby the lining, *n*, is firmly retained within the pressing cylinder. The end of the pressing cylinder is contracted at *f'*, and forms a shoulder for the abutment of the collar, *j*, the diameter of the aperture of which regulates the pressure to which the matters are

submitted. Within the tube, *n*, there is fitted a solid plunger, *k*, which receives a motion from the crank, *d*, by means of the connecting-rod, *l*, the parallel motion being obtained by the wheel, *m*, on the cross-head, *o*, traversing on the side of the bedplate. *x* is a hopper bolted to a flange on the pressing cylinder, and in communication with it there is an opening in the tube, *n*, corresponding with the opening into the hopper, so that the substances placed in the hopper

Fig 375.



may drop into the tube, *n*. Where the plunger, *k*, is withdrawn from beneath the opening at that part of the pressing cylinder which is occupied by the lining, there are drilled numerous small holes, *f'''*, communicating at various points with the spiral groove in the tube, *n*. On the outside of the pressing cylinder there are formed two collars, *f'''*, which abut against the projecting pieces, *a''*, and caps, *e*, and cause the pressing cylinder to be retained firmly in its place. When steam is the motive power applied to the oil-press, the crank which is actuated by the steam piston is formed on the end, *d'*, on the crank shaft of the oil-press, and placed at such an angle to the crank, *d*, that when this crank is pushing the plunger, *k*, to the end of its stroke, the steam piston will be at half-stroke, whereby the motive power applied will be greatest at the time that the press offers the greatest resistance; and the steam piston, also, when passing its dead points, will have to overcome the friction of the machinery only, as the plunger, *k*, will be in the middle of its back-stroke. If other motive power than steam is applied to turn the crank, *d*, it is necessary to have a fly wheel on the shaft, *d'*, as also such cog wheels as are necessary to connect it with the first mover.

In applying this apparatus to the expression of oily seeds, the latter, after grinding, and heating if necessary, are introduced into the hopper, and motion being transmitted to the crank in the manner before described, the plunger, *k*, commences a reciprocating movement in the tube, *n*, of the pressing cylinder; each time that it recedes in the direction of the crank, it moves from under the opening in the hopper and allows a portion of the seed to fall into the tube, while the reverse motion of the plunger drives it towards the open end of the cylinder, its passage being much retarded by the friction against the sides of the lining of the tube, but chiefly by the contraction of the escape aperture through the collar, *j*; the plunger, therefore, exerts an amount of pressure upon the seed corresponding to the size of the

escape aperture. The expressed oil, passing through the wire gauze and bag, finds its way through the perforations into the spiral channel, and from thence it finds egress by the perforations, *f'''*, in the pressing cylinder, and as it falls is received by the cistern, *a'*, from which it is drawn by the pipe, *y*. Two or more of these pressing cylinders may be used side by side, actuated either by one crank throw, or by separate throws upon one shaft, placed in such a manner as to equalize as far as possible the amount of resistance throughout the revolution of the crank shaft, and instead of the cylindrical pressing plunger, an angular section may be given to the pressing vessel and plunger. Besides its use in the extraction of oil from seeds, this press may be employed in the expression of other matters containing oil.

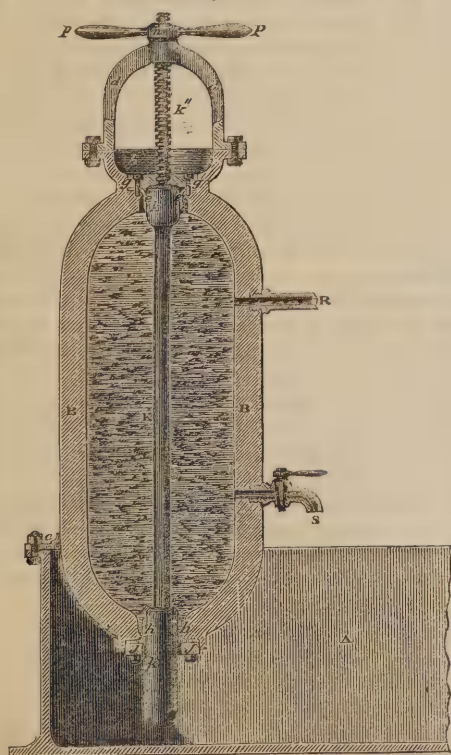
In cases where it is necessary to heat the bruised or ground seed during the process of expression, the pressing cylinder is made of larger diameter and of greater length, and the cistern, *a'*, is divided into two separate compartments, over both of which the pressing cylinder is to extend; a strong wrought-iron tube is inserted in its open end, and extends about half-way to the hopper, where it terminates in a solid pointed end. This tube occupies the centre of the pressing cylinder, and in the annular space around it are the ground seeds or other matters to be pressed. The temperature is raised to the required point by steam let into this iron tube, the end of which, extending beyond the cylinder, is securely attached to a bracket projecting from the bedplate, and is thus held firmly in its place, notwithstanding the force exerted against the pointed end. Thus arranged, the ground seed or other matters falling into the pressing cylinder, are thrust forward by the plunger, and give out a portion of oil in that state known as *cold drawn*, and which falls into the first compartment of the cistern, *a'*; the further progress of the meal along the pressing cylinder brings it in contact with the

pointed end of the heated tube, where it divides and passes along the annular space between the tube and the lining, and being thus spread into a thin cylindrical layer around the tube, it rapidly absorbs heat therefrom, and a second portion of oil is given off and received by the second compartment of the cistern, and thus the two operations of hot and cold pressing are carried on collaterally.

BESSEMER and HEYWOOD's patent further includes a method of treating oily and oleaginous substances for the extraction of their oil, in which the matters to be operated upon are subjected to the action of pressure in water, so as, after temporary admixture of the oil with water, to facilitate the separation of the oil from the matters containing them.

The apparatus used is represented in Fig. 376 in vertical section taken through the centre of the apparatus. It consists of a cast-iron cistern, A, having semicircular ends, and open on the upper side; at one end of it is a cylindrical vessel, B, with hemispherical ends. This vessel is of considerable strength, and should be capable of withstanding a pressure of five

Fig. 376.



thousand pounds to the square inch. It is held in an upright position by a flange, c, formed upon it, and extending round one half of its circumference. This flange rests upon a similar one formed around the upper side of the cistern, A, and is bolted thereto. At the upper part of the vessel, B, is formed a sort of basin, b, the edge of which supports an arch-shaped piece of iron, d. At the centre of the basin is an opening into the vessel, and a hydraulic cup leather, e, is secured

within the opening by means of the collar, g; in the bottom of the vessel, B, there is also an opening into which is fitted a cup leather, h, secured in its place by the ring j, which is firmly bolted to the vessel, B. A strong wrought-iron rod, K, extends from the top of the arch, d, down through the vessel, B, having two enlargements or bosses, k, k', formed upon it, which are fitted to the cup leathers. The upper part of the rod, K, has a screw formed upon it at K'', which passes through the boss, k, and enters the boss, n, in which a screw thread is formed. The boss, n, is provided with handles, p, by turning which the rod, K, may be raised or lowered when required. R is a pipe through which water may be injected into the vessel, B, by a force pump, such as is generally employed to work hydraulic presses. S is a cock whereby a portion of the contents of the vessel may be run off, and the pressure relieved when requisite. The two bosses, k and k', being of equal area, whatever pressure may be exerted within the vessel, B, it does not tend to lower or raise the rod, K, but, acting on the cup leathers, preserves the joint tight, and prevents the matters under pressure from leaking out. This form of apparatus is applied principally in the extraction of the portion of oil remaining in the *marc* or cake that has already undergone the first expression. For this purpose the cake is finely ground, and mixed with as much warm water, or water rendered slightly alkaline, as will reduce it to a semi-fluid state. This is then submitted to the action of the apparatus as follows:—The handles, p p, are turned round, and the boss, k, withdrawn from its opening, while the boss, k', which is much longer, still closes the lower aperture. The semi-fluid materials are then put into the basin, b, and fall from thence into the vessel, B, when it is fully charged. The rod is again lowered, and the communication with the hydraulic press pump is made by means of a tap attached to the pump, from which the water flows through the pipe, R, into the vessel, B, and thus, with a few strokes of the pump, the whole of the contents of this vessel will be subjected to the requisite pressure. An interval of a few minutes is allowed for the combination of the oil and water; the cock, s, is then opened, and a small portion of the fluid contents of the vessel allowed to escape into the cistern; the pressure being thus relieved, the handles, p p, are again turned, so as to lift the rod, K, sufficiently high to withdraw the boss, k', from the lower opening. The contents of the vessel, B, then flow out into the cistern, A, and the boss, k', being again lowered so as to close the lower aperture, the vessel may be refilled for another operation. The pressure thus brought upon the mixture of oleaginous matters and water will cause the oil therein contained to mix with the water, and the former may be afterwards separated from the milky-looking fluid, either by repose in suitable vessels, or by evaporation of the water by heat. If the oil is required for soap-making, the mixture of it with the water may be applied without separation. After the materials have been withdrawn from the cistern, A, and strained, the solid portions are again submitted to pressure, and from the expressed liquid the albumen is removed by boiling, and the oil separated as before.

H. W. WOOD, of London, some years ago invented a process for the extraction of certain oils from seeds, in which diluted acid is applied to the seed, previous to pressure; whereby, according to the patentee, the seed will part more thoroughly with the oil. The process is as follows:—During the grinding of the seed, it is regularly sprinkled with the dilute acid, in the proportion of two ounces of hydrochloric acid, of specific gravity 1.160, mixed with six and a quarter pounds of water to every hundred pounds of seed. The mixture of seed, acid, and water is permitted to stand for a longer or shorter period, depending on the quality of the seeds, usually not more than twelve hours. The mixture is then submitted to pressure in bags, the latter being placed alternately in the press with plates of iron. A hydraulic press is preferred. By this treatment, a more than ordinary quantity of oil is said to be obtained from a given weight of seed.

Amongst the great number of oils now known, there are several which are admirably suited for various purposes, but which nevertheless, on account of their price, depending usually on local circumstances, such as cost of freight, *et cetera*, are very little or not at all used by our manufacturers. Should, however, accidental circumstances at any time occasion an advance in the price of the more common oils, some of those above alluded to might be procured in large quantities, and would probably, in a short time, altogether supersede many of the oils now in use. Whilst, therefore, it is desirable to draw the attention of manufacturers and consumers to the numerous foreign and colonial oils not at present well known in this country, it is, at the same time, important to point out how greatly the value of such oils depends on the care bestowed on their preparation, especially as regards cleanness of the seeds, and the careful exclusion of impurity of all sorts in the process of extracting the oil.

PURIFICATION OF SEED OILS.—Many oils in their natural state are always more or less impure, and some of them so viscous as to be quite inapplicable to the lubrication of machinery, or to illuminating purposes, without previous purification. The impurities consist for the most part of albuminous, mucous, gelatinous, and coloring matters. A great part of the mucilaginous matters, and all bodies merely in a state of suspension, are deposited by repose for a sufficient length of time; but in order completely to clarify the oil, it is necessary to employ other means of depuration. The method most generally adopted is that suggested by THENARD. As already noticed, the concentrated acids exert a remarkably energetic action upon the combustible oils; if the power of these acids, however, is weakened by lessening the quantity used, the foreign matters in admixture are then chiefly affected. Sulphuric acid, for example, in the proportion of one or two per cent. of the oil, acts as a depurating agent, precipitating the mucilage and parenchymatous matters; first, by its powerful dehydrating action, it removes the water, by which these substances were held in solution in the oil, and afterwards chars the mucous matters themselves, thus either rendering them insoluble, or otherwise effecting their destruction. The oil itself is also to a certain extent acted upon: it

becomes green or dark brown, and after some time yields a deposit of the same color, becoming itself perfectly bright and clear. THENARD's purifying process is conducted as follows:—The oil, first heated to 100° or upwards, is placed in a convenient vessel, and from one to two per cent. of sulphuric acid is gradually poured in, with constant and violent agitation. As the action of the acid depends more or less upon the amount of contact between the two liquids, as well as upon the degree of heat, it is, of course, desirable to employ such an apparatus as will allow the easy and rapid admixture of the oil and acid. This is best supplied by an agitating tub, movable round its own axis, or it may be itself immovable, but with a movable fan in its axis. When, after continued agitation, the dark-colored fluid appears to consist of a clear liquid, holding flocculent matter in suspension, the action of the acid is terminated. This, however, is perceptible only after about twenty-four hours' repose. At the end of this period, a quantity of water, heated to 140°, and equal to about two-thirds of the oil, is added, and the mixture is agitated until it acquires a milky appearance. After several days' repose, the clarified oil rises to the surface of the mixture of acid and water, and the black flocculent matter forms a deposit beneath the two liquids. The oil, however carefully it may be decanted, always requires to be filtered to remove the matters still held in suspension. To effect this operation, the oil is drawn at once from the depositing tubs into vats with conical openings in the bottom stopped with cotton plugs, or it is passed through baskets lined with moss or carded cotton. The filtration is always a difficult operation, the plug-holes becoming quickly and repeatedly choked with the solid matters. A much better method is to pass the oil through a displacing funnel, the apertures in the diaphragm of which are furnished with filaments of carded wool or cotton. By some manufacturers a modification of THENARD's process is pursued, which consists in neutralizing the sulphuric acid by the addition of a mixture of chalk and water, or milk of lime. The operation is then concluded in a much shorter period, and the separation of the oil and water is far more complete.

The black deposit produced by the action of sulphuric acid, after having been heated and subjected to pressure, yields about eighty per cent. of oil, which, after clarification and filtration, is little inferior to the oil first obtained.

COGAN's modification of THENARD's method of purification is designed to obviate the difficulty of getting rid of the charred matter and excess of acid employed. Steam is the agent made use of; and by its judicious introduction the oil appears to be almost entirely freed from acid, and the black feculent dregs subside in the course of twelve hours, leaving the supernatant oil quite clear and greatly improved in color, and in those qualities for which it is valued by the painter. The two combined processes are conducted as follows:—The quantity of oil operated upon is about one hundred gallons. For this about ten pounds of sulphuric acid are required, and this is diluted with an equal bulk of water. To the oil, placed in a convenient vessel, one-third part of the dilute acid is added, and

the whole is carefully stirred for an hour or more with a wooden scoop, till the acid is thoroughly incorporated with the oil, and the latter has assumed a darker color. A second similar quantity of acid is then added and mixed with agitation as before, and after this, the remaining third of acid is poured in. The stirring is now continued incessantly for two hours more, when the color of the mixture resembles that of tar. It is allowed to stand at rest for twelve hours, and then transferred to a copper boiler. This latter has a steam pipe entering at the bottom, which divides into three or four branches, each terminating in a perforated plate. Steam is forced through this pipe, and, passing in a very divided state into the oil, penetrates into every part of it, and raises the temperature to 212°. The steaming process is continued for about six hours, at the end of which time the oil is transferred to a cooler, of the shape of an inverted cone, terminating in a short pipe, provided with a stopcock inserted in its side a few inches from the bottom. After standing twelve hours, the black watery acid liquor is withdrawn by opening the stopcock at the bottom. The clear and limpid oil is then drawn off by opening the tap in the side of the cooler. What remains below this cock is turbid, and this, being let out into a reservoir, is either clarified by subsidence, or mixed with the next portion of raw oil.

The quality of oils to be used for the lubrication of machinery, or for illuminating purposes, is much improved by the application of solution of tannin, by which the foreign matters are rendered more completely insoluble. In this process a strong infusion of nutgalls is mixed with the oil by agitation. After deposition the clear oil is decanted from the precipitate, and similarly treated with a solution of acetate of lead, acetate of alumina, or sulphate of zinc, to remove any excess of tannin. During these operations, the oil should be kept as near 70° as possible. The oil is afterwards dried by agitation with freshly-calcined sulphate of lime, or anhydrous carbonate of soda, which are allowed to deposit by rest. The addition of from five to ten per cent. of essential oil, or of a hydrocarbon—as mineral naphtha or oil of turpentine—to oils purified as above, renders them much more valuable as sources of light. They are intimately mixed either by agitation, or by passing the hydrocarbon in the state of vapor into the oil.

The treatment of oils and fatty matters, by submitting them to the action of streams of air or steam, is an efficient method of purification and bleaching. This mode of treatment was adopted by T. J. KNOWLYS of Lancaster, who, some years ago, obtained a patent for a process for clarifying and improving the quality of linseed and other oils to be applied in the manufacture of paints, varnishes, *et cetera*, by exposing the oil to the conjoint action of light and air. To this end the oil is first heated in the usual manner, or mixed with a portion of manganese or litharge, which are left to react upon it for a few days, and then separated by straining. The filtered oil is then exposed to the action of light and air, or steam, in a suitable vessel, and with constant agitation, so as to present continually a fresh surface.

OLIVE OIL.—*Huile d'olives*, French; *olivenöl*, *baumöl*, German; *oleum olivæ*, Latin.—Olive oil appears to have been known from the remotest antiquity. The olive tree—*olea europæa*—is one of the prettiest in nature. Very few vegetables have been so repeatedly noticed or so enthusiastically described by the ancient writers, and from the earliest ages it has been adopted as the emblem of benignity and peace.

The precise period of the discovery of olive oil, and of its application to the wants of man, is not recorded. It appears to have been known from the earliest times, since the method of producing it is mentioned by Moses, and what is very remarkable, it is, with slight variation, the process employed at the present day. It is obtained from the bluish or brownish green integument, or sarcocarp, of the fruit or olives. Several varieties of olives are met with in commerce, but the most common is the small French *olea europæa longifolia*, and the large Spanish *olea europæa latifolia*. The ingathering is performed in different ways, according to the kind of oil to be extracted. If the olives are gathered some time before they are ripe, they yield an oil with an acrid and bitter taste. When more ripe, but still before they arrive at maturity, the oil possesses the peculiar taste of the fruit, and may be preserved for a lengthened period without becoming rancid. When fully ripened, so as to drop from the trees, they yield a fine oil, but more fatty, and also more susceptible of change by exposure. November and December are the principal harvest months, and if allowed to remain longer on the trees, the olive gradually deteriorates, and yields an oil of very inferior quality. To obtain the finest oil, the olives should be gathered by hand, for if bruised, as in the usual method of beating the fruit from the trees with poles, unless used directly, they ferment, and the oil acquires a highly disagreeable odor and taste.

The process for procuring olive oil is somewhat modified in different countries, though the principle is the same in all, namely, for the purest, gentle pressure of the freshly gathered fruit in the cold; for common or second oil, stronger pressure, aided by partial fermentation of the olives, and the heat of boiling water; and for another still inferior kind, by boiling the husk or *marc*, after the preceding treatment, with water, when a mucilaginous oil rises and floats on the surface. All the varieties are left to repose for a month after being extracted, in order that the impurities may subside.

The following is the method pursued in the South of France:—The ripe olives are crushed in a mill of the most rude construction, comprising usually a single millstone turning in a circular bed; sometimes two millstones, placed wide enough apart not to crush the seeds. The workmen remove all the pulp when sufficiently crushed, and place it in rush sacks, which are heaped up, to the number of eighteen or twenty, on the platform of a press. This is also of a very rude description, and is only capable of a very slow and feeble pressure. The oil which first exudes from the bags, when the olives are of good quality, and the pressure is nicely regulated, is the variety known as salad oil, and is much in request for the supply of the table. After the first pres-

sure, the pulp still contains a considerable quantity of oil, so mixed with albuminous matters that it cannot flow out. To extract a portion of this oil, the press is taken apart, the cakes are broken up in the bags, and the nearly dry residue is digested with boiling water, and again pressed as before. The boiling water being absorbed causes the pulp to swell; the albumen coagulates, and the more fluid oil runs out freely. This operation is repeated two or three times. For the reception of the water containing the oil, two tanks are used, so arranged that in the one the liquids separate into two layers, whilst the other is filling. The upper layer, consisting of oil, is ladled off, and the water below, which still contains oil in suspension with mucus, is collected for further separation into a narrow and deep cistern, from which the water can be removed by a long siphon. After deposition of a portion of water, it is drawn from underneath, the cistern is again filled with a further quantity of the mixture, and when a sufficient quantity of oil swims on the surface, it is skimmed off, as oil of inferior quality. Owing to the imperfections of these processes, a quantity of oil still remains in the refuse in the bags, and the producers of oil find it worth while to submit it to a third operation. The large amount of time and labor consumed in the complete exhaustion, and the fact that the oil obtained is not of as good quality as it might be, has induced DUMAS to give his attention to this subject, and he has suggested several improvements in the old method of extraction. This eminent authority recommends, for the crushing of the olives, the use of mills of similar construction to those employed in the extraction of oil from seeds; and instead of the common presses, he proposes the employment of horizontal hydraulic presses, or of the wedge presses used to remove the oil from crushed seeds, by means of which the oil would be withdrawn more easily and rapidly, and the exhaustion would be much more complete.

The last operation, in the method usually employed, is as follows:—The cake or *marc*, after the second pressure, is immediately moistened with water, as a preventive of fermentation, which otherwise quickly ensues, and effects the destruction of the last traces of oil. The absorption of water is accelerated by heaping the moistened cake in layers in vats. The next step is the separation of the stones: this is effected by means of two machines, adjoining each other, and worked by the same motive power. The first consists of a vertical millstone turning in a pit of masonry or woodwork, through which flows a current of cold water. The cake passed through this is conveyed through a trap-door into the other machine of similar construction to the first, except that the crusher is heavier; and there is attached to the axle an arm, which serves to agitate the paste with the water. In this process the broken stones fall to the bottom, whilst the lighter parts, with the kernels of the seeds, rise to the surface, and are removed by means of hair sieves. These unctuous matters are dried over a fire, until they form a stiff paste, which is then submitted to pressure as before. The oil thus obtained is applied to lighting purposes, and in the manufacture of soap. By the adoption of

the improvements suggested by DUMAS, he considers that this last very tedious course of operations might be entirely dispensed with, and still the same quantity of oil would be obtained, and that of superior quality. Another very desirable improvement would be effected if the growers themselves would extract the oil, instead of, as is usually the case, sending the fruit to the common miller. At these mills they are often allowed to remain in heaps for some days, or until the mill is at liberty; from which cause the oil is of far inferior quality than would otherwise be obtained.

In Naples, the machinery employed by the peasants in the preparation of Gallipoli oil is of the rudest kind. The olives, when ripe, are allowed to drop from the trees, and are collected and conveyed to the mill, chiefly by women and children. The oil, when expressed, is inclosed in sheep or goat skins, and carried on mules to Gallipoli, where it is allowed to clarify in reservoirs cut in the rock on which the town is built, and its ultimate value depends, in a great measure, on the nature of this cistern. In point of fact, Gallipoli owes its celebrity to the facility of the formation of these cisterns, as in them the oil soon clarifies, and may be preserved for a lengthened period without becoming rancid.

The finest olive oil is of a pale yellow color, sometimes inclined to green. It has scarcely any smell, but a bland, mild, and agreeable taste; occasionally it has a nutty flavor, and when swallowed, leaves a slight sense of acrimony in the throat. It is insoluble in water, slightly soluble in alcohol, and in one and a half times its weight of ether. Its specific gravity is 0.910 at 60°. At 36° it deposits white granules, especially if heat has been applied in its extraction. At 22° it deposits twenty-eight per cent. of its weight of margarin, fusible again at 68°, and it yields also seventy-two per cent. of olein. Of the different kinds of olive oil met with in commerce, the produce of Aix, known as Provence oil, is the most esteemed. Florence oil, imported from Leghorn in flasks, packed in chests containing thirty of these, is a very fine kind, used for culinary purposes. Lucca oil is imported in jars holding nineteen gallons each. Gallipoli forms the largest proportion of that brought into this country, and is imported in casks. Puglia and Calabria are the provinces of Naples most celebrated for its production. Sicily oil is principally produced at Milazzo, and is of inferior quality. In some countries, and especially on the continent of Europe, olive oil constitutes an important article of diet. It is extensively used in England in the manufactures, and especially in the treatment of woollen cloths. The inferior kinds are much used in the production of soaps, particularly of the varieties known as Marseilles and Castile soaps. Being less liable to become thick and viscid by exposure to air, it is often used for oiling delicate machinery. For application to watch and clock work, the oil is refined by cooling, separating the fluid portion, immersing in it a slip of sheet lead, or some shot, and exposing it to direct sunlight in a corked phial, when a whitish matter gradually subsides, and the oil is rendered clear and colorless. This, when decanted, is fit for use.

PETER BANCROFT, of Liverpool, in 1846, patented a

process for purifying olive oil, which consists in treating the oil, heated to about 90°, with a strong solution of potassa or soda, either as carbonate or in the caustic condition, giving preference to the latter, as it operates more quickly. The specific gravity of the solution may be 1.2 or even stronger. The oil is kept constantly agitated during the addition of the alkali, and the operation is at an end when a small portion of the oil, placed in a glass bottle, and shaken with a further addition of solution of alkali, deposits only a clear liquid, free from soapy matters. The quantity of solution of alkali required varies from three and a half to eight per cent. The oil is decanted after deposition of the soapy matters, and passed through a filter. So treated, this oil is said to be very valuable as a lubricant for machinery.

Adulterations.—The superiority of olive over other kinds of oil, and its higher price, render it liable to adulteration with rape and poppy oils, and especially with lard oil—what is called *superfine* Lucca oil often containing as much as sixty or seventy per cent. of the latter. Several methods have been proposed to detect these sophistications. Poppy oil may be discovered by the phenomena of *beading*, or the appearance of a number of air bubbles on the surface after violent agitation of the oil, which are not produced with pure oil. GURBOURT recommended congelation, but this test is ineffective unless the adulterant is present in large quantity. The most reliable test is that suggested by POUTET, which depends upon the peculiar action of nitrous acid upon olive oil. A nitrate of mercury is prepared by dissolving six parts of quicksilver in seven and a half parts of nitric acid, of specific gravity 1.36, without applying heat. When one part of this freshly prepared solution is added to ten parts of pure olive oil, the mixture becomes concrete in the course of a few hours. The admixture of foreign oils prevents this congelation, so that the resulting mixture is more or less liquid in proportion to the quantity of the adulterant present. The twentieth part of poppy oil is easily detected by this method, but, in order to arrive at satisfactory results, a comparative experiment should be made with a mixture of oils of known composition. Other methods will be given when treating generally of the adulteration of oils and fats.

Physiological Effects.—According to Dr. BEAUMONT, olive oil is extremely nutritious, but rather difficult of digestion. However, when taken as a condiment with salad, it promotes the digestibility of the latter. In larger doses, olive oil acts as a gentle laxative, with freedom from pain. It is often administered in cases of irritant poisoning, as an emollient and demulcent, to shield the stomach from the action of acid and corrosive substances.

Statistics.—The quantity of olive oil imported annually, from the years 1844 to 1850 inclusive, was as follows:—

	Gallons.
1844.....	3,770,424
1845.....	3,103,380
1846.....	2,150,568
1847.....	2,190,384
1848.....	2,541,672
1849.....	4,274,928
1850.....	5,237,316

ALMOND OIL.—*Huile d'amandes*, French; *mandelöl*, German; *oleum amygdalæ*, Latin. This oil is obtained by expression from the seeds of the *amygdalus communis*, either sweet or bitter, usually from the latter, on account of their comparative cheapness, as well as of the greater value of the *marc* or pressed cake. Almonds were well known to the ancients, and are alluded to in the writings of MOSES—Genesis xliii. 11. HIPPOCRATES employed the expressed oil, as well as the almonds themselves, both sweet and bitter, in medicine. DIOSCORIDES describes the method of extracting the oil.

ROBIQUET discovered in bitter almonds from one to 2.5 per cent. of a peculiar principle not contained in the sweet variety. This principle, which is termed amygdalin, is a colorless, crystalline, nitrogenous body, with a bitter taste, and free from odor.

The fixed oil of almonds is obtained by expression from either kind; and if contact of water be carefully avoided, the oil from the bitter is quite as bland as that from the sweet variety. The almonds, previously cleansed of the adherent furz and dust by being well shaken and sifted, are bruised or coarsely powdered, and pressed in hempen cloths or bags, between iron plates, either cold, or, preferably, slightly and uniformly heated by hot water or steam. The yield of oil varies from twenty-eight to fifty-four per cent. When recently expressed, this oil is turbid, but by rest and subsidence becomes quite transparent. The mucilaginous matter should, however, be separated as quickly as possible, as it promotes rancidity; and the oil should be preserved in well-stopped bottles.

Almond oil is pale yellow and very fluid, inodorous when fresh, and of a faint oleaginous taste. It quickly becomes colorless by exposure to light. It remains fluid at a much lower temperature than olive oil, but at 14° it deposits twenty-four per cent. of concrete matter. Its specific gravity at 60° is about 0.918. Cold alcohol takes up about a twenty-fourth of its weight, and boiling alcohol a sixth. It is also very soluble in ether. Its principal use is in pharmacy, as an ingredient in emulsions, and occasionally in liniments, ointments, and soaps. As it contains less margarin than olive, it yields softer soap, and is better adapted to the preparation of oleic acid. The cake left after expression of the oil is sometimes ground, and is known as almond powder, and used as a detergent for preserving the skin soft and pliable.

Adulterations.—Commercial almond oil is frequently adulterated to a considerable extent with lard or olive oil; indeed, according to MORFIT, what is sold as the genuine article is often olive oil, merely flavored with that of almonds. According to PEREIRA, teal oil, or oil of *sesamum*, is occasionally substituted for almond oil, from which, however, it may be known by the deposit of margarin being formed much more readily than in oil of almonds.

Physiological Effects.—Almond, like olive oil, is highly nutritive, but difficult of digestion. It possesses also the medicinal as well as dietetical qualities of olive oil. In large doses it is a mild laxative. Its local action is emollient. It is employed medicinally for the same purposes as that of olive. Sometimes it is

administered to allay cough, or as a laxative, but, according to CHRISTISON, is not well adapted for either purpose. It is also used for outward friction, and for cosmetic soaps.

RAPE OIL.—This oil is prepared from the seeds of several species of the genus *brassica*, belonging to the family of *crucifera*, as the *brassica napus*, or winter rape, and the summer rape, or *brassica præcox*. Besides oil and woody fibre, these seeds contain a considerable quantity of mucus, albumen, and other allied substances. Only the driest possible seeds, such as have been stored for several months, and protected from moisture, are expressed. It is usual also to submit the seed to steam heat previous to pressure, as, if the albumen present is not completely coagulated the oil obtained is much less in quantity, and far inferior in quality, to that otherwise extracted. The very large proportion of fluid contents, other than oil, contained in fresh seed, constitutes the great difficulty in obtaining an average oil both as to quantity and quality; but by the above method of treatment this obstacle is overcome, and the oil expressed, containing only a trace of albumen, and a greatly-reduced proportion of mucus, becomes comparatively easy of purification. As newly expressed, even with every precaution, it is viscid, owing to the mucus and other foreign matters unavoidably present. These, and the coloring matter also retained by the oil, lessen its combustibility, and occasion much smoke during its burning.

Purification.—Rape oil is most conveniently depurated by the process recommended by THENARD, and already described. A two-hundredth part of sulphuric acid is added, and the mixture well agitated; it is then left at rest for about twenty-four hours, and afterwards shaken with two-thirds of its bulk of water at 160°. The emulsion thus produced, after standing about eight or ten days in a situation the temperature of which is maintained at 80°, separates into two portions, when the upper layer of clarified oil may be drawn off and filtered through a displacing funnel, the apertures in the diaphragm of which are furnished with filaments of carded wool or cotton, and is then fit for use. In this operation the coloring matter is deposited in the form of dark greenish flocculi, which, by the action of the sulphuric acid, are converted into an insoluble state.

Another mode of treating the several varieties of rape oil has been recommended by DEUTSCH, by which it is said to be rendered more applicable to the several manufacturing and other operations in which it is employed. His process is as follows:—The oil is placed in a copper pan or boiler, and fire-heat applied until the oil begins to be decomposed, when the heat is so regulated as to keep the oil in a uniform state of ebullition for about three or four hours. The spongy scum which separates, after a time begins to subside, whilst the oil becomes clear and transparent, and of a green color. The fire is then removed, and the oil is allowed to settle for one or two days, when the clear green oil is drawn off. If the oil has not acquired a green color, it is an indication that the process has not been well performed, or that the oil employed was of inferior quality. The several varieties of rape oil, after this treatment, may be advantageously employed

for the oiling of wool in the process of its manufacture, and they may also be employed for the lubrication of machinery. For the latter purpose, if it be desired to diminish its fluidity, a solution of caoutchouc obtained by boiling the latter in the oil, may be added to the oil, which should be heated and well stirred, to effect a uniform mixture. The oil may be rendered less fluid by mixing it with tallow or other grease.

WARBURTON'S method of effecting the purification of rape oil is by treatment with caustic alkali, in which the albuminous and other impurities are soluble, and are separated, associated with soapy matters. In a suitable vessel, containing fifty-two parts of caustic soda solution, of specific gravity 1.010, are to be put one hundred pounds of the refined oil; these are to be stirred with a wooden ladle till well mixed. The mixture is then allowed to stand twenty-four hours undisturbed, in a cold place, after which it is then slowly warmed, and again well stirred. After twenty-four hours' subsidence all the oil will have separated; if such should not be entirely the case, the complete separation may be effected by the addition of a small quantity of spirit of wine. The oil drawn off from the liquor is afterwards well washed with hot water, till the pure oil is obtained without taste or color, and if desired, may be passed through a filter. The soap which deposits may be used as an ordinary detergent.

Rape oil is of a light-yellow color and has a peculiar taste and smell. The smell becomes much stronger when the oil is heated; and the color darkens to greenish-yellow when the temperature is increased to 398°. The specific gravity of that from the *brassica napus* is 0.9128 at 60°, and from the *brassica rapa*, 0.9167. It contains forty-six per cent. of solid fat, which congeals at about 28°, but requires to be heated to about 43° before it again fuses. It is employed in the manufacture of woollen goods; in the preparation of some kinds of leather; for oiling machinery; in the production of soap; and also for burning. After purification from mucilage, *et cetera*, rape oil is said to be better suited for the lubrication of machinery than any other oil. It is now extensively used for locomotives, for marine engines, and also as lamp oil. According to Mr. BROTHERTON, a manufacturer of oils, good English-grown rape seed yields oil of superior quality to any foreign seed ever brought to his notice, and he consequently recommends its cultivation to agriculturists. The inferiority of the oil obtained from Indian or colonial seed probably depends, in a great measure, on the want of sufficient care being paid to the purity and cleanness of the seed itself, and not to any real deficiency in the oil.

Colza oil is extracted in the same manner as the preceding from another variety of seed of the same genus of plants—the *brassica campestris oleifera*. It is produced in France in large quantity, and is used for the same purpose as rape oil. It is of a yellow color, and nearly free from odor. Its specific gravity is 0.9136 at 60°. It congeals at about 22°. It is sparingly soluble in cold alcohol, but readily soluble in this fluid when assisted by heat. Colza oil is largely used for illuminating purposes, and may be burned without previous purification.

A Parisian, named NUERBERGER, in 1856, obtained a patent for the extraction of oil from the seeds of other genera of the order *crucifera*. This oil forms a substitute for colza oil, and may be used for lighting and other purposes. The three genera from which the oil may be procured, are the genus *thlaspi*, or shepherd's-purse; the genus *capsella*, or common shepherd's-purse; and the genus *iberis*, or candy tuft. The species *capsella bursa pastoris* yields the largest proportion of oil. The latter is obtained precisely as colza oil, and is also purified in the same manner.

Teel Oil, or Oil of Sesamum.—The plant yielding this oil, the *sesamum orientale*, is extensively cultivated throughout India for the sake of the fine oil expressed from its seeds. The latter are imported from Calcutta under the name of teal seeds. They are about the size of white mustard seeds. Three varieties are known—namely, the white, the colored, and the black. It is principally from the latter that the sesamum oil of commerce is obtained. The seed contains about forty-five per cent. of oil. This has been already mentioned as an adulterant of almond oil, and, according to PEREIRA, may be used as a substitute for the latter.

Oil of Behen or Ben.—This oil is obtained by expression from the decorticated seeds of the *mohringa aptera et oleifera*, a tree resembling a willow, and indigenous to Arabia and Syria, but cultivated also in the West Indies. The oil is colorless and inodorous, and has an agreeable flavor. By repose it separates into two portions, one thick and the other fluid at very low temperatures. The latter, as it resists the rancidifying action of the air, is highly valued for lubricating watch and clock work. The oil itself is much esteemed as an agent for the extraction of the delicate perfume of certain flowers by the process of maceration. It is also used as the base of macassar oil. Oil of ben contains a peculiar fat, named moringin, which, by saponification and decomposition of the soap, yields moringic acid. This acid is solid at 32°.

Beech Oil.—This oil is obtained from the nut of the *agus sylvatica*, or beech-tree. It is extracted either by cold or hot expression of the nut, previously decorticated. The per centage yield is about sixteen. The oil is of a clear, yellow color, is inodorous, but has a slightly acid taste, which, however, is dissipated by keeping or by ebullition with water. Its specific gravity is 0.9225 at 60°. At 29° it becomes solid. It is not well known in this country. In some districts of France, however, it is extensively used for culinary purposes, as well as for the production of soap and as a source of light. The cake remaining after expression of the bruised nut is useful as food for cattle.

Oil of Mustard.—This oil is procured by expression of the bruised seeds of the black or white mustard. The mustard plant—*sinapis*—of which there are several species, appears to be indigenous to this country. It was formerly cultivated in Durham, but is now grown principally in the neighborhood of York. In India and the East, mustard is cultivated solely for the sake of the fixed oil it contains. The seeds of black mustard were first analysed by THIBIERGE, and have been since examined among others by PELOUZE, ROBIQUET,

BUSSY, and FREMY. From their labors we learn that this seed contains myronate of potassa, myrosin, fatty, gummy, and coloring matters, a peculiar green matter, sugar, sinapisin, free acid, and salts. The proportion of oil is about twenty-eight per cent. of the seeds. According to the analysis of JOHN, white mustard seeds consist of an acrid volatile oil, yellow fat oil, brown resin, gum, extractive ligneous fibre, albumen, free phosphoric acid, and salts. ROBIQUET and BOUTRON, however, have proved that white mustard does not contain volatile oil, nor any substance capable of producing it. The yield of oil from white mustard seed is about thirty-six per cent. Oil of mustard is of a reddish or brownish yellow color, and is nearly inodorous. It has a thick oily consistence, and may be preserved for a lengthened period without becoming rancid. Its specific gravity is about 0.916. It requires one thousand parts of alcohol at 0.90 for solution, but dissolves in four parts of ether. By saponification glycerin is eliminated, and by decomposition of the soap produced, *erucic acid* is liberated. The formula for this acid is $C_{44}H_{41}O_3$, HO. It forms acicular crystals which fuse at 93°. Oil of mustard may be applied to the same purposes as rape oil; it has been used in the manufacture of soap, and also medicinally as a purgative and anthelmintic. The expressed mustard cake, owing to its acidity, is unfit for food for cattle, and is only useful as a manure.

Cocoa-Nut Oil is extracted from the kernels of the cocoa-palm—*cocos nucifera et butyracea*—either by expression or by ebullition with water. The cocoa-palm is a native of tropical countries, but does not thrive except near the coast. Five varieties are indigenous to Ceylon. The bark yields a peculiar oil used by the Cingalese in the form of ointment in cutaneous diseases. The nucleus or kernel of the cocoa-nut has been analysed by BRANDES, BUCHNER, and BIZIO, and according to the latter authority is composed as follows:—

	Centesimally
Oil,.....	71.488
Zymome,.....	7.665
Mucilage,.....	3.588
Crystallizable glycerin,.....	1.595
Yellow coloring matter,.....	0.325
Ligneous fibre,.....	14.950
Loss,.....	0.389

Albumen of cocoa-nut,100.000

In Malabar and Ceylon two methods of extracting the oil or *cocoa butter* are practised; the one is by pressure, the other by boiling the bruised nut, and skimming off the oil as it rises to the surface. The kernels of this palm are also brought to Europe, and the oil is extracted by the aid of heat, the fruit having been previously ground or cut into small pieces. The oil, as shown by TINDALL, consists of a fluid and a solid fat, which are most probably distinct and separate in the seeds, but become mixed under the press, and so much the more the higher the temperature is raised; so that fluid or solid fat, or such as is of medium consistence, may be obtained as desired, and according to the amount of pressure applied, and the temperature at which the operation is conducted. Commercial cocoa-nut oil is concrete at temperatures

below 69°, and at about 74° is fluid. The solid constituent of this oil varies from that of other oils, and is named cocostearin or cocosin. The principal use of cocoa-nut oil is in the manufacture of soap and candles. As a material for the production of soap, it is in many respects valuable, the soap being brilliant white, very hard and light, and to a larger extent soluble in saline and alkaline waters than most other soaps, and consequently useful for washing in salt water. Cocoa-nut oil has also been used as a therapeutic agent, and by some is considered little inferior to olive oil. On the continent of India, as well as in Ceylon, it is used as a pomatum for promoting the growth of, and preserving and softening the hair. It is stated also, that if it were perfumed, and used for this purpose by Europeans, its virtues would be displayed to such advantage as to insure its general use. Its odor, and the rapidity with which it becomes rancid, are, however, a great objection to its employment, either in medicine or as a pomatum. The olein of cocoa-nut oil, which remains liquid at ordinary temperatures, cannot be burned in an argand lamp of ordinary construction, in consequence of its charring the wick: with a view to cheapness, and to combustion in what is known as the solar lamps, it may be employed in admixture with spermaceti oil, but the latter is deteriorated in proportion to such addition. Cocoa-nut oil is a very complex fat, yielding, according to GEORGEY, no fewer than six acids on saponification. These acids are—

Caproic acid,	C ₁₂	H ₂₄	O ₂	HO
Caprylic acid,	C ₁₆	H ₃₂	O ₂	HO
Rutic acid,	C ₂₀	H ₄₀	O ₂	HO
Laurostearic acid,	C ₂₄	H ₄₈	O ₂	HO
Myristic acid,	C ₂₈	H ₅₆	O ₂	HO
Palmitic acid,	C ₃₂	H ₆₄	O ₂	HO

Cocosin or cocostearin is separated from the liquid portion of cocoa-nut oil by pressure, by ether, or by solution in boiling alcohol, from which the stearin crystallizes on cooling, exactly as in the case of ordinary stearin. Full information on this, and the acid prepared from it, will be found at page 410, vol. i.

Palm Oil.—This very important fatty oil is procured from the fruit of a species of palm—*avouira elais* or *elais guineensis*—cultivated on the west coast of Africa, and in tropical America. The fruit of the palm is about the size of a pigeon's egg, and of a deep orange yellow color. It consists of a hard stone, within which is the seed, and surrounding the nut is a fibrous, oily, yellow sarcocarp, or fleshy integument, from which, by boiling in water, the oil is separated, rises to the surface, and may easily be collected. Fresh palm oil has an orange-yellow tint, a sweetish taste, and possesses an odor somewhat resembling that of violets ororris root. It has the consistency of butter or lard, is lighter than water, and, by exposure to the air, quickly becomes rancid, and of a paler hue. Its melting point is variable, ranging from 76° to 95°, and is still further heightened by age. It is slightly soluble in cold, more readily in boiling alcohol, but is deposited from the latter on cooling. In ether, it dissolves in all proportions. Palm oil was once considered of no importance in the arts and manufactures. At the present time it is exported from one port on the

African coast to the amount of upwards of twenty thousand tons annually, in exchange for foreign produce; and the annual consumption of palm oil in this country is upwards of twenty-five thousand tons, which are imported in exchange for goods of British manufacture. As it occurs in commerce, palm oil is in a state of rancidity, containing fatty acids in their free state, instead of in combination with oxide of glyceryl. The characteristic orange color of this oil is to be attributed to the spontaneous decomposition of a peculiar principle of the palm, always associated with the oil. The various processes for the destruction of this principle have been referred to in the article CANDLE, and will be alluded to also in connection with the manufacture of soap. Palm oil is composed, according to STENHOUSE and FRÉMY, of margarin, olein, a peculiar fat named *palmitin*, and coloring matter. In addition to these, there are found in commercial palm oil, oleic, palmitic, and sebacic acids in the free state, and also free glycerin. The principal use of palm oil is, after admixture with other oils, in the production of soap and candles. In soap-making, the oil is used both bleached and as imported, according to the kind of soap required; in the candle manufacture, the solid constituent only is used, and is hardened by the addition of wax. In Africa, palm oil is employed by the natives as a kind of butter. In this country, it is occasionally used by way of friction in cases of bruises and sprains.

Palmitin.—This solid fat constitutes about two-thirds of the weight of palm oil. It may be obtained tolerably pure and in large quantities, by pressing palm oil at a temperature of from 50° to 54°, and repeating the operation at about 75°. As thus procured, it appears as a wax-like mass, and is used in the manufacture of a variety of stearin candles, whilst the yellow fluid oil is saponified. It is obtained pure by washing the residue of the second pressure with hot alcohol, dissolving it in hot ether, and crystallizing repeatedly till the melting point becomes constant. Palmitin is insoluble in water, and only very sparingly soluble in boiling absolute alcohol, but very readily dissolves in ether. It fuses at 118°, and congeals on cooling into a friable mass similar to wax. Besides palm oil, palmitin is contained in bees-wax, in cocoa nut oil, and, according to HEINTZ, also in human fat. STENHOUSE represents palmitin by the formula, C₃₅H₇₀O₂, and as being composed of palmitic acid and oxide of glyceryl.

Butter of Cacao.—This substance is the fatty matter of the chocolate nut. The *theobroma cacao* is the tree producing this nut, and is grown extensively in Demerara, Berbice, the West Indies, and South America. There are numerous species of this tree, bearing different kinds of fruit, both as to form, size, and the number of seeds which they contain. They vary also in the yield of oil, not only according to the species whence obtained, but also to the mode of treatment after being gathered and removed from the fruit. The average size of good nuts is that of the sweet almond, but rather more thick. Those from Caracas or New Granada, are especially remarkable for the large proportion of fatty matter they contain. Cocoa and chocolate are preparations of the nut of this tree, produced by roasting and grinding, and sometimes with

the addition of various other ingredients, as sugar, starch, gum, treacle, arrowroot, *et cetera*. LAMPADIUS analysed the kernel of the cacao nut, with the following results :—

	Per cent.
Fat oil,.....	53.10
Azotized substances,	16.70
Starch,.....	10.91
Gum,.....	7.75
Coloring matter,	2.01
Woody fibre,.....	0.90
Water,.....	5.28
Ash,.....	2.00
Loss,.....	1.35
	100.00

The chocolate nut also contains an alkaloid, discovered by WOSKRESENSKY, and termed *theobromine*. It is strikingly analogous to *caffein*, and especially remarkable for the large quantity of nitrogen it contains, amounting to 35.4 per cent. It is white, pulverulent, and of a bitter taste, and is nearly insoluble in water, alcohol, or ether.

Butter of cacao is obtained from the powdered kernels after being mixed with ten times their weight of boiling water, by expression in canvas bags, between heated iron plates. One pound of cacao yields from five to six ounces of oil. It is purified by long boiling with water, or on the small scale by boiling alcohol. The crude oil is yellowish and has the smell and taste of the nut. In the pure state it is colorless, inodorous, and tasteless. It is not liable to become rancid, and hence the great value of the nut as an article of diet. Its consistence is about that of tallow and its flavour rather agreeable. Its specific gravity is 0.91; its melting point about 120°. It is for the most part a crystalline combination of olein and stearin, fusing at about 85°. Cacao butter is readily soluble in hot alcohol, but is deposited on cooling. Ether also dissolves it. It may be employed in the manufacture of soap and candles. Cacao butter soda-soap is an agreeable toilet article for persons troubled with a rough skin or chopped hands. From its little liability to become rancid, cacao butter is peculiarly adapted to the preparation of such ointments as are to be kept for a length of time.

Laurel Oil.—This oil, termed also *oil of bays*, is imported from Trieste. It is procured from either the fresh or dried berries of the sweet bay—*laurus nobilis*. This plant is cultivated in the South of Europe, and bears a fruit of a bluish-black color, oval, and about the size of a small cherry. According to the analysis of BONASTRE, laurel berries have the following composition :—

	Per cent.
Volatile oil,.....	0.8
Laurin,	1.0
Fixed oil,	12.8
Stearin,	7.1
Resin,	1.6
Uncrystallizable sugar,	0.4
Gummy extractive,.....	17.2
Bassorin,.....	6.4
Starch,.....	25.9
Lignin,.....	18.8
Soluble albumen,.....	traces
Acid,	0.1
Water,.....	6.4
Salts,	1.5
	100.0

Laurel oil is obtained from the berries by boiling and by expression. According to DUHAMEL, the berries are bruised in a mortar, boiled for three hours in water, and then pressed in a canvas bag. The oil exudes with the decoction, and when cold, floats on the surface. The dried berries are steamed until thoroughly soaked, and then quickly pressed between heated iron plates. By the latter process they yield one-fifth of their weight of oil.

Laurel oil is of a greenish color, of the consistency of butter, and of a peculiar and characteristic smell. It melts at about 100°. It is partially soluble in alcohol, and completely so in ether. It consists for the most part of a peculiar variety of stearin, named *lauro-stearin*; the residue is a green liquid fat, probably olein. Laurel oil is saponifiable. It is occasionally employed in medicine as a stimulating liniment in sprains and bruises, and in paralysis. Its principal use, however, is in veterinary medicine.

Piney Tallow.—This fat is obtained from the seed of the *vateria indica*, a tree which is extensively grown on the coast of Malabar. The fat is not well-known in this country. A sample of it was shown in the Great Exhibition, and attracted much attention. To obtain it the seeds are boiled with water for some time, and on cooling, the concrete fat is removed. According to BABINGTON, its ultimate constituents are 77 of carbon, 12.3 of hydrogen, and 10.7 of oxygen. It is a white solid oil, fusible at 97°. It forms excellent material for soap and candles. Its great advantage over some other oils is, that the candles made of it do not give out suffocating acrid vapors when extinguished.

Butter of Nutmegs.—The fruit of the *myristica moschata* by expression yields this oil—known also as oil of mace. The nutmeg-tree grows to a height of twenty to twenty-five feet, and in appearance resembles a pear-tree. It is cultivated in the Moluccas, and in the East and West Indies. Several varieties of nutmegs are met with in commerce. Their principal consumption is for dietetical purposes. BONASTRE'S analysis of these nuts is as follows :—

	Per cent.
Volatile oil,.....	6.0
Liquid fat,	7.6
Solid fat,	24.0
Acid,	0.8
Starch,	2.4
Gum,.....	1.2
Lignin,.....	54.0
Loss,	4.0
	100.0

The process employed in the extraction of the fixed oil is bruising the nut to a paste, inclosing the mass in a bag, and submitting it for some time to the action of steam. The whole is then placed between heated metal plates, and subjected to long-continued expression. The yield of nutmeg butter is about twelve per cent. of the weight of the nuts employed. It is imported in oblong cakes, covered with leaves, and weighing about twelve ounces. It is of a reddish-yellow color, firm consistence, and possesses the agreeable smell and taste of the nutmeg. According to SCHRADER, this oil consists of fifty-two per cent. of a liquid, and forty-four per cent. of a solid fat, with four of volatile oil. The solid portion consists for the most

part of a peculiar fat, named *myristin*, or *sericin*. The liquid oil is yellowish or brownish, soluble in cold alcohol, and in ether. Butter of nutmegs is readily saponifiable. It is an article also of the *materia medica*, and is sometimes employed as an unguent in cases of rheumatism and palsy. A spurious kind is said to be occasionally met with, composed of lard which has been boiled with powdered nutmegs, and flavored with sassafras. It may be readily known from the genuine butter by its insolubility in boiling alcohol.

Some other varieties of solid oil are imported in small quantity from the East Indies, but are not of sufficient importance to call for detailed notice; certain it is, however, that should accidental circumstances at any time occasion a scarcity of the oils now generally applied to manufacturing purposes, an almost inexhaustible supply of them might be obtained with little difficulty, and would probably replace the more common oils, without disadvantage either to the manufacturer or the consumer.

DRYING OILS.—The drying oils differ from those above described, by their peculiar behavior on exposure to the air, and also, as previously noticed, by the difference in their behavior under the influence of nitrous acid. The cause of the singular property of drying in contact with atmospheric air is not distinctly understood, but is usually attributed to some peculiarity in their olein.

LINSEED OIL.—This, the most important of the drying oils, is obtained by expression from the seeds of the common flax, *linum usitatissimum*. This plant is extensively cultivated in this, as well as other European countries, both for its fibre, used in producing thread, and for the oil obtained from its seeds. It is said to be a native of Britain, and yet it appears that flax-seed was not sown in England till about 1533, when it was directed to be sown for the production of flax for the manufacture of fishing nets. The seeds, commonly termed lintseed or linseed, are small, oblong, smooth, and pointed at one extremity. Externally, they are of a glossy brown color; and internally, yellowish white. Their taste is oily and mucilaginous. The mucilage, however, for the most part exists in the seed coats, and not in the nucleus, the latter being the richest in oil. The following analysis of linseed is by MEYER:—

	Per cent.
Fat oil,.....	11.265
Wax,.....	0.146
Acrid soft resin,.....	2.488
Resinous coloring matter,.....	0.550
Yellow extractive and tannin,.....	1.917
Sweet extractive, malic acid, and salts,.....	10.884
Gum,.....	6.154
Nitrogenous mucilage, acetic acid, and salts,.....	15.120
Starch, with salts,.....	1.480
Albumen,.....	2.782
Gluten,.....	2.932
Husk,.....	44.382
	100.000

According to GMELIN, the ashes contain oxide of copper. The proportion of fat oil contained in the seed is certainly much greater than that given in the preceding analysis; for, by expression in the cold, the yield of oil is from twenty-one to twenty-two per cent. of the seeds, and by the assistance of heat, combined

with a more powerful and long-continued pressure, as much as twenty-eight per cent. may be obtained. If a very pure oil be required, the process of cold expression must be pursued; a very good oil, however, may be obtained by a steam heat, not exceeding 200°. The ordinary method of getting rid of the large quantity of mucilage is by torrefaction, after which the seeds are bruised and submitted to pressure. The *marc* remaining after the expression of linseed oil is generally known as *oil cake*, and is an article of great importance to the agriculturist, being extensively employed, especially in the winter season, as food for cattle. By far the best oil cake is that from English seed. Independent of its use as an article of food, oil cake is an excellent medicine for cattle, as a preventive of constipation, besides which, it gives to the hide a *sweetness of coat* unattainable by other means. Foreign oil cake is certainly largely adulterated with the husks of other seeds, and many circumstances seem to lead to the conclusion, that the adulterant has been added previous to the expression of the seed. In this case, of course, foreign linseed oil must also contain spurious admixture, and will be less valuable as a drying oil than that expressed in this country. As regards oil cake, the consumer is assured that he will best consult his own interest by, in every case, submitting a sample to the inspection of a competent chemist previous to purchasing, for, in addition to the admixture of less nutritious seed coats, as bran, *et cetera*, many other positively injurious substances, as sawdust, clay, and other earthy matters, are frequently found in English, as well as foreign cake; and, in a case recently brought to the notice of the Editor, in which some sheep had died suddenly, the only cause to which death could be attributed was the enormous quantity of *sand* which he found in the stomach, and which the Editor considered could only have been introduced therein in admixture with the cake given as food.

The linseed meal—*farina lini*—of the Edinburgh Pharmacopœia, is powdered oil cake, and is frequently employed in this country as an emollient poultice. In this state also, it is often adulterated with bran, sawdust, *et cetera*. NORMANDY gives as a test of the genuineness of linseed meal, that when treated with ether it should yield fifty-three per cent. of oil. This, however, is manifestly a mistake. Linseed itself contains less than thirty per cent. of oil, of which, in most cases, twenty-five are extracted by expression, so that it will rarely happen that more than five or six per cent. at the utmost can be present in official linseed meal. Some medical practitioners prefer what they suppose to be simply powdered linseed, but which, in reality, is powdered oil cake, subsequently mixed with a greater or less quantity of oil. In this case, of course, a larger proportion of oil may be found on examination, but it by no means follows that meal containing less than fifty-three per cent. of oil should be designated as spurious. But to return from this digression to the consideration of oil of linseed. If extracted by cold expression, when it is termed *cold drawn* linseed oil, it is paler colored, less odorous, and has less taste, than that obtained by the aid of heat. In the latter case, the oil is of an amber or brownish-yellow color, and

also more susceptible of rancidity than when cold drawn. The smell and taste of linseed oil is highly characteristic and peculiar to itself. Its specific gravity, according to SAUSSURE, is 0.9395 at 52°. It dissolves in five parts of boiling, and forty of cold alcohol, and in about one and a half times its volume of ether. According to SACC it consists of one equivalent of margarate of glyceryl, and ten equivalents of a peculiar fat, termed *linolein*. If cooled down to about minus 20°, it may be kept some time without suffering any important change. After the expiration of a longer or shorter period, however, dependent upon the precise temperature, it becomes darker-colored and deposits a portion of its solid constituent along with coloring matter; at a few degrees lower, it becomes entirely converted into a concrete yellow mass. Linseed oil may be completely decolorized by the action upon it of protosulphate of iron in conjunction with sunlight. A solution of two pounds of the salt in two and a half pounds of water, is poured into a flask containing two pounds of linseed oil, and the whole is submitted to sunlight for some weeks with frequent agitation. The oil becomes limpid and colorless, and may be drawn off by a siphon or otherwise.

Linseed oil is most largely used in the manufacture of paints and varnishes. Its drying properties, as previously remarked, are much increased by boiling with a small quantity of litharge, or of peroxide of manganese. It is used also in the preparation of printers' ink, in the preparation of black enamel for leather, and in the varnishing of oiled silk. For the finer purposes of art, it is purified and decolorized as above directed. In white-lead works, linseed oil is bleached by sulphuric acid, and the small portion of acid always remaining in the oil after this operation, has the good effect—by converting into sulphate any hydrate of lead that may be present in the white-lead with which it is ground—of preventing the production of the yellow higher oxide when the paint is exposed to the air. A method of purification especially to be recommended when the oil is to be used in the preparation of varnish, is to triturate the oil with dry sulphate of lead in sufficient quantity to form a milky mixture. After a week's exposure to light, and with frequent agitation, the mucus and parenchymatous matters deposit with the sulphate of lead, and leave the oil perfectly clear. The oil will then, after some time, become quite white. The precipitated matters form a compact membrane above the salt of lead, and become so hard that the supernatant clarified oil may be poured off. The lead sediment may again be used for the same purpose. Varnish so prepared is especially valuable in those cases where the presence of a salt of lead would be injurious—as for instance with lac colors, with sulphide of cadmium, and other pigments containing sulphur. When long kept in a bottle only half filled with it, the linseed oil becomes more thick, and does not dry as well as before. By this treatment, however, it acquires the property of comparatively ready solubility in alcohol, and is therefore added with advantage to several spirit varnishes to diminish their brittleness.

The substance known as *caoutchouc* of oils is obtained from linseed oil as follows:—The oil is exposed for some time, as in the preparation of printers' ink, to a

high temperature, when it becomes converted into a dark tenacious mass. If this be boiled for some hours with dilute nitric acid, it acquires a thick consistency, and becomes hard on exposure to the air, but softens again by the heat of boiling water, and again hardens to a consistency resembling that of caoutchouc, for which, indeed, it may in some instances be substituted. This singular body is soluble in oil of turpentine, in bisulphide of carbon, and in dilute alkaline solutions; from the latter it is thrown down unaltered on the addition of an acid. Other drying oils, beside linseed, yield a similar substance, though not so abundantly. Linseed oil is frequently adulterated with resin or colophony. This may be detected by digesting the oil with alcohol, decanting the latter, and adding acetate of lead, when the appearance of a white precipitate is indicative of this falsification.

By digestion with alkalies or with metallic oxides, linseed oil is easily saponified. The proportion of oxide of glyceryl in this oil is greater than in most other oils, and hence, by far the most advantageous method of preparing glycerin, is by moderately heating this oil with oxide of lead.

Walnut Oil.—This drying oil is derived from the kernels of the *juglans regia*, or walnuts. The nuts are freed from their ligneous shells, inclosed in bags, and submitted either to cold or hot pressure. That prepared by hot pressure has a peculiar taste and smell, the latter being especially recognizable during its combustion. The oil obtained by cold expression is pale, yellowish-green or almost colorless, has an agreeable odor and taste and a sirupy consistency. If colored, it loses the greenish hue after some time. It congeals at about the same temperature as linseed oil, and possesses the property of drying by exposure in even a higher degree than the latter. In drying, it absorbs fifteen and a half times its volume of oxygen, at the same time giving off carbonic acid to the amount of two-fifteenths of the oxygen absorbed. The hot-pressed oil is usually high colored, has a powerful odor, and contains large quantities of mucilage. The specific gravity of walnut oil, according to SAUSSURE, is 0.9283 at 52°; 0.9194 at 76°; and 0.874 at 200°.

It is principally used in painting, and by varnishers, and being comparatively clear and colorless, is especially valuable as the vehicle for flake white, and other pigments, when it is desired to preserve the brilliancy of their tints. When fresh, it is occasionally employed for culinary purposes, but when rancid, it is purgative. Sometimes also it is employed as a source of light.

Poppy Oil.—The seeds of the poppy—*papaver somniferum*—yield this oil by expression. This plant appears to grow wild in some parts of Great Britain. It is extensively cultivated in Hindostan, Persia, Asia Minor, and Egypt, on account of the opium obtained from it. In Europe, the poppy is cultivated for the capsules or *poppy heads*, either as medicinal agents, or for the oil obtained from their seeds. No analysis of the seeds appears to have been made. Poppy oil is whitish-yellow, inodorous, with an agreeable almond flavor; it much resembles olive oil, for which, as already noticed, it is sometimes used as an adulterant. When pure, it is much less viscous than most oils, and remains liquid

even to 0°. Its specific gravity is 0.9249 at 60°. It is soluble in about twenty-five parts of cold, and six of boiling alcohol, and in ether in all proportions. It is used as a means of detecting the presence of spirit of turpentine in essential oil. In France and on the Continent, it is frequently used for culinary purposes, as a substitute for olive oil. When its drying properties are increased by treatment with litharge, it is frequently used in painting. It is employed also for illuminating purposes.

Hemp-seed Oil.—This oil is extracted from the seeds of common hemp—*cannabis sativa*. The plant grows wild in Persia, Caucasus, and the North of India. It is cultivated in various other countries. The seeds are small, ash-colored, shining, nut-like bodies. They are employed for feeding cage birds, and, according to BURNETT, possess the singular property of changing the color of the plumage of bullfinches and goldfinches from red and yellow to black, if the birds are fed on the seeds for too long a time, or in too large a quantity. The following is their composition as obtained by BUCHOLZ :—

	Per cent.
Fixed oil,.....	19.10
Resin,.....	1.60
Sugar and extractive,.....	1.60
Gummy extract,.....	9.00
Soluble albumen,.....	24.70
Ligneous fibre,.....	5.00
Husk,.....	38.30
Loss,.....	0.70
	100.0

The oil is extracted principally in Russia. The yield is stated by PEREIRA to amount to twenty-five per cent. of the seeds. This, however, is only in extreme cases, the quantity usually obtained rarely exceeding from fifteen to twenty per cent. The oil has a greenish-yellow tinge, a disagreeable smell, and a mawkish taste. The specific gravity at 52° is 0.9276; at 5° it becomes thicker, and at *minus* 16° it is solid. It is readily soluble in boiling alcohol, and in about thirty parts of this spirit when cold. It is used in painting, and in the preparation of a soft soap. It is occasionally employed in Russia as a source of light, but is apt to form a viscid adherent varnish, which impedes its passage through the lamp.

CASTOR OIL.—*Huile de ricin*, French; *ricinusöl*, German; *oleum ricini*, Latin. This oil is extracted from the seeds of the *palma christi*, or common ricinus, which is cultivated in the East and West Indies, and in the United States of America.

The plant yielding it was known in the most ancient times; indeed many suppose the plant called the *gourd*, mentioned in JONAH, to be the same as that now recognized as the castor oil plant. The Egyptians were certainly acquainted with it, as CAILLAUD discovered its seeds in some Egyptian sarcophagi, conjectured to have been upwards of four thousand years old. It was known to the ancient Greeks, and is alluded to by HERODOTUS and HIPPOCRATES, the latter of whom employed its root in medicine. The Latins gave it the name of *ricinus*, whence its botanical appellation. In this country the *ricinus communis* is an annual, and seldom exceeds four feet in height. In other countries

it is said to be perennial, arborescent, growing to the height of fifteen or twenty feet, and of many years' duration. It has large vine-shaped leaves, green spikes of flowers, and rough capsules containing ovate shining black seeds, spotted with grey. The subjoined analysis of the seeds of this plant is by GEIGER :—

	Per cent.
Seed coats,.....	{ Resin and extractive,.... 1.91
	{ Brown gum,..... 1.91
	{ Ligneous fibre,..... 20.00
Nuclei of the seeds,...	{ Fatty oil,..... 46.19
	{ Gum,..... 2.40
	{ Albumen,..... 0.50
	{ Ligneous fibre and starch, 20.00
Moisture,.....	7.09
	100.00

In opposition to GEIGER's results, BUCHANAN states that the residue freed from oil consists for the greater part of emulsion, is not colored blue by iodine, and instead of starch contains sugar; for an emulsion of castor seeds, mixed with yeast, undergoes the alcoholic fermentation at a low temperature.

Extraction of the Oil.—Various methods have been adopted for the preparation of castor oil. The expression of the seeds in the cold, though a more tedious process, yields a much superior oil to that obtained when the pressure is assisted by heat. Previous to expression the seeds should be deprived of the outer coating or shell, when they yield an oil nearly colorless, or with a slight yellow tint.

According to SOUBEIRAN, BUSSY, and LECANU, all processes in which heat is employed are objectionable, as the oil is rendered acrid from the liberation of fatty acids. In the American Dispensatory, on the contrary, the application of heat is stated to improve the oil by volatilizing a disagreeable acrid principle; and hence the almost universal practice in America is first to submit the seeds to gentle torrefaction, the heat being insufficient to scorch or decompose them. They are then introduced into a powerful screw press, and submitted to pressure. A whitish oily liquid exudes, which is boiled with a considerable quantity of water in iron boilers, and the impurities skimmed off as they rise to the surface. The coagulated albumen forms a layer between the oil and the water, and the starch and gum are retained in solution in the water. The clear oil is next drawn off and boiled with a small quantity of water until aqueous vapor ceases to rise, and till a small portion of the liquid taken out in a phial preserves a perfect transparency on cooling. The effect of the latter operation is to clarify the oil, and render it less irritating, by driving off volatile acrid matter, the quantity of which is doubtless much increased by the process of torrefaction to which the seeds are subjected. The process of cold expression, purification by subsidence and decantation, is also employed in America, though on a much less extensive scale.

In England castor oil is expressed by BRAMAH's hydraulic press, or by the common screw press, in a room artificially heated. It is purified by rest, decantation, and filtration, and bleached by exposure to light on the tops of warehouses. In Calcutta, according to PEREIRA, the process is as follows :—The fruit is shelled by women; the seeds are bruised between rollers, then placed in hempen cloths, and pressed in

the ordinary screw or hydraulic press. The oil thus procured is subsequently heated to 212° with water, in a tin boiler, by which the albumen is coagulated, and, with the mucilage, separates as a scum. The oil is then passed through flannel, and run into square tin cases. The best oil of this variety is sold in London as *cold-drawn castor oil*. According to AINSLIE castor oil is obtained in the East Indies also by decoction, and this process is likewise pursued in the West Indies.

The process of FIGUIER is now followed on the Continent of Europe on a considerable scale. It consists in mixing the seeds, first deprived of their outer coating and bruised into a paste, with alcohol. This mixture is inclosed in canvas bags, and submitted to pressure. Part of the alcohol is recovered by distillation of the mixture of oil and spirit; the residue is then mixed with a large quantity of water, when the oil rises to the surface, and is drawn off. It is again heated to remove traces of moisture and then filtered. This process is more expensive than those previously given, and the product is inferior.

After its arrival in this country, foreign castor oil is filtered, and bleached by exposure to solar light on the tops of warehouses. Of the several varieties met with in commerce, the East Indian castor oil is the most abundant. It is an oil, in every respect, of good quality, but inferior to English cold-drawn oil. American oil rarely finds its way into this country. It has a less acrid taste than the East Indian variety, but is objected to because at a low temperature it congeals quickly, deposits a white substance termed margaritin, and becomes opaque.

Properties.—When very pure, castor oil is a thickish, viscid fluid of a bright yellow hue, with a slightly nauseous smell, and a mild, somewhat sweetish taste, succeeded by a slight sense of acrimony. The oil of commerce is, however, frequently of a greenish, and occasionally of a brownish color, with a hot acrid taste. Its specific gravity is, according to SAUSSURE, 0.9801 at 49°; 0.9699 at 52°; and 0.9575 at 76°; and is, consequently, heavier than most other fixed oils. Its composition and properties are essentially different from those of other oils. It is soluble in absolute alcohol in all proportions. Spirit of wine, of specific gravity 0.8425, dissolves about three-fifths of its weight. It is also readily soluble in ether. This oil forms the connecting link between the siccative and non-drying oils. By long exposure to the air it becomes rancid, but gradually hardens without becoming opaque. It retains its fluidity even at a temperature of 0°. At a lower degree, it congeals into a transparent yellowish mass. The action of heat upon castor oil has been particularly investigated by BUSSY and LECANU. When heated in a retort, so as to distil over about one-third, there remains a substance, solid at ordinary temperatures, having the appearance of a yellowish porous body resembling caoutchouc. It requires a high temperature for its decomposition, and is easily inflammable, without undergoing fusion. It is insoluble in water, alcohol, ether, and in the fixed and volatile oils. The alkalies convert it into a species of soluble soap. The products of distillation are a little gas, and a liquid containing acetic, ricinic, ricinoleic, and margaritic acids, and an

odorless, colorless, volatile oil, which crystallizes on cooling.

Adulteration.—Castor oil is said to be frequently adulterated with other fixed oils, and especially with lard oil. For the detection of this falsification, the Edinburgh Pharmacopœia directs that it be examined as to its solubility in alcohol, which dissolves its own volume of castor oil. This test, however, is of no practical value, as the solubility of other fixed oils is greatly increased by admixture with castor oil, and even a third of its weight of another oil may be present, and still a perfect solution be obtained with an equal volume of alcohol. Of the different kinds of genuine oil, English is, according to PEREIRA, the most soluble, and East Indian, the least soluble, in rectified spirit. A far more dangerous fraud than the above, is the occasional one of adding a small proportion of *croton* oil, with the view of increasing its purgative activity, and this, unfortunately, is not of easy detection.

Physiological Effects.—On animals generally, castor oil acts as a laxative or gentle purgative. Its great advantage over other purgatives is the rapidity of its action—usually not more than two or three hours after its exhibition. It not unfrequently occasions nausea, or even vomiting, but this effect is rather to be attributed to its disgusting flavor than to any positively emetic property. Some continental writers have stated it to be very unequal in its action, sometimes operating with considerable violence, and at others with great mildness. This is not found to be the case in this country, though PEREIRA readily admits that a difference in the mode of its preparation may materially affect its aperient property. As obtained by boiling, it is deeper colored, more acrid, and more susceptible of rancidity, than the cold drawn oil, and at the same time is undoubtedly possessed of more active properties. The bleaching process, although it removes color and taste, is also injurious to the oil, often rendering it almost inactive; and therefore, medicinally, the pale straw-colored oil—not absolutely tasteless, and with a certain degree of smell—is to be preferred. Castor oil is employed principally in cases of inflammation of the stomach, in spasmodic affections of the bowels, especially in lead colic, in other internal inflammatory and spasmodic diseases, and as a purgative in habitual costiveness. The dose is from two drams to two ounces, and it may be taken swimming on the surface of milk or coffee, warmed and beaten up with the yolk of egg or mucilage of tragacanth, or with the addition of a little orange wine. The vessel from which it is taken should be previously warmed, and moistened with water or other liquid. The nauseous clammy taste is most easily removed by masticating a crust of bread or a little oatmeal.

Statistics.—The quantity of castor oil imported annually during a period of seven years was as follows:—

	Pounds.
1843,.....	1,051,792
1844,.....	1,223,264
1845,.....	1,801,632
1846,.....	1,487,168
1847,.....	451,584
1848,.....	513,856
1849,.....	1,084,272

Grape-seed Oil.—This oil, called also *oil of wine-stones*, is extracted by pressure from the seeds of the grape—*vitis vinifera*. The yield is sometimes to the amount of twenty-two per cent. Its color is at first pale-yellow, but after some time it assumes a darker tint, and becomes at the same time viscous, thick, and rancid. When fresh and pure it has little odor, and a very mild taste, and hence is useful for culinary purposes. Its specific gravity is 0.9202 at 59°. It is used principally as an article of diet.

Cotton-seed Oil.—The seeds of the cotton plant—*gossypium barbadense*—yield an oil which may at no distant period become an important article of commerce. The plant is grown principally in the Southern part of the United States of America, but also in India, China, and other warm climates. Owing to the enormous quantity of cotton annually produced, there must always be an abundance of seed, which it is desirable to convert to some useful purpose. The subject has long engaged the attention of parties interested in the promotion of the useful arts. Even so far back as 1785, the Society for the Encouragement of Arts and Commerce offered a prize for the manufacture of oil from cotton-seed on the large scale, but no successful claimant has yet appeared. It has, however, been extracted to a certain extent in Egypt, America, and India. The great difficulty in the way of its introduction appears to have been that of effecting its purification. Of late years, this oil has attracted a greater share of attention, and means have been devised of purifying it, and removing the dark color which it possesses in the raw state. Even now, however, large quantities of cotton-seed are annually destroyed, as far more is produced than is required for the crop of the succeeding year, and this has hitherto, for the most part, been thrown away as useless, or in some cases applied as a manure; still it is now in some solitary instances collected and exported for the manufacture of oil and oil-cake. A sample of the oil and expressed cake were shown in the Great Exhibition by R. BURN of Edinburgh, and of raw and bleached oil by DE GÉMINY of Marseilles, to whom prize medals were awarded. The latter was from Egyptian seed.

Croton Oil.—This acrid oil is extracted from the seeds of the *croton tiglium*, and is imported from Madras and Bombay. In size and shape these seeds much resemble castor-seeds. They have no smell; their taste is at first mild and oleaginous, afterwards hot and acrid. Besides BRANDE, PELLETIER, and CAVENTOU, Dr. NIMMO also examined them. The result of BRANDE'S analysis is subjoined:—

Volatile oil,	traces.
Fixed oil, with crotonic acid and crotonin,	17.00
Crotonates and coloring matter,	0.32
Brownish-yellow resin,	1.00
Stearin and wax,	0.65
Extractive, sugar and malates of potassa and lime,	2.05
Starch, with phosphate of lime and mag- nesia,	5.71
Gum and gummosin,	10.17
Albumen,	1.01
Gluten,	2.00
Seed coats and ligneous fibre,	39.00
Water,	22.09
	100.00

Croton oil is extracted by expression from its seeds. That of the shops is very impure, being a mixture of the oil with other constituents of the seeds. DUMAS gives the process for obtaining it as follows:—The crushed seeds are submitted to the press, and the oil that flows out is allowed to stand from twelve to fifteen days to deposit; it is then drawn off and filtered. The expressed cake is treated with twice its weight of rectified spirit, and heated in the salt-water bath. The alcohol dissolves a large quantity of the oil remaining in the *marc*, and is separated from it by evaporation. Sometimes, the seed, freed from their husks, are pulverized and treated at once with spirit; the mixture is heated in the salt-water bath, allowed to cool, inclosed in a bag, and pressed. The alcohol is afterwards removed from the oil by distillation. Croton oil is of a brownish-yellow color, has a very disagreeable characteristic odor, and a strongly acrid taste. It is soluble in alcohol and in ether. In doses of one drop, it operates on man as a violent purgative. It appears to consist of a mixture of a fatty oil with another very acrid substance, very soluble in cold alcohol, and containing a large quantity of crotonic acid, both free and in combination with oxide of glyceryl, and with magnesia. The combination of the acid with the latter base was supposed by BRANDE to be a peculiar alkaloid.

ANIMAL OILS.—It is unnecessary again to allude to the origin and formation of animal fats, the various theories concerning which have been previously fully detailed and discussed. It will be sufficient to say here that by far the greatest proportion of the fat of animals is the result of the deoxidation of the amylaceous principles of vegetal food, and that the fat originally formed and existing in vegetal food also accumulates, undergoing considerable modification in the animal body. Hence the fat of the *herbivora* is that which most closely resembles the fat of vegetables; and the fat of the *carnivora*, having undergone a still further modification in the animal body, is that which most widely differs from vegetal oils. It has also been already noticed in what part of the animal fat is for the most part secreted. It is contained in what is termed adipose membrane, and may be obtained by exposure to a sufficiently high temperature to liquefy the fat, and tear asunder its including cells. To assist the operation, the fat should be divided into small pieces, so as to allow the more uniform influence of heat; and it is important that the melting process be performed before any putrefaction of the membrane, or of other fibrous and fleshy accidentally adhering matters, has taken place. The fat is usually melted in an open copper exposed to the direct action of the fire, and after fusing for a considerable time, the membranous matters collect at the surface. These are removed, and after having been pressed to remove adhering oil, they form *greaves*, sometimes termed also *cracklings*, from their crispy nature, and in the form of flat cakes are sold as food for dogs, as manure, and for the production of yellow prussiate of potassa. The melted fat is passed through a sieve into another copper, where it is washed with a quantity of boiling water. The impurities settle down with the water, and the fat is drawn off into tubs and allowed to cool.

In France, and on the Continent, another method is adopted for the separation of fatty matters from the cells or tissues in which they are confined. The fatty matter is placed in contact with very dilute sulphuric acid for a few days, after which the fat is removed from the macerating vessel, and with the addition of about half its weight of a little stronger acid, put into a suitable wooden vessel, and subjected to a jet of steam, which soon causes the whole to boil. Under the influence of heat and of the dilute acid, the albuminous tissue which envelopes the fatty matter is rapidly destroyed, and the latter set free floats on the surface of the boiling water; after which the jet of steam is stopped, and the liquid fat is drawn off into a proper receiver. The addition of a little strong acid again prepares the melting-vessels to receive a new charge of the digested fat, which may also be drawn off after a short time. Larger pans are required in this operation than in the former, to perform the same amount of work; but the work is done more quickly. The animal matters remaining in the pan can be used as manure, or, after mixing with a little sawdust, as fuel. By this method, also, the operation of fat-melting is rendered perfectly safe, and the highly disagreeable odor characterizing the vicinity of establishments devoted to this purpose, is entirely removed.

The variable consistency, color, and odor of the different fats depends for the most part upon the kind of animal whence obtained, its climate, and its food; but male animals generally yield a firmer fat than female. A good quality of fat can come only from a healthy animal, and winter fat is better than that taken in summer. According to WATT, the fat of an animal is more solid the further it exists from the surface of the body; and the delicacy of the cellular tissue enveloping the fat is in proportion to the consistency of the latter. He is of opinion also that the fat of animals in temperate and tropical climes is much more firm than that from those of cold regions. This statement, however, requires additional experience and observations before it can be received as a law of the animal economy.

Fats always melt at a lower temperature than the solid acid which they yield by saponification; but the melting point varies with the part of the animal whence extracted. They are generally tasteless and neutral when fresh, but acidify and become rancid by exposure to air. Their specific gravity is below that of water, and they are all more or less fusible. Alcohol partially dissolves them, but they are wholly insoluble in water. In carnivorous animals the fat is usually soft and rank-flavored; in the ruminants nearly inodorous. In well-fed young animals it is generally white and abundant, and in the old, yellowish and more scanty.

The following is a list of the principal animal fats, with the fusing point of each:—

	Fusing point.
Badger fat,.....	86·0°
Beef suet,.....	98·5
Calf suet,.....	136·8
Camel suet,.....	131·0
Cows' butter,.....	79·7
Dog fat,.....	79·75
Elephant fat,.....	82·0
Fox fat,.....	129·0
Hare fat,.....	117·5
Hogs' lard,.....	80·5

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	Fusing point.
Horse grease,.....	140·0
Human fat,.....	77·0
Goat fat,.....	"
Stearin of human fat,.....	120·0
" mutton suet,.....	109·0
" beef suet,.....	111·0
" hogs' lard,.....	109·0
Neat's-foot oil,.....	liquid below 32·0

TALLOW.—Under this name is included the fat of oxen, sheep, goats, deer, and some other animals. They all consist for the most part of stearin, with a little olein, while some also contain certain quantities of a particular ingredient which communicates to the fat characteristic properties. As far as their application is concerned, they are alike in properties. As a source of light, tallow is more or less valuable according to its greater or less degree of solidity; and is found from experience to be more solid, and consequently more valuable, in animals fed upon dry, ripe fodder, than in such as are supplied with green food or grains. Hence the tallow imported from Russia, where the animals are fed for eight months upon dry fodder, is generally superior to that produced at home.

The process for the separation of tallow from the membrane and tissue in which it is included in the animal body, is the same as that given for preparing the animal fats in general. The methods of purification and clarification are modified according to the purpose to which it is to be applied, and the greater or less degree of cleanliness, or freedom from foreign matters, of the fat itself. To separate the solid and liquid constituents of tallow, it is melted, and constantly stirred whilst in the act of congelation. It is then pressed in woollen bags, at a temperature of about 95°; the olein which is thus pressed out still retains much stearin, but by repeatedly pressing in a similar manner, lowering the temperature each time by a few degrees, an olein is obtained, fluid at 32°, and the stearin is hard and granular. The hardening and whitening of tallow may be accomplished by other means than pressing, a description of which will be found under the article CANDLE. Also, for further information upon this and other of the following fats, see vol. i., page 413 *et sequitur*.

Tallow Oil.—The liquid fat separated from tallow by pressure is known under this name. The best method of obtaining it consists, according to MORFIT, in steaming the tallow in wooden tubs for several hours, drawing off the upper clear portion after sufficient repose for subsidence of foreign matters, and gradually cooling in large tubs between 70° and 80°. These tubs are provided with a cullendered diaphragm, about six inches from the bottom, and which should be covered with coarse flannel cloth. During repose, the solid portion of the tallow separates in granules from the superstratum of fluid olein, and deposits upon the diaphragm, thus allowing the liquid olein to percolate upon the opening of the cock at the bottom, and be drawn off into receivers. The solid residue, upon being subjected to pressure in Russian canvas bags, yields more olein, and itself remains hard and white. Tallow oil is thick and mushy, and admirably suited to the manufacture of the finer kinds of soap.

Beef Tallow.—The fat of oxen is firm and brittle,

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has a yellowish-white color, and a slight but peculiar odor. It melts at a temperature of 100°, is insoluble in water, but soluble in forty parts of boiling alcohol of specific gravity 0.821. It consists of olein and stearin, in the proportion of three parts of the latter to one of the former. The solid constituent or stearin is white, granular, and crystalline. It melts at 111°, and again solidifies at 102°. It has about the same translucency as white wax. Its feel is not greasy, and in burning it gives a light similar to that of wax. It dissolves in absolute alcohol, to the amount of fifteen and a half parts in a hundred. The olein of beef fat is colorless, with only a slight odor. Its specific gravity is 0.913. One hundred and twenty-three parts are soluble in a hundred of absolute alcohol, at the temperature of 167°. Beef tallow is used principally in the manufacture of soap and candles.

Mutton Suet.—This fat is similar to the preceding, but is whiter. It is very firm and brittle, has scarcely any smell, is completely insoluble in water, slightly soluble in alcohol, and melts at temperatures between 100° and 106°. The solid portion of this fat, which amounts to seventy-four per cent., consists, according to HEINTZ, of stearin, margarin, and palmitin. It is white and lustreless. It begins to solidify at 99.5°, is translucent, and partially soluble in alcohol. The olein of mutton suet is colorless, has a slight odor of the flesh of the animal, and a specific gravity of 0.913. Eighty parts of it are dissolved by one hundred of absolute alcohol, at the temperature of 167°. In addition to these ingredients, mutton suet probably contains *hircin*.

Goats' Fat.—This fat resembles that of the ox, but it has a disagreeable smell, arising from the presence of a peculiar oily matter, first discovered by CHEVREUL, and termed by him *hircin*. It is liquid, and is found in the olein when the fat of goats is separated into its solid and liquid constituents. It is composed of oxide of glyceryl, united to a peculiar acid named *hircic*. Although *hircin* has not yet been obtained pure, CHEVREUL prepared the acid into the constitution of which it enters. His process was by saponification, decomposition of the soap by tartaric or phosphoric acid, and distillation of the mixture of fatty acids, when *hircic* acid is found in the receiver under the form of a colorless volatile oil. It has a capreous and acetic odor, an acid reaction, is difficultly soluble in water, and easily so in alcohol. With the bases it forms salts, of which that of baryta is difficultly soluble.

Cows' Butter.—This fat is derived from the milk of the cow. The various methods of manufacture, *et cetera*, have been treated under a separate article, page 397, *et seq.* It may be purified from buttermilk, cheese, and other impurities, by melting it, when the foreign matters subside with the water, and the pure oil rises to the surface. The characteristic odor and flavor of butter are owing to the presence of a small quantity of several peculiar fats, named—*butyrin*, *caproin*, *caprylin*, and *caprin*. These fats are combinations of oxide of glyceryl with the volatile butyric, caproic, caprylic and capric acids. According to HEINTZ, the solid portion of butter contains, besides palmitic acid, another acid which he terms the *butic*, and gives the following formula:— $C_{40}H_{40}O_4 = C_{40}H_{39}O_3, HO$.

Hogs' Lard.—This fat is generally prepared from the adipose matter of the omentum and mesentery of the hog. It is white, and has very little odor. It melts at 100°, forming a transparent and nearly colorless fixed oil. According to SAUSSURE, its specific gravity is 0.9302 at 60°. One hundred parts of boiling alcohol dissolve nearly three parts of its olein. Exposed to the air for some time, it becomes gradually yellow-colored and rancid, acquires a powerful odor and an acid reaction. In this process a volatile fatty acid is developed, which CHEVREUL considers analogous to caproic acid. Hogs' lard consists essentially of olein, stearin, and margarin, and by saponification gives nine parts of glycerin and 94.65 of a mixture of the fatty acids. According to BRACONNOT, the proportion of olein is sixty-two, and of the solid constituents thirty-eight per cent. The solid portion is without smell, translucent, dry, and granular. It melts at 109.5°. On congealing, it assumes an imperfectly crystalline texture.

Lard Oil.—This fluid oil is prepared from lard in the same manner as is directed for tallow oil. It is considered much superior to sperm or olive oil for greasing wool, and, from its low price, is largely used. It is usually sufficiently white and clear for use, and should on no account be bleached by chemical means, as it is liable to retain enough of the bleaching agent to injure its quality, and render it inapplicable for many purposes.

Human Fat.—The fat of man has a similar consistency to hogs' lard. Its melting point seems to vary with the part whence it is extracted. It requires forty parts of hot alcohol of the specific gravity 0.821 for solution. On cooling, the alcoholic solution deposits stearin, which, after re-solution and deposition, and pressure in blotting paper, may be considered pure. This stearin crystallizes in a mass of small needles. It is colorless, has little lustre, and melts at 122°. One hundred parts of boiling anhydrous alcohol dissolve 21.5 of this stearin, but the greater part is again deposited on cooling. The olein of human fat is a colorless oil, which solidifies in needles at about 24°. Its specific gravity at 59° is 0.913. It has no smell, but a sweetish taste. Alcohol dissolves more than its own weight of this olein. By saponification, human fat yields 9.66 parts of glycerin, and 95.24 of margarin and oleic acids per cent.

Under the name of *adipocere*, FOURCROY described a peculiar fatty substance found in a cemetery at Paris, and supposed to have been partly formed during decomposition. CHEVREUL has shown that this matter is the original fat of the body, which has resisted putrefaction, and is partly in the state of fatty acid, and partly as ammonia soap, with traces of lime and magnesian soaps. This substance may often be found in the neighborhood of graveyards.

Neat's-foot Oil.—This oil is obtained from the feet of oxen; and as it remains liquid below 32°, and is in other respects a useful lubricant, is much employed to oil machinery. In America, according to MORFIT, it is extracted by the following process:—The feet, as collected from the slaughter-houses, are soaked in cold water to remove the blood, and, after removing the sinews, are placed perpendicularly in sufficient boiling

water to cover the hoofs. In about a quarter of an hour they are to be taken out, and the hoof separated by a suitable machine. The next step is to joint them with a knife, to sever the toes from the large bone. The latter is boiled with water by steam, while the former, which are more obstinate in yielding their fat, are boiled in the open pan with water previously used for the large bones. After the boiling, the liquid is left to repose, so that the oil may rise to the surface and be drawn off. The collected oil deposits after some time a thick stratum of dirty semifluid fat, from which the clear supernatant portion must be decanted.

This oil consists of olein, margarin, and stearin; it is white and fluid at ordinary temperatures, but congeals a few degrees below 32°. It is very frequently adulterated with horse oil, common lard oil, bone fat, some vegetal oils, and even with fish oils. The pure oil is not liable to change or rancidity, and is used as a lubricant, and is especially useful for machinery exposed in cold situations, as in the case of church clocks, *et cetera*, which require an oil not liable to become concrete.

FISH OILS.—Certain fish, especially the *cetacea*, yield a greasy fluid or oil, called or named according to the fish whence it is extracted. All fish oils contain certain peculiar animal matters, which impair their illuminating power, but do not injure them for the purposes of the soapmaker. They are extracted by melting the blubber, and the foreign matters are then partially separated by steaming the oil and allowing it to repose. Under the term, *train oil*, are included, whale, seal, cod, shark, and all oils obtained from fish of a like nature.

Whale Oil.—This well-known fish oil is obtained by boiling the blubber of the *Balena mysticetus*, or great northern whale. The pursuit of this whale forms an important branch of industry, as well as a nursery for British seamen. It was formerly found on the east shores of Greenland, but of late years in Davis' Straits and the interior of Baffin's Bay. The whale fishers merely cut out the blubber, pack it into casks, and carry it to the seaports to be melted out. The carriage gives rise to an incipient decomposition of the animal matters, and of the fluids attached to the blubber, which, although it aids the melting, occasions the formation of a peculiar fat, termed *phocenin*, which is the cause of the disgusting odor which always accompanies train oil. The cellular tissue of the blubber thus becomes so broken down that the oil runs off by itself, when the whole is put into casks with wirework bottoms, such as are used in the melting houses. The oil is afterwards heated to 212° that the impurities may be more easily separate, and after standing some time, the clear oil is decanted.

In train oil the impurity is not mucus, as in the vegetal oils, but animal gelatin or glue, and, besides this, volatile, stinking matters. Some clarifiers use a solution of tannin for purifying it, which forms with the gelatin insoluble flakes; others employ metallic salts, as sulphate of copper or acetate of lead, which act in a similar manner. The nauseous odor is most easily removed by bleaching-powder.—*Knapp*.

The color of whale oil is brown, and it has a disagreeable fishy smell. Its specific gravity at 68° is

0.927. When cooled to 32°, it deposits stearin, and the residual oil is soluble in less than its own weight of boiling absolute alcohol; the stearin is soluble in about twice its weight of this liquid. When the solution is cooled, it deposits first white brilliant crystals, and afterwards crystals tinged with yellow, and a thick brown liquor remains. When this stearin is saponified and the soap is decomposed by an acid, glycerin is obtained, and about forty per cent. of fatty acids, with a little *phocenic* acid in admixture.

Seal Oil.—The seal-fishery is by far the most important part of the trade of Newfoundland, the annual catch of the fish being little short of three quarters of a million. The principal seals captured are the *hood* and *harp* seal, of which the latter is the best and most productive. The first operation after landing and weighing is the skinning, or separation of the fat from the skin; after which the fat is cut off, and transferred to the seal-vat. The latter consists of what are termed the *crib* and the *pan*. The crib is a strong wooden erection, from twenty to thirty feet square, and twenty to twenty-five in height. It is firmly secured with iron clamps, and the interstices between the upright posts are filled in with small round poles. The floor is of strong timber, capable of sustaining three or four hundred tons. The crib stands in a strong wooden pan, three or four feet larger than the square of the crib, so as to catch all the droppings. The pan is about three feet deep, and tightly caulked. A small quantity of water is kept on the bottom of the pan, for the double purpose of saving the oil in case of a leak, and for purifying it from the blood, and any other foreign matter of a higher density. The oil extracted by this process is all cold-drawn, which accounts for the disagreeable odor of seal oil. When the vats begin to run, the oil drops from the crib upon the water in the pan, and as it accumulates it is drawn off into casks, and is ready for exportation. The first running, which is caused by compression from its own weight, continues from two to three months, yielding what is termed *pale* seal oil, until from fifty to seventy per cent. is drawn off, according to the season, and also in proportion to the quantity of old seal fat put into the vat. Owing to its toughness, the latter does not yield to compression, nor does it give up its oil until decomposition sets in; and hence it does not, by this process, yield pale seal oil. As putrefaction proceeds, the color changes to straw; and, as the season advances, becomes every day darker, and a more nauseous odor is eliminated, until the brown oil at last runs out. As this running slackens, it becomes necessary to turn over what remains in the vats. The crib being generally divided into nine apartments, or *pounds*, this operation is performed by first emptying one of these, and dispersing the contents over the others, and then by filling and emptying them alternately, the entire residue—a complete mass of putrefaction—is turned over. By this means a further quantity of brown oil is obtained. The remains are then finally boiled in large iron pots, which during the whole season are in constant requisition for boiling the cuttings and clippings of the skin, and other parts of the pelts, which it is unadvisable to put into the vats. The produce of this, and the remains of the

pelts, are what is termed *boiled seal oil*. The refuse from the vats is found to be very valuable manure, and is readily purchased by the farmers in the neighborhood.

S. G. ARCHIBALD, of Newfoundland, has devoted much attention to the improvement of the method of extracting seal oil, and states that the different kinds of seals' fat, if taken while fresh, and subjected to a process of artificial heat, are capable of yielding not only a uniform quality of oil, but the oil so obtained is much better in quality than the best prepared by the old process, and free from the unpleasant smell common to all seal oil. He afterwards invented a steam apparatus for *rendering* seal and other oils, which is said to answer the purpose admirably.

Seal oil is used solely for illuminating purposes, and when tolerably pure, answers admirably, giving a beautiful, brilliant light, and producing no offensive smell, nor any clogging of the wick. Owing to the offensiveness it communicates to its salts, it is not applicable for the production of soap.

Porpoise Oil.—This, the produce of the *delphinus phocaena*, much resembles whale oil. It is liquid, and has a yellow color. When freshly extracted, it has a fishy smell, but by exposure to sun and air becomes nearly odorless. It then, however, acquires an acid reaction. It is soluble in about five parts of boiling absolute alcohol, but a portion of its solid constituent is deposited on cooling. By saponification it yields glycerin, with oleic, margaric, and phocenic acids.

Shark Oil.—This oil is procured from the liver of the basking shark—*squalus maximus*—of the bay of Galway, or sun-fish, as it is commonly called. The quantity of oil obtained from a single fish frequently amounts to one hundred and twenty gallons. It is light-yellow, of specific gravity 0.870 to 0.876, and retains its fluidity several degrees below the freezing point of water. It is said to give a brilliant flame, and without clogging the wick. RONALDS, who made a partial examination of it, reports that it consists of glycerin, a peculiar oleic acid, very rich in carbon, and another undefined liquid oil.

COD-LIVER OIL.—This oil is extracted from the liver of the common cod, and various other allied species of fish, but principally from the above—*gadus morrhua*—and the ling—*lota mola*. PENNANT describes the

method pursued in Newfoundland for its extraction as follows:—They take a half-tub, and, boring a hole through the bottom, press hard down into it a layer of spruce boughs, upon which they place the livers, and expose the whole apparatus to as sunny a place as possible. As the livers corrupt, the oil runs from them, and straining itself through the spruce boughs, is caught in a vessel set under the hole in the tub's bottom. According to Dr. DE JONGH, the usual mode of preparation in Norway is to store the livers in vats or tubs as soon as they are separated from the fish, where they are left until the end of the fishing season, when the oil that has separated is decanted, and forms the pale oil of commerce. The residue of the livers, being then submitted to heat, yields the darker oil. The best English oil, according to Dr. GARROD, is thus prepared:—The livers are collected daily, so that no trace of decomposition may have occurred, carefully examined, in order to remove all traces of blood and impurity, and to separate any inferior livers; they are then sliced and exposed to a temperature not exceeding 180°, until all the oil has drained from them. This is filtered, afterwards exposed to a temperature of about 50°, in order to congeal the bulk of the margarin, and again filtered and put into bottles well secured from the action of the air. In TAYLORS', every liver is opened, examined, washed free from blood, and, if sound and fit for use, is cut in pieces and put with others into a large pan with a portion of water. To the external surface of this pan steam is admitted, and the temperature being very carefully adjusted to about 180°, the livers are heated for a sufficient length of time to allow of the complete separation of the oil. The result of this process is the production of a sweet and nearly colorless oil, which is skimmed off and filtered through flannel. This, having been congealed for the separation of its margarin, is again filtered when required for use.

Three varieties of cod-liver oil are met with in the English market, and are known as the pale, the light-brown, and the dark-brown or black. The first is that extracted from the livers before putrefaction has commenced; the two latter have either remained longer in contact with the livers, have been prepared at high temperatures, or have been obtained from livers in a state of decomposition. Appended is Dr. DE JONGH's analysis of the three varieties:—

	Pale oil.	Brown oil.	Black oil.
Oleic acid, with gaduin and two other bodies,.....	74.03300	71.75700	69.78500
Margaric acid,.....	11.75700	15.42100	16.14500
Glycerin,.....	10.17700	9.07300	9.71100
Butyric acid,.....	0.07436	—	0.15875
Acetic acid,.....	0.04571	—	0.12506
Fellinic acid, and cholic acids, with a small quantity of margarin, } olein, and bilifulvin,.....	0.04300	0.06200	0.29900
Bilifulvin, billifellinic acid, and two peculiar substances,.....	0.26800	0.44500	0.87600
A peculiar substance, soluble in alcohol,.....	0.00600	0.01300	0.03800
A peculiar substance, insoluble in water, alcohol, and ether,.....	0.00100	0.00200	0.00500
Iodine,.....	0.03740	0.04060	0.02950
Chlorine and traces of bromine,.....	0.14880	0.15880	0.08400
Phosphoric acid,.....	0.09135	0.07890	0.05365
Sulphuric acid,.....	0.07100	0.08595	0.01010
Phosphorus,.....	0.02125	0.01136	0.00754
Lime,.....	0.15150	0.16780	0.08170
Magnesia,.....	0.00880	0.01230	0.00380
Soda,.....	0.05540	0.06810	0.01790
Iron,.....	—	—	a trace.
Loss,.....	3.00943	2.60319	2.56900
	100.00000	100.00000	100.00000

Of the three varieties of cod-liver oil, the most colorless, prepared entirely from fresh livers, is to be preferred, as it possesses the constituents of the oil in the purest state, and is, therefore, the most valuable as a therapeutic agent. From the investigation of several medical men, who have devoted much attention to the investigation of the therapeutic value of the several kinds of oils, the following may be gleaned in favor of the pale variety:—It is the real oil, as contained in the liver of the cod-fish—rich in biliary matters, and also in iodine and other inorganic principles; it contains no products of putrefaction, such as are found in the dark oils; it sits more easily on delicate stomachs; and experience has proved it to be a most effective therapeutic agent.

Adulteration.—Cod-liver oil is said to be extensively adulterated, and in some cases, indeed, an entire substitution is stated to be made, consisting of train oil, admixed with iodine, either in the free state, or as an alkaline iodide. This addition of iodine, or an iodide, may be readily detected by adding a solution of starch and a little sulphuric acid, when the blue iodide of starch is instantly developed.

Physiological Effects.—In the dose of a tablespoonful, cod-liver oil acts as a laxative, diaphoretic, and diuretic. The disagreeable flavor, especially of the dark-colored varieties, occasionally creates nausea and sickness, but when habit has surmounted the repugnance to it, these effects cease. In several cases it has proved an emenagogue, and on some occasions it has given rise to a cutaneous eruption. Dr. BARDSEY found that most persons were disposed to fatten under its use. According to Dr. THOMPSON and others, the olein is the active agent, while the presence or absence of iodine, bromine, *et cetera*, in the infinitely small proportions in which they are met with as constituents of the oil, cannot affect the results of its administration, and, in the opinion of Dr. WILLIAMS, cod-liver oil affords fat of a better kind, more fluid, less prone to change, and more capable of being absorbed into the structure of the body, than other forms of fat. Cod-liver oil has proved most useful in such cases as are of a gouty, rheumatic, scrofulous, or phthisical nature. But even in these it requires a long-continued use to prove successful. The oil is best adapted for relaxed, torpid, and phlegmatic temperaments, and for scrofulous subjects. The dose at the commencement for an adult is a tablespoonful, which has been sometimes increased to six times this quantity, and when given immediately after a farinaceous meal, and without any vehicle, rarely creates nausea or vomiting.—*Pereira*.

Sperm Oil.—This oil is obtained from the white whale—*physeter macrocephalus*. This, termed also the *cachalot* and sperm whale, is remarkable for the enormous size of its head, which is square, and apparently cut off in front. The animal is pursued chiefly for this oil, but it yields also *ambergris*. The oil is met with in several parts of the body, but the head is the principal receptacle of it. Here it is found in a large excavation of the upper jaw, anterior to, and quite distinct from, the true cranium which contains the brain. Like the fat of other animals, this oil is contained in cells, or cellular membrane; but besides these cells,

there are also ligamentous partitions going across, which serve as supports for the enormous quantity of oil of which the bulk of the head is principally made up. Sperm oil is extracted from the *case* by means of an opening made in the triangular-shaped cavity situated in the right side of the nose and the upper surface of the head, and the liquid contents are removed by a bucket. The dense mass of cellular tissue beneath the *case* and nostril, and which is technically called *junk*, also contains oil. Directly it leaves the skull of the animal, the oil begins to deposit large quantities of *spermaceti*, in the form of small crystalline laminae, from which the oil flows out by pressure, and is subsequently purified by the addition of a small quantity of solution of potassa, which precipitates certain matters by neutralizing the acid that held them in solution. Sperm oil is of a yellow color, has a slightly unpleasant smell, and is well suited for burning in lamps. It saponifies easily, and the soap obtained is brown, rather soft, and entirely soluble in water. According to HOFSTADTEN, it contains spermaceti, oleic, valerianic, and phytetoleic acids. The formula for the latter is $C_{32}H_{52}O_2$, HO. It is colorless, inodorous, melts at 86° , and solidifies at 82° . It does not yield sebatic acid by distillation, nor elaidic acid by the action of nitrous acid.

ADULTERATION OF OILS.—The enormous consumption of the various kinds of oils in the arts, manufactures, and other purposes, renders it a point of great importance to be able to detect the admixture of one oil with another of inferior quality, inasmuch as, owing to the physical similarity of the several varieties, great temptation exists for the commission of such frauds. The admixture of fish oil with animal or vegetal oils may be readily detected by the brown or black hue produced by the action of a stream of chlorine, and also, according to CALVERT, by the reddish coloration developed by boiling a mixture of the oil with solution of caustic soda. For the detection of a mixture of a siccative with a non-drying oil, several methods may be applied, as that of POUTET, which consists in the application of protonitrate of mercury, by which the non-drying oils yield elaidin; or that of BOUDET, which depends upon the same reaction, to produce which, however, nitrous acid is substituted for the mercury salt; and, in addition, the reaction discovered by MAUMÉNE, who showed that the non-drying oils give rise to a much higher temperature, when mixed with strong sulphuric acid, than is the case with those belonging to the class of siccatives. The fixed oils which may be solidified by BOUDET's method are those of sweet almonds, of filberts, and of colza; and of the drying oils, castor oil only is solidified by this treatment. One hundred parts of the oils mentioned, when treated by a mixture of nine parts of nitric acid with one of peroxide of nitrogen, require different lengths of time to become solid, as shown in the table subjoined:—

Oils.	Color developed by addition of the mixture.	Number of minutes required for congealing.	Proportion.
Olive oil,	Greenish-blue,	73	10-0
Sweet almond oil,	Dirty-white,	160	22-2
Oil of filberts,	Greenish-blue,	103	14-0
Oil of acajou,	Lemon-yellow,	40	6-0
Castor oil,	Golden-yellow,	603	82-6
Colza oil,	Yellowish-brown, ..	2400	328-0

HEIDENREICH determines the purity of the fixed oils, and the admixture of cheaper oils, approximately, as follows:—First, by observing the peculiar smell of the oil when gently heated in a small porcelain or platinum capsule, by means of a spirit lamp. The odor evolved will resemble that of the plant or animal from which it was obtained. This characteristic is said to be valuable if observed in conjunction with the genuine oil, and to furnish accurate indications of the presence of linseed, whale, train, or rape oils, in any mixture. The smell of the oil, however, as observed by PERROT, is not always a safe criterion, since an oil of the same fruit or nut has not always the same odor, but differs with the climate where produced, and the varied mode of extraction. HEIDENREICH further applies concentrated sulphuric acid, in the proportion of one or two parts per cent. of oil, and by this admixture a very intense action immediately ensues, the temperature rises, and the mixture becomes colored. A few drops of the oil are placed on a glass plate, having a sheet of white paper underneath; and to the oil is added a small drop of sulphuric acid, of specific gravity 1.632, when, according to the oil employed, a characteristic color will be developed without stirring. In the case of *rape oil*, a greenish-blue ring gradually forms at a certain distance from the acid; whilst towards the centre, where the action is more intense, light yellow-brown streaks may be observed. With *oil of black mustard*, the reaction much resembles that of rape oil, but is more violent. In *train oil*, a very peculiar

motion occurs, commencing at the centre, and extending to the outside; at the same time a red tint appears, which grows more and more vivid, until after ten or fifteen minutes the margin assumes a violet tinge, which, in about two hours, is uniform throughout. *Olive oil* instantly becomes pale yellow, and afterwards yellowish-green. In *poppy and sweet almond oils*, the color developed resembles that of the greenfinch, but afterwards becomes of a dead yellow hue. In *linseed oil*, a beautiful dark brownish red web is formed, gradually changing into brownish-black. Lastly, *tallow oil* is rendered brown.

If, in the process of HEIDENREICH, instead of the acid being allowed to act on the oil undisturbed, the two liquids are stirred together by means of a glass rod, the phenomena vary from those above described.

PERROT, reviewing the process of HEIDENREICH, directs twenty drops to be employed; and instead of the glass-plate and white paper, he uses capsules of white porcelain. In the place of sulphuric acid, he used also a saturated solution of bichromate of potassa in this acid, and in the proportion indicated above, namely, one drop to twenty of oil. In applying this method, it is always necessary, to insure greater certainty, to compare the effects upon the oil to be examined, with an oil the purity of which is undoubted. The appended table shows the reactions produced by sulphuric acid alone, and by the solution of bichromate in the acid:—

Oils.	Sulphuric Acid.		Solution of bichromate of potassa in sulphuric acid.
	Not stirred.	Stirred.	
Tallow oil,.....	Reddish spots with reddish circles.	Reddish-brown.	Reddish-brown.
Sweet almond oil,	Greenfinch yellow, with orange spots.	Dirty-green.	Yellowish small lumps.
Train oil,	Brown small lumps on a brown ground.	Lees of wine.	Brownish-red small lumps on a red ground.
Hemp-seed oil,	Reddish small lumps on a yellow ground.	Greenish-brown.	Yellow small lumps on a green ground.
Rape-seed oil,.....	Scarcely perceptible spots, or slight green coloration.	Green.	Yellow small lumps on a green ground.
Fish-liver oil,	Dark-red.	Dark-red.	Dark-red.
Linseed oil,.....	Reddish-brown.	Clotted on a grey or green ground.	Brown small lumps on a nearly colorless or slightly green ground.
Oil of madia sativa,	Slightly reddish-brown, underneath a film inclining to grey.	Olive-green.	Light-brown small lumps on an olive-colored ground.
Nut oil,	Yellowish-brown.	Clotted dark-brown.	Small brown lumps.
Olive oil,	Yellow, or orange-yellow.	Dirty-brown.	Brown.
Poppy oil,	Yellow, or greenish-yellow spots.	Olive or slightly green.	Small yellow lumps on a yellow or colorless ground.
Neat's-foot oil,.....	Yellow slight spots.	Dirty-brown.	Brown spots on a similar ground.
Castor oil,	Yellow slight spots.	Almost colorless.	Slightly green.

The action of the reagent upon the oil is not the same under all circumstances, but differs with the place of its growth, the manner of pressing, and its age. If, however, any oil be examined comparatively with a perfectly pure one, the proof of sophistication may be rendered pretty certain by observing the difference. After the discovery of fraudulent admixture, the oil is tested to ascertain the adulterant, either by reagents, or by the odor evolved when gently heated as before men-

tioned. This having been found out, small quantities of the suspected oil are added to a perfectly pure sample of the kind of oil under examination, and by this means the proportion of the mixed oils may be approximately estimated. Several cases of adulterated oils have lately been submitted to the Editor; and by carefully observing the reactions specified he has been able to state, to a certainty almost, the per-centage of foreign oil in each sample.

GENERAL TABLE OF REACTIONS.

Oils.	Caustic soda, spec. gravity 1.340.	Sulphuric acid, spec. gravity 1.845.	Sulphuric acid, spec. gravity 1.880.	Sulphuric acid, spec. gravity 1.885.	Nitric acid, spec. gravity 1.180.	Nitric acid, spec. gravity 1.220.	Nitric acid, spec. gravity 1.330.	Caustic soda, spec. gravity 1.340.	Phosphoric acid, density.	Sulphuric acid + nitric acid.	Aqua regia + spec. gravity 1.340.
Olive,.....	slight yellow.	green tinge.	greenish-white.	light-green.	greenish.	greenish.	greenish.	fluid white mass.	slight green.	orange- yellow.	—
Gallipoli,	ditto.	ditto.	grey.	brown.	ditto.	ditto.	ditto.	fibrous white mass.	ditto.	dark- brown.	—
India nut,....	thick and white.	—	dirty white.	light-brown.	—	—	—	ditto.	—	orange- white.	—
Pale rapeseed,	dirty yellowish- white.	—	pink.	brown.	—	—	—	fluid white mass.	—	dark- brown.	—
Poppy,.....	ditto.	—	dirty white.	—	—	yellowish-red.	red.	light-red fluid mass.	—	slight yellow.	—
French nut,...	ditto.	brownish.	grey.	brown.	yellow.	red.	dark red.	fibrous red mass.	brown yellow.	dark- brown.	yellow.
Sesame,	ditto.	green tinge.	greenish dirty white.	—	orange- yellow.	ditto.	ditto.	fluid red mass with brown li- quor beneath.	—	green, be- coming in- tense red.	ditto.
Castor,.....	white.	—	dirty white.	—	—	—	—	fibrous white mass.	—	brownish- red.	—
Hempseed, ..	thick brownish- yellow.	intense green.	intense green.	intense green.	dirty green.	greenish dirty brown.	greenish dirty brown.	fibrous light brown mass.	green.	green, be- coming black.	green.
Linseed,	fluid yellow.	green.	dirty green.	green.	yellow.	yellow.	green becom- ing brown.	fluid yellow mass.	brown yel- low green.	ditto.	greenish- yellow.
Lard,.....	pinkish-white.	dirty white.	dirty white.	light-brown.	—	—	very slight yellow.	fluid mass.	—	brown.	—
Neats-foot, ..	dirty-yellowish white.	yellow tinge.	brownish dirty white.	brown.	light-yellow.	light-yellow.	light-brown.	fibrous white mass.	—	dark- brown.	slight yellow.
Sperm,.....	dark-red.	light-red.	red.	intense brown.	slight yellow.	ditto.	red.	fluid mass.	dark-red.	dark- brown.	ditto.
Seal,.....	ditto.	ditto.	ditto.	ditto.	pink.	light red.	ditto.	ditto.	ditto.	ditto.	ditto.
Cod liver,....	ditto.	purple.	purple.	ditto.	—	—	ditto.	ditto.	ditto.	ditto.	yellow.

Another systematic method for testing the purity of oils, for which chemists are indebted to CALVERT, has been lately published, and goes far to solve this most intricate department of analytical chemistry. It consists in the employment of caustic alkali, and of various acids at different degrees of dilution, as well as mixtures of acids, and of acids and alkalies, successively applied. The preceding table, constructed by this chemist, indicates the reactions depended upon. The first test in the list is employed in the proportion of one volume of solution to five of oil, and is especially valuable to distinguish fish from other vegetal and animal oils. The test and oil are to be well mixed, and then heated to the point of ebullition. In the case of sulphuric acid, the same proportions as of caustic soda are employed in each case, and the mixture well agitated. With the acid, of specific gravity 1·475, the appearance is noted after standing fifteen minutes; with that of 1·530 after reposing five minutes; and with that having the density 1·635, after two minutes. With nitric acid, the mixture is made in a like proportion in each case, and the reaction noticed after five minutes. The caustic soda and nitric acid are applied together, by adding ten volumes of the former to five of the oil which has just been acted upon by one of nitric acid. The phosphoric acid is employed precisely as the other acids, and is extremely sensitive in the case of fish oils. The sulphuric and nitric acids are used in the proportion of one volume of a mixture of equal measures of acid with five of oil, and the appearance is observed after the lapse of two minutes. This test is especially applicable to the detection of oil of sesamum in admixture with other oils. Lastly, the aqua regia employed is composed of twenty-five volumes of hydrochloric acid, of specific gravity 1·655, and one of nitric acid, of specific gravity 1·330, and is allowed to remain at rest about five hours. The reactions given are those that ensue when a mixture of five volumes of oil with one of aqua regia is agitated, and allowed to stand five minutes. On the subsequent addition of caustic alkali to this mixture, a very vivid and distinct coloration is perceptible in many cases, and this, with the other appearances mentioned, render this last a most valuable agent for the detection of several instances of admixture.

STATISTICS.—Of the six principal vegetal oils, namely, palm, cocoa nut, castor, olive, linseed, and rape, the first four are imported in the state of oil only; the last two, chiefly as seed. The following table exhibits the proportions of the latter imported in the year 1850:—

	Linseed. Quarters.	Rapeseed. Quarters.
Russia,	482,813	3,235
Sweden,	870	—
Norway,	268	—
Denmark,	37	3,092
Prussia,	87,273	645
Hanse Towns,	1,153	2,872
Holland,	7,734	201
Naples,	1,476	—
Austrian territories,	40	2,480
Greece,	—	1,637
Wallachia and Moldavia, ..	910	1,280
Egypt,	17,517	—
East Indian empire,	26,144	13,126
Miscellaneous,	262	922
Total,	626,495	29,490

The quantity of the four principal vegetal oils imported in 1850 and the preceding two years, is shown by the following table:—

	Hundredweights		
	1848.	1849.	1850.
Palm oil,	510,218	493,331	448,589
Cocoa-nut oil,	85,463	64,452	98,040
Castor oil,	4,588	9,681	—
	Tuns.		
Olive oil,	10,086	16,964	20,783

The proportion in which these oils were furnished by various countries in 1849, was:—

	Palm oil. Hundredweights	Olive oil. Tuns.	Castor oil. Hundredweights.
Western Africa,	475,364	1	—
United States,	13,349	—	290
Naples and Sicily,	14	9,661	—
East Indies,	—	—	9,315
Canary Islands,	3,719	—	—
Malta,	—	2,237	—
Turkish Empire,	—	1,712	—
Tuscany,	—	832	—
Spain,	—	753	—
Brazil,	525	—	—
Ionian Islands,	—	506	—
Morocco,	—	368	—
Madeira,	353	—	—
Sardinia,	—	333	11
Miscellaneous,	7	461	65
Total,	493,331	16,864	9,681

The subjoined table exhibits the proportions of the several fixed oils and seeds entered in the port of Liverpool in 1849 and 1850, from the countries named:—

Oils.	Countries.	1849. Tuns.	1850. Tuns.
Poppy seed,	—	—	3
Ground nut,	—	80	90
Castor,	East and West Indies,	5	45
Castor seed,	Lisbon,	—	700
Rape,	Antwerp,	6	15
Rapeseed,	Antwerp,	3	5
Olive,	Manilla,	56	8
"	Barbary,	2,785	2,330
"	Malaga,	246	—
"	Levant,	1,243	2,100
"	Corfu,	280	762
"	Leghorn,	—	15
"	Palermo,	2,785	8
"	Gallipoli,	2,420	4,815

At the Great Exhibition a class of substances was exhibited, under the head of OILS, which are likely to prove of great commercial importance, as they possess properties differing from the finest vegetal oils; and some of them can, it appears, be supplied in large quantities, and at moderate cost. The jury, with a view to mark their appreciation of this class, awarded a prize medal to R. CLARENCE, Cape of Good Hope, for oil obtained from sheep's tails; and honorable mention to several exhibitors from the United States, for oil obtained from lard, by pressure, at a very low temperature. The collection of oils exhibited by the East India Company was very extensive, and contained a large number of highly interesting specimens.

In concluding this article, the Editor must express his thanks to his talented student, Mr. J. W. KYNASTON of Lincolnshire, for his very kind and valuable assistance

OPIUM—English, French, German, and Latin—is the inspissated juice of the head of the poppy—*Papaver somniferum*. The word is derived from the Arabic *afium*. The poppy is very extensively cultivated in Asiatic Turkey, Egypt, Persia, India, and occasionally in France, Germany, and England. The young plants are set in rows, about six inches asunder, and at first watered abundantly. When about six or eight inches high they are richly manured, and again abundantly irrigated as they are about to flower. When the seed vessels—Fig. 377—are nearly full-grown, the collection of the opium commences. For this purpose a body of women or children go over the fields about sunset, and make a number of parallel longitudinal incisions in each head, taking care not to

Fig. 377.



Fig. 378.

penetrate into the cavity where the seed is lodged. This is done with sharp shells, or preferably with a knife called a *nushtur*—Fig. 378—which consists of three or four blades tied together, so as to make fine parallel gashes, as shown in Fig. 377. Through these incisions the juice flows, and is scraped off and put into earthen pots, to be dried in the sun. To this is frequently added an inferior matter, obtained by subjecting the heads to pressure, and even by boiling the heads in water, and concentrating the extract. The greatest yield of good opium in India is stated at forty-one pounds per acre, and the average at from twenty to twenty-five pounds.

VARIETIES.—The quality of opium varies greatly, according to the country where it has grown, the species of poppy cultivated, the nature of the season, and the care taken in its collection and preservation. Some varieties are inferior to others, in the ratio of three to one. In the European markets the preference is given to the opium of Smyrna. This sort comes into the market in soft lumps, of greater or less bulk, the surface of which is covered with dock seeds, from the leaves in which they have been folded. It is light-colored internally, but the surfaces, when broken or cut, darken on exposure to the air. The smell is strong and peculiar, and the taste bitter and acrid. It contains ten to fourteen per cent. of morphin.

The opium of Constantinople is found in regular flat cakes or loaves, covered with poppy or tobacco leaves. It is drier than the Smyrna variety, and even brittle. In the hand it softens, and furnishes a fawn-colored paste, which turns brown on exposure to the air. It smells like the Smyrna opium, but fainter. Its yield of morphin is six or seven per cent.

The Egyptian or Alexandrian opium comes into the market in small, very dry, and very flat loaves, very clean at the surface, and showing scarcely a trace of the leaves in which they have been folded. Its color is dark-brown; its fracture clean and shining. It has a very feeble smell, and contains only three or four per cent. of morphin.

The opium of India is found in rounded masses of a darker hue, and more smooth and soft texture. It has an empyreumatic smell, and a less bitter but more nauseous taste. It is wholly soluble in water, and contains more or less sulphate of lime. Its per centage of morphin is two to five.

English and German opium resembles the East Indian in appearance, but is lighter in hue, and in quality equals the very best Smyrna. Opium collected in France has yielded sixteen to twenty-eight per cent. of morphia. The fickleness of the climate, and above all things the high price of labor, render it very improbable that opium can ever be advantageously cultivated in Western Europe.

PROPERTIES.—Genuine opium has a heavy narcotic smell, a very disagreeable bitter taste, with a warmish and subacid after-taste. It should be of a rich deep fawn color, or brown, of a tough plastic consistency, and a smooth uniform texture, marking paper with an interrupted streak. Its specific gravity is 1.336, which is one of the proofs of its purity, as few vegetal substances are so heavy, except gum-arabic and opoponax. Bad opium wants the peculiar narcotic odor; it is friable or soft, full of dark-brown or black patches, or is all of a deep black, marks with a continuous brown streak, tinges water yellow, easily melts when exposed to heat, and tastes sweetish.

Opium is soluble in water, alcohol, and ether, and more readily in proof spirit. It also dissolves in acetic, citric, or any of the vegetal acids in solution. Boiling water dissolves about forty-one per cent., holds fifty per cent. in solution, and leaves the remaining nine untouched.

Opium is of an exceedingly complicated nature. Besides moisture, gum, caoutchouc, lignin, and bassorin, it contains at least thirteen or fourteen distinct principles, most of which occur in no other substance. Of these, nine are of a basic or alkaline nature—morphin, codein, narcotin, narcein, paramorphin, papaverin, opianin, narcogenin, and pseudomorphin; two are neutral, meconin and porphyroxin; whilst four, meconic acid, a brown extractive matter, a resin, and a fixed oil, possess acid properties; and an essential or volatile oil is too little known to admit of classification.

These substances occur in varying proportions, some of them in very minute traces, whilst others are in many samples entirely wanting. It is still doubtful whether all actually exist as such in crude opium, or whether some of them are not *alteration products*, formed by the influence of the reagents used to effect their extraction. It is also questionable, as far at least as the basic constituents of opium are concerned, whether they are totally distinct and unconnected principles, or merely successive modifications of one or two bodies.

PROXIMATE PRINCIPLES.—The Editor will next pass to a description of the various constituents of opium, with their methods of extraction.

Morphin.—This, the most important constituent of opium, was discovered in 1816 by SERTUERNER. Its composition is indicated by the formula $C_{20}H_{20}N_2O_6$, and its symbol is M. It crystallizes in four-sided prisms of an adamantine lustre, containing two equivalents,

or 5.73 per cent. of water, which is expelled at 248°. At higher temperatures it fuses into a yellow liquid, and is subsequently decomposed.

This alkaloid is inodorous, strongly bitter, insoluble in cold water. It dissolves in ninety-two parts of boiling water, and is again deposited in crystals as the solution cools. It dissolves in forty parts of anhydrous alcohol, and in about thirty of proof spirit at a boiling temperature. It is sparingly soluble in ether, but readily in the fatty and essential oils. It dissolves in the fixed caustic alkalies, and to a small extent in ammonia. In nitric acid it dissolves with a blood-red color. Morphin ranks amongst the more powerful bases; its solutions redden turmeric paper, and turn violet paper green. If thrown in powder into a saturated solution of the sesquisulphate of iron, as nearly neutral as possible, it strikes a blue color. The sulphate of this base is formed whilst the iron, reduced from sesquioxide to protoxide, combines with *morphic acid*, a product of the decomposition of a part of the morphin. Morphin decomposes iodic acid in solution, setting the iodine free, whilst the other organic ingredients combine with the acid to form iodates. This reaction is, therefore, used for the detection of morphin. The solution in question is rubbed in a mortar with a little mucilage of starch. A few drops of iodic acid, or of a dilute solution of the perchloride of iodine, are then added. The blue tint which iodine forms with starch is, in this case, a proof of the presence of the alkaloid.

Where alcohol is dear, the process of GREGORY and ROBERTSON will be found preferable. These chemists extract a known weight of opium in cold water, and evaporate to the consistence of sirup. It is then redissolved in water, and again concentrated. To the boiling liquid dry chloride of calcium is added, in the proportion of nearly one-fourth of the opium employed. The chloride of calcium must be perfectly free from iron, otherwise the deep-red meconate of iron will be produced, and greatly impede the purification. The hot liquid is now mixed with cold water, which throws down meconate and sulphate of lime, coloring matter, resin, and the volatile oil of opium.

The precipitate is filtered off, and the clear liquid concentrated, when a fresh deposit of meconate of lime will be formed. Filter again, wash the precipitate on the filter with a little cold water, and add the washings to the filtrate. This is now evaporated down to the consistence of sirup, and allowed to stand for some days. There is then obtained a crystalline mass—a double salt of morphin and codein—and a dark mother-liquor, containing an acid meconate of lime, a little morphin, and the narcein, meconin, narcotin, and paramorphin.

The crystalline mass is drained, pressed between sheets of bibulous paper, redissolved in water, acidulated with a very little hydrochloric acid, and evaporated to crystallization. The mother-liquor, on concentration, generally yields a further deposit. The crystals are redissolved in hot water, the solution neutralized with a little chalk, and treated with animal charcoal. The amount of water must be enough to retain the salt in solution on cooling, and the temperature must not exceed 190°. After twenty-four hours the solution is

filtered, and a few drops of acid added, which favors the crystallization. The crystals are redissolved and again crystallized, pressed between bibulous paper and dried in the stove. The mother-liquor is treated in the same manner with chalk and charcoal.

The salt obtained in this manner is a double one, free from narcotin. It is dissolved in water, boiled, and treated with ammonia, which precipitates the morphin. This is filtered off, washed with a little cold water, and dried. From the filtrate codein is obtained.

Morphin is often contaminated with narcotin, which may be entirely removed by ether, or the impure mass may be treated with very dilute acetic acid which dissolves the former, leaving the latter untouched. To determine the purity—from narcotin—of any sample of morphin, it may be dissolved in hydrochloric acid, and treated with caustic potassa in excess, in which the morphin will entirely dissolve, while any narcotin present remains untouched. If a very small portion of morphin is placed in a watch-glass with a little pure sulphuric acid and an equal quantity of water, and if a particle of bichromate of potassa be added, a nickel green color appears, which changes, first to a copper green, and finally, to a dark dirty green.

The salts of morphia are mostly crystalline, bitter, very soluble in alcohol, but insoluble in ether. They are precipitated from their solutions by alkaline carbonates; caustic alkalies added in excess redissolve the precipitates. They are thrown down by infusion of gall nuts; they strike a blue color with the neutral sesquisalts of iron, and decompose iodic acid in the same manner as free morphin. Terchloride of gold precipitates the salts of morphin with a yellow color, which changes to blue. Nitrate of silver communicates to them a blackish-grey color, and is gradually reduced.

Codein was discovered by ROBIQUET in 1833. The anhydrous substance consists of $C_{35}H_{20}NO_5$. ANDERSON and REGNAULT give the formula $C_{38}H_{21}NO_6$. By solution in water, or in aqueous ether, it is obtained in crystals often of considerable size, belonging to the right prismatic system, but presenting a considerable number of modifications. These crystals contain two equivalents, or 5.67 per cent. of water, which they lose at elevated temperatures, and at 302° fuse without decomposition or volatilization. One hundred parts of water at 60° dissolve 1.26 of codein, at 110°, 3.7, and at 212°, 5.9 parts. If more codein is present than boiling water can dissolve, the undissolved portion fuses and forms a kind of oily layer at the bottom of the vessel. It dissolves in alcohol, more readily when hot than when cold, and is taken up very freely by ether. It is insoluble in very highly concentrated solutions of potassa, which, joined to its behavior with ether, distinguishes it from morphin.

Codein is a very powerful base; it turns red litmus paper blue, and precipitates the oxides of lead, iron, cobalt, and nickel from their solutions. It is precipitated from the solutions of its salts by potassa and by ammonia; in the latter case, however, it does not fall immediately, but is slowly deposited as small transparent crystals.

Codein is obtained from the last filtrate in GREGORY and ROBERTSON'S process for preparing morphin. As

the codein forms only from one-sixteenth to one-thirtieth of the morphin, it is of course mixed in this fluid with a corresponding amount of chloride of ammonia, which must first be decomposed by potassa. Much advantage is gained by first evaporating the liquid to crystallization, and pressing the crystals first deposited: as, however, they are but little less soluble than chloride of ammonia, this process must not be carried too far, or much of the codein will be wasted. The crystals so obtained are dissolved in boiling water, and a highly concentrated solution of caustic potassa is added in excess. Codein is in part precipitated as an oily liquid, which gradually concretes into a solid mass, and in part deposited as crystals when the liquid cools. By evaporating the fluid another crop of crystals is obtained, and finally, when the mother-liquor has been very highly concentrated, it is filled, on cooling, with morphin in long silky crystalline needles.

The crystals of codein thus obtained are dissolved in hydrochloric acid, boiled with animal charcoal, and reprecipitated with a slight excess of potassa. The precipitate is finally dissolved in ether, which ought to be free from alcohol, and allowed to crystallize.

The salts of codein are for the most part soluble and crystalline. Their solutions give with bichloride of platinum a pale-yellow pulverulent precipitate; with chloride of mercury a white precipitate, soluble in boiling water and alcohol; and with chloride of palladium, a yellow precipitate, which is decomposed on boiling, with separation of the metal.

Narcotin consists of $C_{40} H_{25} NO_{14}$. It is a white inodorous substance, forming prismatic crystals, which fuse at 338° , and solidify at 266° , the solidification being attended with a loss of weight amounting to three or four per cent. If it is cooled slowly, several centres of crystallization form at its surface and gradually increase in size. It is insoluble in cold, and requires five hundred parts of boiling water for solution. It dissolves in one hundred parts of seething alcohol, but is taken up more readily by this menstruum at the boiling point. It is very soluble in ether, in the fatty and the essential oils.

Narcotin is without action on the sesquisalts of iron, on iodic acid, and the terchloride of gold. Nitric acid colors narcotin an orange-red. In sulphuric acid, containing about one-thousandth of nitric acid, the liquid assumes in the course of seven or eight minutes an intense blood-red color, which the addition of more nitric acid destroys. Peroxide of nitrogen acts so energetically upon narcotin, that, if the quantity be not very small, ignition ensues in a few seconds.

To prepare narcotin, the grounds left after the extraction of opium by water are boiled with dilute acetic acid, the liquid is strained and filtered, and the clear liquid is precipitated by ammonia. The precipitate is then redissolved in strong boiling alcohol, along with a little animal charcoal. The solution is filtered whilst boiling, and, as it cools, narcotin is deposited in crystals.

Narcotin combines with the more powerful acids, forming salts which are intensely bitter. They are thrown down from their solutions by infusion of gail-nuts, and by the caustic alkalies; but the precipitate caused by the latter does not redissolve in excess.

Narcein— $C_{40} H_{29} NO_{18}$ —is extracted from the dark-brown mother-liquor obtained in the preparation of morphin. It is sparingly soluble in water, insoluble in ether, but very soluble in alcohol. It forms fine silky crystals, which have a metallic taste. It dissolves in dilute acids, but without neutralizing them, and the solutions on evaporation deposit narcein unaltered. It is colored blue by strong acids and by chloride of calcium, but not by sesquisalts of iron.

Paramorphin or *thebain*—was discovered by THIBOUMERY, and was examined by KANE, who assigns to it the formula $C_{38} H_{31} NO_6$. Paramorphin is strongly analogous to narcotin; but it crystallizes in short needles, fuses at a much lower temperature— 266° —is much more readily soluble in alcohol, and its taste is acrid rather than bitter. It has an alkaline reaction, and combines with acids, forming crystalline salts. It is obtained by extracting opium with excess of lime, treating the residue with a dilute acid, and precipitating with ammonia. The powder is treated by alcohol, which, on evaporation, leaves paramorphin in crystals.

Papaverin was first obtained by MERCK. It has the formula $C_{40} H_{21} NO_6$. It is insoluble in water, and sparingly soluble in cold alcohol and ether, but dissolves more freely on the application of heat, and is deposited in irregularly agglomerated, colorless, prismatic crystals. When moistened with concentrated sulphuric acid it acquires a deep-blue color. When treated with moderately strong nitric acid it is converted into a yellow crystalline mass. It restores the blue color of reddened litmus, and neutralizes acids, forming crystalline salts.

It is obtained by precipitating the aqueous extract of opium with soda, exhausting the precipitate with alcohol, and evaporating the brown tincture thus obtained to dryness. The dry resinous residue is dissolved in dilute acid, the liquid filtered and precipitated by ammonia, when a resinous matter is obtained which contains the papaverin. This is then redissolved in dilute hydrochloric acid, and precipitated with acetate of potassa. The precipitate is washed with water, and treated with boiling ether, from which, on cooling, the papaverin is deposited in crystals.

Opiatin was discovered in Egyptian opium by HINTERBERGER. Its constitution is represented by $C_{42} H_{21} NO_{14}$. It was at first mistaken for narcotin. Opiatin crystallizes in long colorless, transparent, diamond-like needles, of the prismatic system. It is inodorous, insoluble in water, and but sparingly soluble in boiling alcohol, from which, on cooling, it completely separates. The solution has a powerful and persistent bitter taste, suffers no alteration at the temperature of the water bath, and has a decided alkaline reaction. It is not affected by concentrated sulphuric acid, but dissolves in nitric acid with a yellow color. Sulphuric acid, to which nitric acid has been added, gives a blood-red tint, which after a short time passes into a straw-yellow. Opiatin forms salts with the acids, and crystalline double compounds with the chlorides of platinum and mercury. From the solutions of its salts it is thrown down in white flakes. It was obtained by extracting the opium with water, adding ammonia to the solution, washing the precipitate obtained, first with water

and then with alcohol, and drying. It is now dissolved in alcohol, deodorized with animal charcoal, and separated from morphin by repeated crystallizations out of alcohol.

Narcogenin has been separated by BLYTH, and found to consist of $C_{36}H_{18}NO_{10}$.

Along with narcotin, to which, when perfectly freed from other compounds, BLYTH assigns the formula $C_{46}H_{25}N O_{14}$, WERTHEIM has discovered two other homologous bodies.

Pseudomorphin has been found in a few samples of opium by PELLETIER, according to the analysis of which it consists of $C_{27}H_{18}N O_{14}$. It forms shining scales sparingly soluble in water, insoluble in alcohol and ether, but soluble in alkalies. Like morphin it is colored blue by sesquisalts of iron. It dissolves in hydrochloric and acetic acids, but its salts have not been fully examined.

Porphyroxin or *opin*, is a neutral body, which crystallizes in colorless minute shining needles. When heated it melts, becomes resinous and friable. It is colored of an olive-green by strong nitric or sulphuric acids, and is dissolved by dilute hydrochloric acid, the solution turning red when boiled or allowed to stand. The acid solution is decolorized by alkalies, and yields with terechloride of gold a dirty-red precipitate, a rose-colored one with acetate of lead, and a brown with protochloride of iron. The solution is not changed by chlorine water, and takes a characteristic red tint. It is probably identical with sanguinarin and cholerythrin. Porphyroxin is prepared by taking the ethereal extract which, after exhaustion with water, remains from the preparation of meconin, and treating with boiling alcohol as long as anything is taken up. The crystalline mass which separates on cooling and evaporation is dried, dissolved in boiling alcohol, and treated with ammonia in excess. The precipitate formed is dissolved in hydrochloric acid, evaporated to a sirup, freed from any crystals that may separate, the liquid again precipitated with excess of ammonia, and the deposit taken up in boiling alcohol, when, on evaporation, porphyroxin separates in minute crystalline needles.

Meconin is a neutral, non-nitrogenous body, which does not form salts. It is prepared by exhausting powdered Smyrna opium with boiling ether. The residue, after distilling off the ether, is repeatedly boiled with water, the solution evaporated, the residue dissolved in ether, decolorized with animal charcoal, evaporated, and the meconin obtained recrystallized from water.

Meconic acid is best obtained in a state of purity by dissolving the pure meconate of potassa in eighteen parts of hot water, and adding two or three parts of concentrated hydrochloric acid. As the liquid cools crystals are deposited, which are redissolved in water, again treated with hydrochloric acid, and thus obtained entirely free from potassa. It should not be boiled in presence of any acid, as it is thus converted into komenic acid.

Meconic acid forms beautiful pearly crystalline scales, of a harsh sour taste, sparingly soluble in cold, but more readily in hot water and in alcohol. The anhydrous acid consists of $C_{14}HO_{11}$, and is denoted by the symbol Me; the acid dried at 212° contains in addi-

tion three, and the crystalline acid nine equivalents of water.

By prolonged boiling in water the acid is decomposed, yielding komenic, oxalic, and carbonic acids, besides a deep dusky-yellow coloring matter. Sulphuric and hydrochloric acids at 212° convert meconic acid into carbonic and komenic acids. The same products, with the addition of water, are obtained on exposing meconic acid to a temperature of 248° ; but at greater heats the komenic acid is again resolved into pyromeconic and carbonic acids. Caustic potassa or soda in excess converts meconic acid into oxalic and carbonic acids, and a brown matter not perfectly known. Charcoal readily absorbs meconic acid, and cannot, therefore, be used in its purification. Meconic acid and all its soluble salts give an intense blood-red color with the sesquisalts of iron, a reaction often employed for the detection of small traces of opium. It should be borne in mind that a very similar reaction with sesquisalts of iron is produced by indigotic acid and the alkaline indigotates, as well as by hydrosulphocyanic acid and the soluble sulphocyanides.

Meconic acid forms three classes of salts, containing respectively one, two, or three equivalents of base.

The bibasic meconate of potassa—Me, 2 KO HO—is obtained by adding a solution of caustic potassa to the crude meconic acid, obtained from the meconate of lime, till a greenish tinge begins to appear. A gentle heat is applied till the whole is dissolved. As the liquid cools, the impure salt crystallizes out in large quantities. This is purified by pressure between folds of bibulous paper, and repeatedly crystallized. This salt, which is used for the preparation of the pure acid, is sparingly soluble in cold water. The monobasic salt—Me KO, 2 HO—is formed by the cautious addition of hydrochloric acid; and the tribasic—Me 3 KO—by the addition of a proper quantity of caustic potassa. This salt is yellow and soluble.

Meconate of lime, an insoluble bibasic salt, is obtained by adding a solution of chloride of calcium to the infusion of opium, as in the process of GREGORY and ROBERTSON for preparing morphin. For the preparation of meconic acid, one part of this salt is mixed with twenty parts of boiling water and three parts of concentrated hydrochloric acid. As the solution cools, a monobasic salt—Me Ca O, 2 HO + aq—is deposited in silvery crystals. These are strained off, dried, and again treated in the same manner, avoiding a boiling temperature, till a crystal, heated upon platinum foil, leaves no residue of lime. The crude acid thus obtained is converted into meconate of potassa and purified, as stated above.

Meconate of sesquioxide of iron is a very soluble salt, of a blood-red color, which is decolorised by sulphurous acid and protochloride of tin.

The brown extractive acid requires further investigation. It is probably a mixture of different matters, and, perhaps, a product of alteration.

The resinous matter of opium contains nitrogen. It is brown, without smell or taste, insoluble in water and ether, but soluble in alcohol. It is softened by heat, and dissolves in alkalies. The oily matter has usually a yellow or brownish tinge, due probably to impurities.

It is acid and saponifiable. The essential oil has not yet been obtained in a state of purity.

The lignin, bassorin, gum, and caoutchouc require no remarks.

ESTIMATION.—Opium is most extensively adulterated, *perfectly genuine samples* being in fact very rare. The drug of commerce contains water, clay, sand, gravel, sulphate of lime, pieces of lead, dung of sheep and oxen, extracts of liquorice, of belladonna, of hemlock, celandin, and lettuce, of *glaucium luteum*, bruised grapes freed from their stones, poppy stalks and husks, previously beaten up with white of egg, aloes, gum-arabic, and tragacanth. Sometimes also the grounds of opium, from which the morphin has been extracted, are sold as the entire drug.

The amount of water may be ascertained by drying a weighed portion in the steam bath, and noting the loss. Mineral adulterations may be detected by incinerating a known quantity of the drug, and weighing and examining the residue.

Generally speaking, however, the only satisfactory method of testing opium is to determine the quantity of morphin which it contains.

For this purpose GUILLIERMONT recommends to take two hundred grains of the sample to be tested, cut it in slices, and rub it well in a mortar with four times its weight of alcohol, strain it through linen, squeeze the residue, and pour upon it three hundred grains more alcohol; mix the strained liquors together in a wide-mouthed flask, and add about sixty grains of ammonia. In twelve hours the morphin will be spontaneously separated in crystals. These are thrown upon a filter, washed with a little water to remove meconate of ammonia, and afterwards shaken in ether, or preferably in chloroform, which dissolves out the narcotin, and leaves the morphin in a state of purity. It is now carefully dried and weighed.

THIBOUMERY extracts the weighed sample of opium repeatedly with water, filters the liquors, mixes, evaporates to a thick sirup, and redissolves in water. A large excess of ammonia is added to the boiling solution, which is allowed to cool, and then filtered. The precipitate collected on the filter is now thoroughly washed with cold water, and dried. It is next boiled in alcohol, specific gravity 0.84, and acetic acid is added drop by drop until the liquid turns red. It is now filtered, and the filtrate is again precipitated with ammonia. The precipitate is pure morphin.

To detect minute quantities of opium, if mixed with other substances, the body to be tested is treated with a little potassa, and well shaken with ether. A piece of bibulous paper is dipped several times in the ethereal solution, and allowed to dry between each immersion. It is then moistened with dilute hydrochloric acid, and exposed to the steam of boiling water, when it acquires a red color, more or less intense, according to the quantity of opium present.

PHYSIOLOGICAL EFFECTS.—Opium is used medicinally as a narcotic, sedative, and anodyne, but it usually acts first as a stimulant, and the sedative and narcotic effects are apparently the subsequent collapse of the system. When it excites, the first symptoms are heat, thirst, absence of mind, and sometimes headache and

vertigo, afterwards exhilaration of mind, which ends in sleep, attended often by the most wonderful and agreeable dreams. On awaking, languor and nausea succeed. In Turkey, Persia, and China it is generally employed as a source of pleasurable excitement, and even in this country the habit of opium-eating appears to be on the increase. The habitual indulgence in this drug brings on the most abject debility and prostration of mind and body. In large doses it produces giddiness, stupor, delirium, convulsions, and death. Upon the lower animals, opium and its various preparations have a less marked action than upon man. Thus an ape has been known to take five hundred grains of morphin in a month, or nearly seventeen grains per day, while one-eighth of a grain is as much as can be safely administered to a man in a single dose. To young children opium, in every form, is peculiarly injurious.

It is far from being thoroughly ascertained upon which of the constituents of opium its physiological action principally depends. Morphin is powerfully narcotic and sedative, but does not appear to produce the excitement derived from the use of natural opium. Codein is said by some to produce a calm and gentle sleep, which does not leave behind the dull headache that generally follows after the use of morphin. Others state that it causes violent excitement and intoxication. Narcotin is generally considered inert, though MAJENDIE maintains that it is very active when dissolved in oil. Meconic acid and the soluble meconates were at one time considered to be the active ingredient of the Manna of St. Nicholas, used as a slow poison in the middle ages; but this view is not supported by more recent observations.

In cases of poisoning with opium, or its alkaloids, the peculiar nature of the symptoms observed before death will generally lead inquiry in the right direction. If evidence on this head is wanting, it is necessary to shred the stomach, intestines, liver, *et cetera*, with their contents, and add to every one hundred parts, twelve parts of anhydrous lime or baryta; pound the whole well in a mortar; heat to 212°, and pulverize the mass most thoroughly. The powder is now three times exhausted with boiling absolute alcohol, and the liquid filtered after cooling. The bodies sought for are thus obtained, contaminated merely with fatty or resinous matters. Evaporate now carefully to dryness, and treat the dry residue with ether, to remove fatty matters. Morphin, if present, will remain undissolved, and may be filtered off and recognized by the usual tests. Codein, narcotin, and papaverin will be dissolved by the ether; add acetic acid, and precipitate with ammonia.

OXALIC ACID.—*Acide oxalique, Acide carbonéux, French; Kleesiure, Oxalsiure, German.*—This acid was obtained by SAVARY, 1773, and WIEGLER, 1779, from the salt of sorrel or binoxalate of potassa, and by BERGMANN from the action of nitric acid upon sugar, but its constitution was first pointed out by SCHEELÉ.

It exists naturally, combined with potassa, soda, or lime, in a great variety of plants, especially *oxalis acetosella* and *corniculata*, *Rumex acetosella* and *acetosa*, also in guano, in certain urinary sediments and calculi,

and combined with protoxide of iron, *Humboldtite*, in beds of brown coal.

It is generated by the action of nitric acid upon vegetal matter, especially upon substances containing no nitrogen—such as starch, gum, lignin, washed sawdust, and most advantageously, sugar or treacle. It is formed also when cyanogen is decomposed by water, or uric acid by chlorine, or the peroxides of lead and manganese; when organic substances are treated with caustic alkali in large excess; and during the preparation of potassium from carbonate of potassa and charcoal.

PROPERTIES.—Oxalic acid, in its ordinary crystalline state, forms large transparent colorless prisms belonging to the oblique system; specific gravity 1.641; inodorous, but intensely sour. It dissolves, if pure, in eight parts of water at 60°, but in two parts if contaminated with nitric acid. Boiling water dissolves its own weight. The crystals usually give out a sharp crackling sound during solution. It dissolves also in four parts of alcohol, and in sulphuric and hydrochloric acids, without decomposition, at ordinary temperatures.

The crystals, if heated in the air, lose two equivalents of water, and form a white, effloresced, powdery mass, which, at about 200°, sublimes, and is deposited upon cold surfaces as transparent, colorless, hard, slender needles. The so-called dry oxalic acid is composed of C_2O_3 , $HO = 45$. Some chemists are of the opinion that its equivalent ought to be doubled, thus: $C_4H_2O_8$ or $C_4O_6 + 2HO = 90$. The radical theory assumes the existence of a hypothetical anhydrous acid, $C_2O_3 = 36$, of which the ordinary dry acid is then regarded as a hydrate, HO, C_2O_3 . Oxalic acid is sometimes represented in chemical formulæ by the symbol, O or Ox .

This is one of the most powerful acids. When dissolved in two thousand parts of water it still reddens litmus. At boiling temperatures, in the moist way, it expels most other acids from their combinations; a fact which depends in part on its fixity, and in part on the insolubility of most of its salts. Thus it decomposes not only carbonates, nitrates, chlorides, but chromates, phosphates, and even some sulphates and fluorides.

Oxalic acid is decomposed if passed through a red hot tube, if treated with chlorine or bromine gas, or if heated with nitric, iodic, sulphuric, phosphoric, chromic, and vanadic acids, or if treated with the peroxides of lead and manganese. In contact with the chlorides of gold and platinum, it is decomposed under the influence of light, the metal being precipitated, and carbonic acid gas evolved. The reaction with salts of gold may be advantageously applied for estimating the amount of oxalic acid present in any of its compounds. The substance in question is dissolved in water if practicable, otherwise in a little hydrochloric acid, and water added in excess. A solution of the auro-chloride of sodium is then added, the liquid boiled for some time, solar light being excluded, the precipitate of reduced metallic gold is allowed to subside, filtered off, washed, dried, ignited, and weighed. One equivalent of gold represents three equivalents of oxalic acid.

MANUFACTURE.—The manufacture of oxalic acid is very simple. Brown sugar or treacle is submitted to the action of nitric acid. The starch-sugar obtained from potatoes or horse chestnuts may be likewise employed.

For this purpose clean potatoes or horse chestnuts, the latter previously freed from their husks, are ground to a pulp, which is then repeatedly washed with water. The mass thus purified is mixed with sulphuric acid to the extent of about two per cent. of the original weight of the potatoes, and a sufficient quantity of water to reduce it to a tolerably fluid pulp. The whole is then run into a leaden tank, and boiled by means of steam pipes passing through the vessel. This operation is continued for some hours until a drop of the liquid, when taken out, is no longer turned of a bluish color on the addition of iodine. The whole is then strained through a horse-hair cloth, and the clear liquid evaporated down at a steam heat, until it has a specific gravity of 1.75, or until a gallon weighs about fourteen pounds. It is now ready for use.

In the conversion of sugar or sirup into oxalic acid, one may use either vessels of earthenware or wooden tanks lined with lead. The former are generally made to hold about two gallons each, and are set in large numbers in a stout water-bath built of brickwork, which is lined with lead or cement, and heated by coils of steam-piping. The wooden tanks are generally about eight feet square by three feet deep, each being heated by about forty-eight feet of one-inch steam-pipe. They should be provided with large taps placed at the bottom to draw off the liquor into the crystallizing pans.

The vessels are now charged with the sugar or sirup, and nitric acid is added. The usual proportions are—to every hundredweight of sugar as much nitric acid as can be obtained from five hundredweight of nitrate of potassa, and two and a half or about three hundredweight of sulphuric acid. The nitric acid should have a specific gravity of from 1.200 to 1.270. If a more concentrated acid is employed great loss is occasioned, since a large part of the sugar is then converted, not into oxalic, but into carbonic acid. The tanks are then heated to about 125°. If the operation is properly managed, there will be a moderate, steady, disengagement of gas, and a very faint smell of nitric oxide, but no appearance of orange fumes. A slight addition of sulphuric acid is generally considered advantageous. When the operation is at an end, the liquid is let off into shallow cooling tanks, which are also made of wood, and lined with lead, and is there allowed to crystallize. The mother liquor is run off from the crystals, and added to the materials in the next operation. The crystals are carefully drained, washed, dried in a stove, and, if necessary, redissolved and recrystallized. The yield is variously stated; one hundredweight of good brown sugar affording, according to some, fifty to sixty pounds; according to others, one hundred and forty pounds of acid. If, however, the process is properly conducted, and the crystals freed from moisture and nitric acid, the result will be about one hundred and twenty-five pounds. Treacle, if of good quality, gives about one hundred and six pounds per hundredweight.

OXALATES.—The salts of oxalic acid are either *normal*, of the composition, C_2O_4M —where M represents any metal—*acid*, C_2O_4M , C_2O_4H , *hyperacid*, C_2O_4M , $3C_2O_4H$, or *basic*. Alkaline normal oxalates are reduced

on ignition out of contact with the atmosphere to carbonates, carbonic oxide gas being evolved. Oxalates of the heavy metals yield either pure metal and carbonic acid gas—copper, mercury, platinum, silver—or oxide, and a mixture of carbonic acid and carbonic oxide gases—iron, manganese, *et cetera*. Most normal oxalates are insoluble in water, but dissolve in dilute nitric acid.

The most important of the salts of oxalic acid are the oxalate of ammonia—formed by neutralizing ammonia or its carbonate with oxalic acid—and the acid oxalate of potassa—*salt of sorrel* or *sal acetoselleæ*— $C_2O_4K + C_2O_4H + 2Aq$. The former is used in the laboratory for detecting and determining lime; the latter is prepared by neutralizing a given quantity of oxalic acid with carbonate of potassa, and then adding as much more acid, or by pressing the leaves and stalks of the *oxalis* species, concentrating the clarified juice to crystallization, and recrystallizing so as to get rid of impurities. It forms oblique prismatic crystals, which are persistent in the air, and soluble in fourteen parts of boiling water. This salt is employed for the same purposes as the free acid. A hyperacid salt, or quadroxalate, of the constitution $C_2O_4K, 3C_2O_4H$, is sometimes found in the market along with, or instead of, the preceding.

Oxalate of lime is a white powder, formed whenever oxalic acid, or one of its soluble salts, is added to a calcareous solution. It is also found in a crystallized state in animal and vegetal tissues. It is insoluble in water, solution of chloride of ammonia, or acetic acid, but dissolves readily in dilute nitric or hydrochloric acid, and is decomposed on prolonged boiling with soluble salts of lead, copper, silver, cadmium, zinc, nickel, cobalt, strontia, or baryta.

ESTIMATION.—Oxalic acid may be very readily detected by adding to its solution, which, if acid should be previously neutralized with ammonia, a solution of sulphate of lime. A white cloud is produced in a few minutes.

The amount of oxalic acid in any substance may be determined either by the process with one of the salts of gold as described above, or from the carbonic acid given off on decomposition of the oxalic acid in contact with sulphuric acid and peroxide of manganese. A weighed portion of the oxalate to be examined, or of the free acid, which must be subsequently dissolved in water, and slightly supersaturated with ammonia, is placed in the larger flask of FRESSENIUS and WILLS' alkalimetric apparatus, along with an excess of finely-powdered peroxide of manganese, freed previously from carbonates by lixiviation with dilute hydrochloric acid. Water is added until one-third of the flask is filled. The other flask is then charged with sulphuric acid, and the operation is conducted exactly as in the examination of a sample of alkali. When the process is at an end, which is shown by a total cessation of the evolution of gas, even though a fresh portion of sulphuric acid is sucked over, the apparatus is weighed, and the loss determined. Every twenty-two grains of carbonic acid lost, represent twenty-three grains of oxalic acid present in the sample. This method is capable of great precision, but requires, of course, a sensitive balance.

PATENTS.—A great object with manufacturers of oxalic acid is to economize nitric acid, by reoxidizing the nitric oxide given off in the process. To this the carbonic acid, which is always simultaneously generated, proves an obstacle. JULLION's method, patented in 1846, is as follows:—The materials are placed in a so called *generating vessel*, holding about a hundred gallons. This vessel resembles a Woulfe's bottle, provided with a movable top fitting air-tight. It is heated by a water bath, or a steam jacket. The nitric acid is then introduced, and a current of air, or of oxygen gas, driven in through a pipe passing through one of the apertures in the top. The nitric oxide given off by coming in contact with the oxygen is partly converted into nitrous acid and peroxide of nitrogen, which are reabsorbed by the liquid in the generating vessel. The rest is led off by a pipe issuing from another hole in the top, which traverses a furnace where it is enlarged, and heated to 600°–900°. Here it is charged with spongy platinum, in contact with which all the lower oxides of nitrogen are converted into nitric acid, which is then condensed in the usual manner.

In CRANE and JULLION's *continuous process*, a covered vessel constructed of slate, and termed a *generator* is charged with mother liquor from a former operation. Above the generator are placed two feeding vessels containing respectively sirup and nitric acid in suitable proportions. The liquor in the generator is then raised to about 180° or 200°, and the nitric acid and sirup allowed gradually to flow in by means of stop-cocks, so that the delivery of the whole may take eighteen hours, by which time the operation is at an end.

Meantime the gases given off from the decomposing sugar or sirup are carried off through a vent pipe issuing from the top of the generator into another vessel containing water. Here it meets with a stream of chlorine gas which decomposes the water, forming a mixture of nitric and hydrochloric acid vapors, which are received and condensed in suitable vessels.

In MACDOUGAL and RAWSON's patent process, the gases given off from the generating vessel are drawn by an air pump through a set of Woulfe's bottles containing water, into which air is also admitted. In this manner nearly the whole of the nitric oxide is said to be reconverted into nitric acid.

ECARNOT passes his gases mixed with a current of steam from a boiler, and with air supplied by a blast over surfaces of pumice-stone.

A variety of other processes for the manufacture of oxalic acid have been suggested, one of which, patented by Dr. WILTON TURNER, is certainly a curiosity, as it, like other absurd patent methods, involves the use of a material *much rarer and more expensive than oxalic acid itself*. He operates upon uric acid obtained from guano. This is to be boiled with water in which peroxide of lead or manganese is suspended. If lead is to be employed, a known weight of uric acid is put in an open iron cylinder sufficiently large to hold a quart of water for every pound of uric acid employed. Clear lime water is added, and the whole is made to boil briskly by a steam heat. Peroxide of lead is then added gradually, as long as it is

observed to be whitened by the liquid. About one hundred and sixty pounds of peroxide are required for every hundredweight of uric acid. The clear liquor is run off, the white sediment of oxalate of lead is washed and boiled with dilute hydrochloric acid. Chloride of lead remains as a precipitate, whilst oxalic acid crystallizes out of the solution. Another product of treating the uric acid with peroxide of lead is *allantoin*, which is converted into oxalic acid and ammonia by boiling with caustic potassa. The ammonia escapes, and may be condensed and collected in a suitable apparatus, whilst the oxalic acid is obtained as oxalate of potassa. The urea generated in this process appears to be wasted.

Uses.—Oxalic acid is employed principally as a discharging agent in certain styles of calico printing, for whitening leather, as for boot tops, and for removing ink and iron-mould from wood and linen. Its acid potassa salt, which serves for the same purpose, is sometimes most reprehensibly sold as *salt of lemons*, a practice which might easily occasion fatal accidents.

Oxalic acid, if taken internally to the extent of half an ounce or upwards, acts as a violent corrosive poison. The remedy is of course chalk, or any other form in which carbonate of lime is most accessible.

PAPER.—*Papier*, French and German; *Papyrus*, Latin.—Mankind have, in all ages and circumstances, except when sunk in the lowest state of barbarism, evinced a strong desire to transmit to posterity a record of their transactions, or something that would be a memorial of their existence and achievements. This principle is inherent in human nature, and has been implanted for the most beneficent ends. Without it the advantages to be derived from a knowledge of the experience and wisdom, as well as the crimes and follies, of preceding generations, would have been lost to posterity, and the history of the past could only have been gleaned from an obscure and uncertain tradition. To gratify this natural desire of living in future ages, men have resorted to various expedients. In the primitive ages they were satisfied with a stone, or a heap of stones, as a memorial of some important transaction; but when population became more dense, and more regular forms of government were established, huge structures were erected, which must have cost an almost inconceivable amount of labor and suffering, and of which the early architecture of Egypt affords the most remarkable example. Subsequently these structures were covered with hieroglyphics, and finally, the same object was more concisely accomplished by the art of writing, which was known at a very early period. The substances used for writing upon in primitive times were first stones and bricks, and afterwards leaves and the bark of trees. Besides these, lead, copper, wax, and wood, were also employed; in fact, almost everything that presented a smooth surface on which inscriptions could be made. Books are said to be in existence, the leaves of which are thin sheets of lead. Linen had also been used at a very early period, as is evidenced by the inscriptions upon the bandages of some of the most ancient Egyptian mummies. At a later date skins and the entrails of animals, and even bones, were applied to the same purpose.

PAPYRUS.—The material which eventually came

into general use, and nearly superseded all others, was the *Papyrus* of Egypt. It was made, as is generally known, from a reed or plant of the same name, which grew in marshy places, and along the banks of the river Nile. It is said to have grown in situations where the water was stagnant and only a few feet deep. At what time it came into use is uncertain. There is reason to believe, however, that its application as a writing material may be dated one thousand years before CHRIST. The prophet ISAIAH speaks of the paper reeds of Egypt as well known, and he lived nearly eight centuries before the Savior. The papyrus was undoubtedly the principal writing material which mankind possessed for many hundred years. As such it was highly valued and extensively used, and has transmitted its name to the material now universally employed. PLINY's account of the mode of preparing it is as follows:—The papyrus, says this writer, was cut before reaching maturity, being then in a soft and spongy state, and was divided by a peculiar needle into thin plates or pellicles, which were laid lengthways on a table alongside of each other, with their edges touching. Another layer was laid across at right angles. These were moistened with warm water and then pressed, which caused them to adhere, so that the two layers became one compact sheet.

It was believed that the water of the Nile possessed a gummy property, causing the layers to adhere in this manner. But BRUCE, the celebrated traveller, denies this, and affirms that while in Egypt he partly succeeded in making paper from the papyrus. He states that the plant contains a large quantity of saccharine matter, which warm water dissolves, and this being brought to the surface by pressure, acts as a glue or size. After it was pressed it was dried in the sun, and was then steeped in a size or starch, made by pouring boiling water on bread and filtering the liquor through a cloth, after which the leaves were again dried in the sun. The finer kinds used for writing are supposed to have been made from the inner part of the stem, while the coarser were made from the outer rind, and were used for packing.

There is some difference of opinion among writers in regard to this account; but the Editor conceives that the process may be explained by supposing, not that the reeds were cut into shreds or thin slices, but that, being composed of coats or layers, they were cut or slit up lengthways, and the successive laminae were easily stripped off one after another. Being in a soft and spongy state, they were fragile; and to render the process of stripping easier, the reeds were probably cut into lengths of ten or fifteen inches. The laminae being too weak singly to undergo the process of preparation were laid one over another and then pressed, which would greatly add to the strength of the article so prepared. When Rome attained universal empire, large quantities were carried thither; and there it underwent a higher degree of finishing, being steeped in a stronger size, dried, beaten with mallets, and smoothed with ivory. By these operations a high polish was given to its surface, rendering it probably equal in that respect to the modern enamelled, or at least glazed paper. The article so finished was cut

into a variety of sizes, but none exceeding two feet in length. Alexandria became the chief emporium of this manufacture. In that celebrated seat of learning it was carried on very extensively, gave employment to a great number of people, and was a most important branch of commerce. Towards the end of the Roman Republic the consumption of papyrus was very great, and it increased considerably during the reign of AUGUSTUS. The demand for it by other nations was also so considerable as sometimes to occasion a scarcity of it at Rome. A popular tumult which occurred there during the reign of TIBERIUS was said to have arisen from this cause. The manufacture probably reached its highest point of prosperity during the peaceful reigns of the ANTONINES; but the article continued for a long time in great demand, and the profit derived from it must have been very considerable. GIBBON, in his *Decline and Fall of the Roman Empire*, tells of one FIRMUS, a wealthy merchant of Egypt, who, taking advantage of the Emperor AURELIAN's war with Zenobia, raised the standard of revolt, assumed the Imperial purple, and, having obtained possession of Alexandria, boasted that he could maintain his army from the profits of the paper trade alone.

In evidence of the extensive use and admirable fitness of the papyrus as a writing medium, it may be mentioned, that eighteen hundred manuscripts of that material have been taken from the ruins of Herculaneum; that a manuscript in the British Museum, which appears to have been written about the year 572, measures eight and a half feet in length; and that one in Paris measures thirty feet. It appears to have been preserved in the form both of books and manuscripts. When bound in a book, a leaf of parchment was inserted between every five leaves; when kept as a manuscript it was in the form of a roll, which varied in length according to the number of sheets pasted together.

Under the Roman Empire paper or papyrus was loaded with a heavy tax, which seems to have been generally regarded as burdensome; for when THEODORIC, king of the Goths, abolished the tax, about the beginning of the seventh century, CASSIODORUS, a historian of that period, congratulates *the whole world on the removal of an impost on an article so essentially necessary to mankind*. It is somewhat remarkable that the British Government is the only one which, in modern times, has continued to follow the example of the Romans in levying this impost; and it is still more surprising that the ruler of a people whom it is the custom to associate with all that is rude and barbarous, should have set an example of enlightenment in dark and troublous times, which even the government of Great Britain, with all its boasted liberality, has not yet imitated. Fortunately, however, a resolution has at length been adopted in the imperial legislature, affirming the inexpediency of the tax on paper, and it cannot be doubted that the days of this barbarous and most impolitic impost are now numbered.

PARCHMENT.—Parchment is another substance which was much used in early times. It is made chiefly from the skins of sheep and goats, and is said to have been invented by EUMENES, a king of Pergamus, who reigned

about two hundred years before CHRIST. It is related that this monarch resolved to collect a library which would equal or excel the famous one of Alexandria; and this so offended PTOLEMY king of Egypt, that he prohibited the exportation of papyrus. EUMENES would not, however, be diverted from his purpose, and he, therefore, had recourse to the skins of animals, the manufacture of which he so much improved as to be termed the inventor of the material. Hence the word *parchment*, from *Pergamus*. At the same time, it is certain that the skins of animals, though less perfectly prepared, were used long before the time of EUMENES, and are spoken of as being employed among the Ionians more than four hundred years before the Christian era.

LEAVES.—The leaves of some kinds of plants, after undergoing a process of drying and rubbing, make a tolerable kind of writing material. Mr. HERRING says that the natives of India use them in preference to paper for ordinary correspondence, and even in important matters. This may arise from a strong attachment to old customs, and not from any alleged superiority in the material. So lately as fifty years ago a Persian manuscript was in existence, supposed to have been written on some kind of leaves.

The substances above enumerated were all used for writing upon; but, however suitable for that purpose, they were altogether useless for printing. The papyrus was too hard and brittle either to receive an impression, or to undergo heavy pressure. The mode of writing upon it, which was with a style or sharp metallic point, shows that it was not suitable to be printed upon. It is, therefore, by no means wonderful that printing was not discovered in the earlier ages of the world.

The relics of Assyrian art which have lately been brought to light, show that the Assyrians had really discovered the art of printing, as far as their materials would admit; and their progress in that direction seems to have been stopped, rather from want of suitable means than by any deficiency of ingenuity. The impression of the foot on sand might, to an observing mind, suggest the idea of printing, as that of weaving might be suggested by the web of the spider. But in the operations of nature, so far as they are open to ordinary observation, there is nothing analogous to papermaking; and indeed it is difficult to understand how any person could conceive the idea of reducing a vegetal to a liquid fibre, for the purpose of obtaining by deposit a thin smooth flexible sheet of considerable strength, and calculated to receive a permanent impression either by writing or printing.

PAPER.—The substances hitherto mentioned have all been natural productions. The labor required to fit them for their intended use, was preparation rather than manufacture, and did not affect their texture. With paper of modern manufacture the case is totally different; its only similarity to leaves and the papyrus consists in its being composed of vegetal matter. In commencing a short historical notice and description of this manufacture, it will be necessary first to define what really constitutes paper.

It is a universally admitted axiom that the meaning of any word is determined by the sense in which it has

long been used. According to this rule, the substance now called *paper* is an aqueous deposit of any vegetal fibre, radically different in its structure from all bodies formerly used for writing upon, being a highly artificial material, and having no resemblance in its texture to any natural substance. A sheet of paper should be of equal thickness throughout, so porous as to admit of an indelible impression, and yet so compact as to undergo without injury almost any pressure. The surface should be so smooth as to be easily written upon, and the sheet so flexible as to fold without cracking. It may be of any *color*, and of any *length*; but seven feet is the greatest *width* to which it has yet been extended.

HISTORICAL NOTICE.—Very little information can now be obtained of the invention and early progress of the art of papermaking. The earliest accounts do not agree either in regard to date or place; but all point to the East as the seat of the discovery, leaving almost no doubt that the principle of the modern art of reducing vegetal fibre to a liquid state is a Chinese invention, dating from about the beginning of the Christian era. A detailed notice of the mode of manufacture supposed to be practised by the Chinese, is given in the *Encyclopædia Britannica*; but, besides that the accuracy of this account may be doubted, the process involves an amount of labor which would render it impracticable in Europe. A great variety of materials appear to be used, all of them vegetal substances reduced to a liquid fibre. The paper produced resembles what is commonly termed *filmsy*, but takes a finer and more delicate impression from copper plates, and is known by the name of *india proofs*. A small quantity of it is used in this country for the finest engravings. It is generally made of the inner bark of the bamboo and cotton tree.

The first accounts of paper bearing any resemblance to the article now manufactured, date from the beginning of the tenth century. It is generally supposed, says the writer in the *Encyclopædia Britannica*, that the paper called *charta bombycenia*, which was invented in Greece, supplanted the Egyptian papyrus, and this paper is incomparably more lasting, and better calculated for all the purposes of writing. It is not precisely known at what period this art, which supposes a great variety of experiments, was first reduced to practice. Whether or not the Greek mode of making paper was imported from China it is now impossible to determine. Some accounts state, that paper was brought by the Arabs to Mecca in the eighth century, along with a knowledge of the art, and by the end of the ninth century they had carried it to the coasts of Barbary and Spain. GIBBON says, that the knowledge of the inestimable art of making paper from linen rags was diffused from the manufactures of Samarcand over the Western world; and in a foot-note he adds, that the librarian CASSIRE relates from credible testimony that paper was first invented, or rather introduced, at Mecca by JOSEPH AMRU, in the year 706 or 710. The Escorial library contains a manuscript on paper of this kind as early as the tenth century. There is little information of the progress of the art during the three following centuries, or even until the beginning of the fourteenth. From an American work,

The Chronology of Papermaking, it appears that in the year 1085 the Christian disciples of the Moors worked the paper-mills at Toledo in Spain to better advantage than their predecessors, and that instead of cotton they used rags, and made the paper with moulds. From the time, however, that paper was manufactured from fibre, moulds or sieves must have been used; and this probably refers, therefore, only to some important improvement which was effected upon them. It is stated in the same work that in the year 1151 the best paper was made at Xativa from rags. At this date also occurs the first notice of water-mills and the use of mallets. But from the disorganized state of society in Europe during this period, it could hardly be expected that an art like papermaking, which even in its simplest form requires an outlay of considerable capital, could make much progress.

The art reappears in Germany towards the end of the fourteenth century; but it is stated that even from the beginning of that century paper-mills were in operation in Tuscany. A mill was erected at Nuremberg in Germany to make paper from linen rags, by ULLMAN STROMER. At this time the process was kept strictly secret, and the workmen were sworn not to divulge it or carry it on on their own account. Notwithstanding all these precautions to keep the art secret, it became known, and was introduced into France, Holland, and Genoa, in all of which it seems to have been prosecuted with considerable success, particularly in France, whence there was a considerable quantity exported to Britain and other countries. The trade began to decline in France about the middle of last century, as other countries, particularly Britain, were by that time manufacturing nearly sufficient for their own use.

The first paper-mill in England, of which there is any particular account, was erected at Dartford in Kent in 1558, by Sir JOHN SPIELMAN, a German jeweller in the employment of Queen ELIZABETH, who, for services rendered in this respect, bestowed upon him the honor of knighthood, and gave him a license for the sole gathering of rags for ten years. Mr. HERRING says, it is quite certain that paper-mills were in existence long before SPIELMAN's time, and adduces a passage in SHAKESPEARE's play of *Henry the Sixth*, in which reference is made to a paper-mill at least a century before this; but he admits that the chronological accuracy of SHAKESPEARE is not to be depended on, and that the earliest traces of the manufacture in this country occur in a book published by CAXTON in 1490. The mill to which reference is supposed to be made, was near Stevenage in Hertfordshire. In the household book of HENRY the Seventh, there is an entry of a reward of sixteen shillings and eightpence given to the *paper mylne*, dated 25th May, 1498; and again in 1499 another reward of six shillings and eightpence is given to *Tate of the Mylne*, supposed to be the mill at Stevenage.

In Scotland the manufacture is of still more recent date. The first paper-mill, according to current accounts, was erected at Netherlee, near Glasgow, by a Dutch papermaker. The calamities which befell Scotland during the reigns of the last three STUARTS

prevented the introduction and development of manufactures; but after the Revolution, when protection was afforded to life and property, papermaking, like other manufactures, began to revive.

The French protestants who fled to England for refuge from the persecution which followed the revocation of the edict of Nantes in 1685, are said to have introduced many improvements into the paper manufacture. About this time white paper, of which little had been made, began to be more generally manufactured, and the quantity rapidly increased. It was estimated that about three hundred thousand reams were produced in 1721, and this was supposed to be about two-thirds of the consumption of the country.

MATERIALS FROM WHICH PAPER IS MADE.—The materials of which paper is manufactured are vegetal substances containing fibre, and are not so limited in number and kind as is commonly supposed. Linen and cotton rags, affording the greatest facilities of manufacture, have most generally been used, and are nearly all made into white paper. The rag merchant packs them according to their quality, and when brought to the mill they are cut, and assorted more perfectly. A large quantity of the rags used in this country are imported, and are principally of linen.

Ropes and the sweepings of cotton-mills, called *cotton waste*, furnish a large supply of material for papermaking. Incongruous as these may appear, they are generally used together, and when properly prepared make a beautiful paper, but require a great amount of labor. *Wrapping paper*, for which great strength is the most important requisite, is generally made from these materials; and they can be used for that purpose with comparatively little labor. But the American makers are in advance of the British in the use of these stuffs. By a peculiar process of cutting, cleaning, and boiling, Mr. H. V. BUTLER of New Jersey has succeeded in making from them the best printing papers which the Editor has yet seen. The sweepings of flax-mills, called *flax waste*, are very useful in making strong wrapping paper, where beauty of appearance is not an object, and furnish a considerable supply to the manufacturer. The best kinds can be used for white paper, but require much labor in preparation. Jute, surat, or nettle bagging, all of which appear to be substances of a similar kind, are now extensively used in making colored and brown papers. They are grown in India, and are made into bags, in which form they are imported into this country.

Straw.—Chemical science has also introduced straw—chiefly that of wheat—into the category of materials used for papermaking. When intended for printing papers, it requires to be boiled in a strong lie, to destroy the silica it contains. The fibre is short and tender, and not calculated to make of itself a good paper. It is, however, improved by being mixed with a stronger substance. Although it is only lately that straw has been successfully used for this purpose, yet as early as 1756 an attempt was made to manufacture paper from it in Germany, and in 1800 the Marquis of SALISBURY presented a book to the king printed on paper made from straw. In 1812 a Frenchman announced a new method, so simple that any person

could make paper from this material in a manner equal to the best workman, and in 1820 M. HUYGERON, another Frenchman, obtained a patent in France for a similar process. In 1828, WILLIAM MAGAW of Chambersburg, U.S., took out a patent for making paper from straw and blue grass. In 1854, M. KELIN of Belgium invented a process for converting straw into paper, which differed from any other in use. The straw was steeped in water sixty hours, when the liquid was run off and the straw washed with a plentiful supply of water. It was then passed between two rollers in a damp state, and afterwards cut into fibres of suitable length, and exposed to the bleaching effect of the sun's rays. It was now submitted to another bleaching process of three or four days, and subjected to the action of a solution of chloroxide of sodium or potassium, until it acquired a sufficient degree of whiteness, when it was put into the engine.

In 1857 another new mode of preparing straw was said to be discovered, but is not yet made public.

Wood.—The linden tree or bass wood affords another material for making paper, and several mills in the United States are at present employed in manufacturing it from this substance. The first attempt to apply it seems to have been made in France in 1776. Other kinds of timber have also been used; and in 1836 R. and J. C. MARTIN secured a patent for obtaining a pulp from wood, by first saturating with water planks or chips, then subjecting their surfaces to a cylinder having teeth resembling a saw or rasp, by which the ligneous fibre was reduced to a pulp. Sanguine hopes were at one time entertained that this plan would prove successful, but the Editor has not heard of its having been seriously adopted by any papermaker. It is difficult to reduce wood to a fibrous liquid, as the fibre is short and weak; and no means have yet been discovered of converting it into a pulp of the requisite fineness without, at the same time, reducing it to powder. If pine wood could be sufficiently bleached and pulverized, a portion of it might be used among pulp with advantage, as the resin it contains would improve the size.

Animal and other Substances.—Several attempts have also been made to fabricate paper, either wholly or in part, from animal substances, but hitherto with little success. Chamois leather, when properly prepared, and a portion of it mixed with pulp, makes a strong tough paper, but of a poor color. The machinery for preparing rags is unsuited for animal substances, its effect being to tear out, while animal materials require to be bruised or rubbed. Paper from such materials was lately manufactured at a mill in England, and was expected to be free of duty, but the case was otherwise decided.

From this enumeration it will be seen, that the field from which the papermaker can draw his raw material is not so confined as has been supposed; and these are but a portion of the substances which have been proposed and experimented upon. Mr. HERRING remarks that the fibre of vegetables which is capable of being made into paper may generally be first manufactured into some other fabric, such as cloth, ropes, or mats, and after it has served its purpose in that form it is then a

fit material for making paper. And in regard to experiments with new substances, he quotes Dr. FORBES ROYLE, who observes, that the generality of modern experimentalists seem totally unacquainted with the labors of their predecessors, many of them commencing improvements by repeating experiments which had been already made, and announcing results as new which had been long previously ascertained. As an evidence of the number of substances which have been tried, this writer refers to a book in the British Museum, printed in Low Dutch, and consisting of upwards of sixty specimens of paper, manufactured from as many different materials, all the result of one man's experiments, and made previous to the year 1772. In point of fact almost every vegetal has been tried. Nettles have always been a favorite article with experimentalists. It is not long since it was announced that hollyhock stalks were to furnish an almost inexhaustible supply for the papermaker. There is no doubt that it is possible to reduce every vegetal to a fibre, and with it to make paper. But notwithstanding all the discoveries of new substances which have been made, and all the protection which patents can afford, it is still found that flax and hemp, or rags, ropes, and other fabrics composed of these substances, constitute the staple materials of the paper manufacturer. And the Editor believes, that until science makes further discoveries in the mode of preparing new substances, papermakers will find it more profitable to abide by the use of the old materials, than rashly to indulge in experiments on their own account.

Supply of Materials.—Judging from the past history of papermaking, there does not seem to be much reason to fear that the present sources from which the paper manufacturer draws his raw material will ever be insufficient to supply the demands of the trade. The fact that it has always been when this manufacture was first introduced into a country that there was any considerable difficulty in obtaining the raw material, and that as the manufacture extended the supply also increased in about the same ratio, would seem to warrant the conclusion, that fears on this subject are groundless, so long as the present sources of supply exist. On the other hand, it must be taken into account that the countries from which the largest quantity of rags is imported are those along the shores of the Baltic and Italy; and were these countries to commence manufacturing for themselves, the supply from them would cease. At the same time, in proportion as civilization extends and population multiplies, new sources will open, and long before an absolute deficiency is felt, science may discover new materials as well as new processes.

The Editor has found some difficulty in reconciling the conflicting statements regarding the importation of rags into this country; but it appears that nearly a seventh part of the raw material is imported. In the year 1853 it was estimated that ninety thousand tons of rags were used in the paper manufactories of Great Britain, of which fifteen thousand tons were imported; but that, taking that year with the two preceding ones, the average annual importation was below ten thousand tons. In that year there was charged with duty, one

hundred and seventy-seven million, eight hundred and thirty-three thousand, and ten pounds of paper, besides about two hundred thousand pounds imported; and thirteen million, two hundred and ninety-six thousand, eight hundred and seventy-four pounds were exported, leaving for home consumption one hundred and sixty-four million, five hundred and thirty-six thousand, one hundred and thirty-six pounds. If, therefore, a seventh part be deducted from the total quantity charged with duty and imported, as representing that which had been made from imported rags, there remains only one hundred and fifty-two million, four hundred and twenty-five thousand, two hundred and ninety-two pounds; or there would have been a deficiency of upwards of eleven million pounds had this country been confined to the home market for its raw material. The discovery, therefore, of some new substance, which would really meet the wants of the paper manufacturer, and which could be provided at a cost not above the present price of rags, would undoubtedly be a national boon.

As these remarks may bring upon the papermaker a multitude of suggestions, and load him with specimens of all sorts of vegetals, from cabbage stalks to bamboo branches, the Editor would advise discoverers of new materials for making paper to work out their own suggestions, and first to ascertain the cost at which the proposed materials could be obtained, and also the cost at which they could be made fit substances for the paper manufacturer, before introducing their discoveries to public notice or incurring the expense of a patent.

PREPARATION OF RAGS.—The proper preparation of the rags is an object of great importance to the papermaker, and one which requires both skill and attention. It is, moreover, a subject on which opinions are divided. In these circumstances it will be sufficient to describe the mode of preparing the rags at the most extensive mill in this country, where the best writing and printing papers are manufactured.

Cutting the Rags.—The first process is the cutting of the rags, which is performed by females. Each woman is stationed at a small table about three feet square, and covered with a netting of wire. In the centre of the table a knife, about eighteen inches long and five inches wide, is placed nearly vertical. The woman stands at the back of the knife, and a quantity of rags are given to her, of which she lays a small portion on the table. She then cuts the rags into strips three or four inches wide, taking off buttons, hooks and eyes, *et cetera*, and laying out all substances unsuitable for the making of paper, such as india rubber, and pieces of woollen and silk. At her right hand is a box divided into several compartments, into which she throws the rags according to their qualities. A large quantity of sand falls through the meshes of the wire-cover into a box underneath. All pockets and seams should be ripped up to allow dirt to escape, and to prevent, as far as possible, anything getting among the prepared rags which would be injurious to the paper, or hard substances, such as pieces of iron, which might break the machinery.

The rags are again examined by women called *overhaulers*, or *overlookers*. There is generally one

overhauler to every eight or ten cutters. Some manufacturers attach great importance to having their rags cut into pieces four inches square. But the mere size of the rags is a matter of indifference. The principal object is to have them in a state which will insure their thorough cleansing in future processes, and cause them to float among water in the rag-engine without twisting and warping round the roller. Anything smaller than is necessary for this purpose causes a greater loss of fibre in the willow and duster.

Willowing of Rags.—From the overhaulers the rags are taken to the *willow*, which consists of two cast-iron cylinders, two and a half feet diameter, and three and a half feet wide, covered with iron teeth projecting about four inches. These cylinders are set one behind the other. Below them is placed a semicircular screen, and a cover of the same shape above. This cover is also provided with teeth, and is adjusted so that the teeth in the cylinders pass those in the cover at a distance of a half or three-quarters of an inch. In front are a pair of rollers and a revolving apron, for the purpose of carrying the rags into the cylinders. These revolve with a rapid motion, and the rags, being thrown by the first into the second, are confined in the cylinders about twenty seconds, when a sliding door, which rises three times in one minute, allows them to be discharged into a duster. As often as this sliding door opens, the revolving apron moves forward, and charges the willow with a fresh supply of rags. The latter, being thus beat and teased in the willow, are loosened in the texture, and a large quantity of sand falls through the screen underneath.

The *duster*, into which the rags are discharged after passing through the willow, is a large cylinder twelve feet in length and five or six feet in diameter, which is placed lengthwise against the willow, and revolves slowly at right angles to it. This cylinder is covered with a coarse wire-cloth, and a number of teeth are fixed into it at regular intervals, which toss and shake the rags, thereby removing any remaining dust, which falls through the meshes of the wire-cloth. The rags are now deemed ready for boiling. About five hundredweight of rags are carried through the willow in one hour. Cotton and flax waste is passed two or three times through the willow.

In willowing there is a considerable loss of fibre, particularly when the process is repeated more than once. The willow dust is therefore preserved, and is used in some inferior mills for making wrapping papers.

Boiling.—Rags are boiled in a solution of alkaline lie made of quicklime and soda, generally in the proportion of one pound of lime to two of soda. This caustic alkali is prepared by boiling the lime and soda together. While seething it should be well stirred and mixed, and afterwards allowed to stand for a few hours, until the sediment falls to the bottom, when a clear liquid is obtained. The quicklime is first thrown among the hot water, and some think it improves the lie to introduce the soda immediately, while the lime is slaking, as a high degree of heat is then evolved, which dissolves the soda very quickly. Others slake the lime in a cistern by itself, and after stirring well, allow the heavier and undissolved portion to fall to the

bottom, then run off the upper portion, which has the appearance of a fine thick cream, into another vessel, and afterwards put in the soda. Another method is to dissolve the lime as above, and run it into the boiler among the rags; the quantity of soda to be used is then put into a bag, which is introduced into the boiler and its contents allowed to dissolve. But the general way is to mix the lime and soda, and run the pure liquid into the boiler. For the finest papers this liquid should be quite pure. Six to ten pounds of soda, and three to five of lime, are generally used for one hundred-weight of rags; but this proportion varies according to the quality of the rags, and every manufacturer has his own method of procedure.

Rags are boiled for the purpose of *killing*, or destroying, minute particles of the stem of the flax and shell of the cotton, which even very fine cloth contains. These substances, which are generally called *shove*, are very injurious to paper, and boiling is the only way to get rid of them. It also loosens the dirt in the texture of the rags, and considerably improves their color. A strong flax rag will lose from one-third to one-fifth of its weight by boiling and washing.

It is not more than thirty years since papermakers began to boil their rags, and the boiler long used was simply a cast-iron vessel, large enough to contain about ten hundredweight of rags. It had a furnace underneath, and was heated by the direct action of the fire. The chief objection to this mode was, that pieces of rags adhered to the sides of the boiler, and were burned. Steam was then tried, and found to be much cleaner in its operation. Circular, and sometimes square boilers, were adopted. When steam came into use, a perpendicular pipe was inserted into the centre of the boiler, which had a double bottom, the upper one being of movable perforated plates, and raised about nine inches above the lower. The steam was admitted from the top, and passed by the vertical pipe into the space between the bottoms, where it escaped into the boiler by tubes radiating from the central pipe to the sides of the vessel. This is still considered by many manufacturers to be a good boiler. An addition was made to it by some papermakers, who inclosed the steam pipe in a larger one, leaving a space of two or three inches between the two. When the liquid containing the rags was brought to the boiling-point, it was forced up between these pipes; and round the top of the outer one was a large flange, which spread the lie over the surface of the rags. A constant circulation was thus maintained by the rising of the lie in the space between the pipes, and its subsequent descent through the rags contained in the body of the vessel. This is reckoned a good boiler, and is still used by a number of papermakers. It is generally made seven feet in diameter by four deep, from the rim to the false bottom, and will boil ten or twelve hundredweight of rags in twelve or fifteen hours. It is known, from its peculiar action, as the *vomiting boiler*.

The apparatus now in greatest repute is the *revolving boiler*, of which at least three different kinds are made. This form of boiler was first applied by H. V. BUTLER of New Jersey twelve years ago. It is a large iron cylinder revolving horizontally on bearings, and divided

into four compartments with double ends; the inner ends being perforated plates by which the boiler is drained, and provided with a small door, large enough to admit a man, by which the vessel is filled and emptied. This boiler operates with less soda, and the boiling is performed in from eight to ten hours. Revolving boilers were first introduced into England about the year 1854 by BRYAN, DONKIN, and Company, of London, who secured a patent for a boiler on this plan. It consists of two iron cylinders lying horizontally, one within the other. The outer cylinder is stationary, while the inner, which is perforated, is so constructed as to

revolve. There is a frame and rack in front, by which the inner cylinder can be drawn out; two large plates are then taken off and the cylinder turned round, when the rags fall out. The front end is bolted on to the outer case, and keeps the boiler steam-tight. In this apparatus the rags require only from eight to ten hours' boiling, and a small saving of soda is effected.

Another revolving boiler has been patented by Mr. JOHN ROBERTSON, engineer to Messrs. A. COWAN and SONS, Valleyfield, near Edinburgh. This apparatus is represented in Figs. 379 and 380. It consists of two cylinders; the outer one, A, is made of boiler-plate,

Fig. 379.

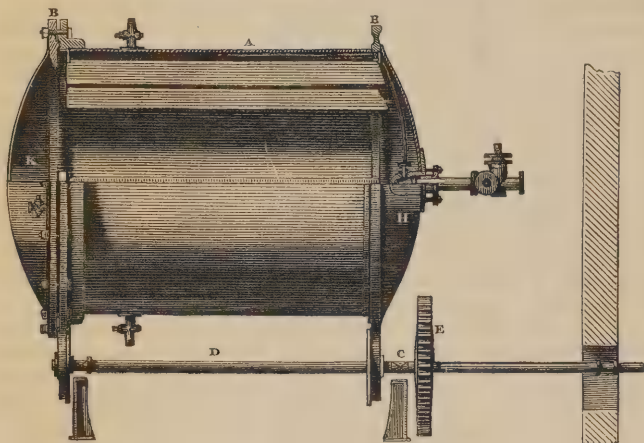
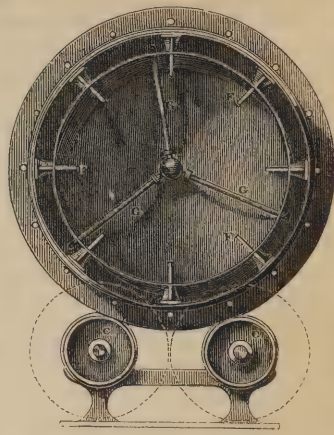


Fig. 380.



and is rivetted to cast-iron flanges, B, which revolve slowly on four friction wheels, C, fixed on two shafts, D, with spur wheels, E, on one end of them for receiving a motion. The inside cylinder is formed of perforated iron plates, with bars or shelves, F F, projecting inwards, for the purpose of agitating the rags. The steam and lie are admitted through the centre of the back end, H, of the boiler, in pipes, G G, leading to the space between the two cylinders. The rags are put in and taken out by removing the other end, K, of the boiler, which end or door is also made of boiler-plate, and is rivetted to a cast-iron flange with a turned face, fitting into a corresponding groove in the flange on the body of the boiler, and secured by strong bolts, making a steam-tight joint. This boiler is calculated to stand a pressure of sixty pounds per square inch, thereby subjecting the rags to a higher temperature than that of boiling water.

An opinion prevails that a high degree of heat is beneficial in boiling rags—that by using high-pressure steam a smaller quantity of soda is required—while by having the boilers steam-tight this high pressure is kept up with a small expenditure of steam. In practice it has been found that, while boilers constructed on this principle effect a considerable economy of time, there is no great saving of alkali, and that a small escape of steam is positively beneficial.

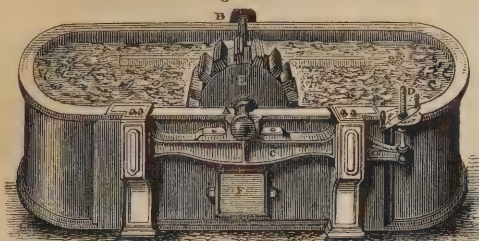
A different system of boiling has been patented by Messrs. CRANSTON and LOVELL of Chirnside. Their apparatus consists of a series of oval stationary boilers,

each containing about seven hundredweight of rags. These are likewise heated with high-pressure steam, which passes from one to another; and the boilers being steam-tight, only a small quantity of steam is required, while a saving of alkali is also effected. The Editor believes this mode of boiling has given satisfaction to those who have adopted it. Strong and perfect boiling is a highly important point in papermaking, and contributes greatly to the production of a clean and pure article. Any defect in this operation can never be remedied by subsequent processes.

Washing Engine.—The rags, after being boiled, are brought to the *washing engine*, which performs a very important part in the manufacture of paper. This engine, which is represented in Fig. 381, is a large iron vessel, into which the rags are put for the purpose of cleansing and reducing them to what is called *half-stuff*. For this purpose the rags are made to revolve among water, a constant supply of which flows in at one end of the vessel, and an equal quantity is lifted out at the other by means of a revolving cylinder covered with wire cloth. This engine is of various sizes, generally about twelve feet long, from four to five feet in width, and two deep. An iron partition runs about eight feet along the centre, leaving a space of two feet open at each end. A few perforated plates are placed in the bottom to allow any sand or dirt to escape, and a grooved box in front of the roller to catch any buttons or hooks, or other hard substances, which may have escaped former processes. Across the centre of the

engine is a spindle, A, of wrought-iron, four or four and a half inches diameter, one end of which carries a pinion, B; the other end rests on a frame or lighter, C C, which can be raised or depressed by means of a screw, D. On this spindle is an iron cylinder or roll, E,

Fig. 381.



generally twenty-four inches in diameter by twenty-eight inches in length, and mounted with forty bars or knives at regular intervals, projecting about two inches, so as to make the extreme diameter twenty-eight inches. The roll makes from one hundred and twenty to one hundred and thirty revolutions per minute, and under it is fixed a plate composed of ten or twelve knives, five or six inches wide, and equal in length to the roll. This plate is fixed in a box or seat, F, in the bottom of the engine. Over the roll is a wooden cover, to prevent the rags and water from flying off by the rapid revolution of the roll; and across this cover is placed a screen of fine wire-cloth, against which the rags and water are dashed by the motion of the roll. In the figure, the cover and screen are removed, to exhibit the internal apparatus. The water, passing through the screen, is carried off by pipes, while the wire-cloth prevents the rags from escaping. Formerly these screens, one before and one behind the roll, were the only means of carrying off the dirty water.

In the year 1837, CHARLES COWAN of Valleyfield Mills invented and patented a revolving washing cylinder, which greatly improved the washing power. This cylinder, which consists of fine wire-cloth, contains a series of circular buckets, starting from a common centre on a spindle, and projecting to the circumference of the cylinder. The latter is twenty-four inches wide by thirty inches diameter, and being immersed in the engine to the depth of six inches, revolves among the rags, while the buckets successively lift the water and pour it out at the centre into a spout. When the engine is empty the rags are brought to it in a box. The roll is lifted entirely free of the plate by means of the lighter screw. A stream of water is then turned into the engine; and as soon as it rises to the level of the roll the workman begins to introduce the rags, spreading them on the surface of the water. About a hundred and fifty pounds are put in at one time. The rotatory motion of the roll draws the rags between the roll and plate, and dashes them from one side to the other, until, being carried round in the spaces between the knives, they are thrown out on the other side. By this action the level of the water is depressed in front of the roll, and on passing through to the other side, it endeavors to regain its level, whereby it flows round the end of the mid-

feather, back to the front of the roll. A continuous circulation of the rags is thus maintained, and the flow of water into the engine is regulated by the quantity lifted out, which is greatest at the commencement; for as the rags are rubbed down into fibre less water is lifted by the washing cylinder. Papermakers calculate on the washing engine using from forty to sixty gallons of water per minute. When the rags have been fifteen to twenty minutes in the engine the roll is gradually lowered, until nearly its whole weight rests on the plate.

The motion of the roll over the plate draws the rags into a fibrous substance called, as already stated, *half-stuff*. Experience and care are required in this operation. If it is performed too quickly, or if the rags are cut too short, the paper will be weak, and a great loss of fibre in future operations will be the consequence. If, on the other hand, the rags are not drawn into fibre they do not bleach equally. It requires not less than two hours to reduce the rags to half-stuff; by this time they should be cleansed, and in a fit condition for being bleached.

In the process of washing the rags a considerable quantity of fibre passes away with the water. To save this fibre, which can be used for inferior papers, Messrs. JAMES PAISLEY and GEORGE BERTRAM have invented and patented a conical cylinder covered with fine wire-cloth. The water, as it passes from the engine, enters the small end of the cylinder, and as it flows down to the wide end, percolates the wire-cloth, leaving whatever fibre it contained. This cylinder can also be applied to recover the fibre which the waste water from the machine contains.

Several other improvements have been made at different times upon the washing engine, professing to increase its washing power and save fibre; but none of them, so far as the Editor is aware, have proved of practical value.

Bleaching.—The quality which chiefly distinguishes the paper of the present day from that made thirty or forty years ago, is its pure white color, which can only be obtained by bleaching. When the art of decoloring with chlorine gas was introduced about the end of last century, manganese and chloride of sodium were mixed together in a close vessel, and sulphuric acid was poured upon them. The chlorine thus generated was conveyed in pipes to a close chamber, in which were placed the rags to be bleached. In the chamber they were exposed to the action of the gas for some hours, and by this means a good result was obtained; but it was a difficult operation, and injurious to the health of the workmen.

When chloroxide of calcium, or lime impregnated with chlorine, was introduced, the method first practised was to put the lime into an iron or lead box and mix it with water. The gas, having a stronger affinity for the water, combined with it, forming what is called bleaching liquor. When the rags had been well cleansed in the washing engine, and reduced to a coarse fibre, as already described, the flow of water through the engine was stopped, and a portion of the bleaching liquor was introduced among the *half-stuff*. The roller was then lifted off the plate, and the stuff was made to circulate in the engine about an hour, which effected a great

improvement in the color. The process of washing was then resumed, and continued until the gas was washed out, after which the stuff or pulp was emptied into the beating engine.

To this method there were several objections, one of which was that the whole of the gas that remained in the stuff when the washing was resumed was lost. About 1820 the present method of bleaching in stationary chests, and thereby saving the liquid which still retained a considerable quantity of gas, was generally adopted by manufacturers.

Present Method of Bleaching.—A quantity of chloroxide of calcium is put into a circular stone cistern filled with water. An upright shaft, which revolves on a bearing in the bottom of the cistern, and has arms projecting to within a few inches of the side, mixes the bleaching powder with the water. When the agitator is stopped, the lime settles to the bottom, leaving a clear liquid with a green tinge, which constitutes the *bleaching liquor*. The proportion of lime and water is generally one pound of lime to two gallons of water, and it is expected to stand 8° of Twaddell's hydrometer, but seldom stands more than 7°.

When the rags have been brought by the washing engine to a fit condition for being whitened, they are emptied into the bleaching engine, which is placed on a lower level to admit of the stuff being discharged into it by a pipe. The bleaching engine is similar in construction to the washing apparatus, but has no plate, as its only office is to mix the stuff with the bleaching liquor. It is made of stone to resist the action of the chlorine, and a part of the bottom is laid with perforated zinc plates, to admit of the stuff being drained. This is generally done by a pump, and the water is used over again for washing the next charge of stuff. When this half-spent lie has been introduced into the bleaching engine, there is added to it a portion of strong liquor, generally from eight to sixteen gallons to the hundredweight of rags. This quantity of bleaching solution contains as much gas as exists in four to eight pounds of lime. The stuff is then allowed to run from fifteen to twenty minutes, and is finally emptied into the bleaching-house, where it remains from eighteen to twenty-four hours.

The bleaching-house is a separate apartment, in which are generally placed two rows of stone boxes or chests, each of sufficient capacity to receive the contents of two engines of stuff. To allow sufficient time for bleaching, there ought to be as many chests or boxes as will contain the supply of stuff required for thirty hours.

Some papermakers allow the *half-stuff* and chlorine to remain from forty-five to fifty minutes in the bleaching-engine, under the impression that the color is thereby improved. It cannot be denied that the color improves very rapidly under the process; but when it is continued more than twenty minutes, the action of the roll on the stuff causes the chlorine to evaporate, which is easily perceived by the smell, and greatly reduces the bleaching powers of the liquor.

About four years ago Mr. DUNCAN of Denny invented a different method of bleaching, which he protected by a patent. The principle of his improvement

consists in the application of heat to the pulp while in the bleaching engine. According to his published statement, its advantages over the old method are, that it is more economical, produces a better pulp, and is more quickly effected; the whole process not occupying an hour. But whatever be its merits, it does not appear that this mode has found much favor with paper manufacturers.

When the stuff is sufficiently bleached, the clear liquid is pumped into a cistern for further use—it being a property of the liquid that it not only extracts but destroys the color, and, therefore, does not become impure by bleaching. On the other hand, the stuff or pulp is put into a strong iron box, and submitted to the action of a hydraulic press, which prepares it for the beating engine.

BEATING ENGINE.—The *beating engine* is of nearly the same construction as the washer, and is used for grinding the *half-stuff* into a fine pulp fit to be made into paper. The roller contains fifty-four, and the plate from seventeen to twenty-four knives. A stream of water is turned into the engine; the *half-stuff* is then introduced, and mixing with the water, is drawn between the roll and plate, producing a continuous circulation, as in the washing engine. Before the roll is lowered to the plate, the *half-stuff* is allowed to run for thirty or forty-five minutes, to wash out the chlorine, which, if suffered to remain, is found to be injurious to the paper.

Within the last few years hyposulphite of soda has been used to neutralize the chlorine. A small quantity of this salt is dissolved in water; and this, being put into the engine, instantly seizes the chlorine, and by combination neutralizes it, forming sulphate of soda, a substance harmless to paper. The washing is then resumed, and continued for a few minutes, to remove the new compounds formed. It may here be remarked that since hyposulphite of soda, or, as it is technically termed, *antichlor*, came into use, the time of washing in the beating engine has been reduced to twenty minutes, thereby effecting a saving of twenty-five minutes, which can be applied to the grinding of the pulp, and, at the same time, no traces of chlorine remain in the paper.

If the pulp is required for printing papers, a solution of soda and rosin is now put into the engine; and, after being well mixed, a few pounds of alum are added, which, combining with the soda, allows the rosin to adhere to the pulp; this is called *engine-sizing*, and is done with the view of preparing the paper to bear ink when printed. Any coloring matter which may be required is next introduced; the roll is then gradually lowered on to the plate, and the process of *grinding*, or reducing to fine fibre or pulp, commences.

The pulp is made long or short according to the quality of the paper. Newspapers, which require strength, are made of long pulp. Writing paper, or paper of a fine texture, is made of shorter pulp. In fact, the quality of the paper depends very much on the manner in which the pulp is prepared in this engine. If the roll is lowered too rapidly the fibre is cut, and produces a tender paper; and, owing to the porous nature of this paper, the sizing, whether for printing

or writing, will be weak. The stuff should be what is called *mellowed* in the engine, and this is effected by a judicious working of the roller—not lowering it suddenly or much at one time, on to the plate; but equally and gradually, until the pulp is ground as fine as is required. This is generally attained in three and a half to four hours; after which the engine is emptied into the stuff chest or reservoir, which is a large cistern capable of containing five thousand or seven thousand gallons of this prepared pulp.

To give an idea of the number of cuts or bruises to which the rags are subjected, it may be stated that the roll containing fifty-four knives revolves a hundred and fifty times per minute over the plate containing twenty knives, thereby making no less than a hundred and sixty-two thousand cuts every minute. This rotary engine was invented by the Dutch about the middle of the last century, and is known by German papermakers as the *Hollander*. Although not free from some defects, it is a great improvement on the old mortar engine. And while great advances have been made in papermaking during the last thirty years, the chief improvement on this engine has been the revolving washing cylinder, already described. The principal defect of the engine arises from this, that while a certain quantity of rags is put into it for the purpose of being ground to fibre or pulp, these rags are not of the same tenacity, and being kept under the action of the grinding process for three or four hours, the weaker rags are reduced to a finer pulp than those of a stronger texture. Also, one engine may be emptied into the reservoir which contains pulp of a longer or shorter fibre than the previous one. In fact, there is no security against this evil but the care and skill of the workman; and, notwithstanding every precaution, it sometimes materially affects the quality of the paper.

To overcome this difficulty, JOSEPH KINGSLAND of New Jersey has secured a patent for a centrifugal pulp engine, which is said to be working satisfactorily in his mill in New Jersey, producing a uniform pulp. This machine has been adopted by EASTON and AMOS of London, by whom further improvements have been made upon it, and who, having also experimented with it at Phoenix paper-mill, Dartford, state, that having now fairly tried it, they are convinced it is a valuable machine, one capable of producing better pulp with less power than any other engine hitherto produced; and that, consequently, its adoption would secure to papermakers very considerable advantages. Hence they are persuaded that it must come into extensive use.

This invention consists in placing a revolving grinder between two stationary grinders; the fibre to be ground or reduced to pulp being caused to pass in a current through the spaces between one of the stationary grinders and one side of the revolving grinder, thence round the periphery of the revolving grinder and the other stationary grinder, to the orifice of discharge. In its actual operation a stream of pulp well mixed with water flows by a feed pipe under, say, four feet pressure into the engine, between the revolving grinding surface, which makes two hundred revolutions per minute against the stationary grinder, and the distance

between the two surfaces can be regulated by a set of screws, thereby producing coarser or finer fibre as required. The moment the fibre is ground it passes into the reservoir. A constant stream is thus flowing through the engine at the rate of a hundred and fifty pounds of paper per hour. The Editor has no doubt but that in a few years this engine will supersede the present beating engine, and will greatly simplify the mechanical operations of the papermaker.

The thorough neutralization of the chlorine is an important matter. When machines began to be generally introduced, the engines in many mills were not adapted for the increased quantity of work a machine could perform, as compared with vats. Too little time was therefore given to the preparation of the pulp, and the chlorine was not sufficiently washed out; and as chlorine, if left in pulp, continues to act on the paper, causing a premature decay, complaints were consequently very frequent, and the decay was ascribed to excessive bleaching and the use of mineral substances. This, although a natural opinion, was not the less a mistake. Excessive bleaching will make paper weak or tender, but if the chlorine has been neutralized it will not otherwise injure it. Mineral substances were at one time pretty freely used, and in some mills this may still be the case. A small quantity is not injurious to paper, and is sometimes used to close the pores, thereby improving the surface. But experience has taught paper manufacturers that the injury these substances do to felts and wires is poorly compensated by any little addition to weight which is obtained from them; and since antichlor came into use, by which the chlorine is easily neutralized, the complaints above-mentioned have been seldom heard.

PAPERMAKING BY HAND.—Having described the method of preparing rags to make paper, the Editor will briefly advert to the old way of manufacturing it.

In papermaking, as first conducted in Europe, the rags were neither boiled nor bleached, but were only cut and assorted; and to facilitate the cleaning and reducing to pulp, they were steeped in water, then laid in heaps, and allowed to ferment and putrefy. This loosened the texture, and prepared them for being cleansed and reduced to pulp. The process of reducing the rags to pulp was performed by stamps or mallets working in a strong wooden box or mortar. A stream of pure water was allowed to flow through the box, thereby carrying off all impurities. This process was continued until the rags were clean, and was necessarily very slow and tedious. When the rags were considered fit to make paper, they were emptied into a chest, from which the pulp was lifted into a vat. This vat was simply a cistern about three and a half feet high, six feet square at top, and tapering nearly to a point at bottom; near which a small agitator revolved, keeping the pulp of an equal consistency throughout.

The sheet of paper was made by a mould, composed of a frame covered with fine wire-cloth, having a movable edge called a *deckel*. This mould the workman dipped into the vat, lifting a portion of the pulp on its surface. The water flowed through the wire-cloth, and left the fibre on the top. The workman then removed the deckel, and passed the mould to another,

who turned it over, and pressed it on a felt, to which the sheet adhered; the mould was then returned to form a new sheet.

About one hundred and thirty sheets were now laid in alternate layers of felts and sheets, and the whole submitted to powerful pressure, which forced out a large quantity of water, and made the paper sufficiently firm to bear handling. The sheets were then taken out of the felts, and being laid together, were subjected to another pressure, after which they were parted or turned over, to prevent their adhering to each other. The paper was then taken to a drying-house, and hung up on lines to dry; from four to eight sheets were hung together. In favorable weather the paper would dry in from three to five days, and in damp weather the drying-house was heated by steam. After being thus exsiccated, it was dipped into size or glue, for the purpose of closing the pores, and enabling it to bear writing upon. When sized, it was gently pressed, and each sheet parted from another, and hung up a second time to dry in the loft or drying-house.

The system of making paper by hand was very slow; it occupied at least three weeks from the preparation of the rags to the finishing of the paper, and often subjected the manufacturers to considerable loss. To work one vat, which would make on an average one hundred and fifty pounds of paper per day, or what can now be made by a machine in one hour, required eight men, and eight or ten women.

There are still a few vats working in the country, generally in the manufacture of paper for which great strength is required; and at Maidstone, in Kent, there are still two mills or factories engaged in hand-making. These were established about one hundred years ago by Mr. JAMES WHATMAN, and great improvements were introduced in them. The paper of one of these mills is still marked—J. WHATMAN, Turkey mill; that of the other is marked simply, —J. WHATMAN. The manufacture of these mills has not yet been equalled, whether by hand or machine made paper.

HISTORY OF THE PAPER MACHINE.—The paper machine, by which so great a development of the paper trade was effected, had its origin in France. LOUIS ROBERT, a clerk in the employment of DIDOT, was the first who appears to have conceived the idea of making a continuous web of paper on an endless wire-cloth, to which a rotary motion was communicated, thereby producing a web or sheet of indefinite length.

However simple this idea may appear to those who are acquainted with the present system of papermaking, it was nevertheless a most extraordinary conception at the time, and marks out the inventor as one of those original thinkers whose ideas, being worked out by men acquainted with details, have done so much to extend manufactures and benefit mankind.

About the year 1798, ROBERT constructed a small model of a machine, by which he could make a narrow continuous strip of paper. M. DIDOT, his employer, became interested in his labors, and with this gentleman's assistance, a machine was constructed by which paper twenty-four inches wide could be produced. But though this rude apparatus might be sufficient to

demonstrate the possibility of applying the rotary motion to papermaking, yet either from the impatience of its inventors, or more probably from its defective construction, it does not appear to have been used for practical purposes, but merely as a subject of experiment. At the same time its merits did not pass unnoticed. Although not immediately put into practical use in France, yet the French government, with just discrimination, presented to ROBERT the sum of eight thousand francs, as a reward for his invention, and the right to it was purchased by M. DIDOT for the sum of twenty-five thousand francs, while that gentleman's brother-in-law, M. GAMBLE, secured a patent for it in England, and also obtained an introduction to the Messrs. FOURDRINIER, who at that time were extensive stationers and papermakers. Messrs. FOURDRINIER entered with great zeal into the project, and under the superintendence of BRYAN DONKIN, they in three years succeeded in constructing a machine which made a continuous web of paper; but, after three years more of intense labor, and an expenditure of sixty thousand pounds sterling, the patentees found that their machine still required extensive alterations and improvements. They therefore applied to Parliament for an extension of their patent for fourteen years.

The bill passed through the House of Commons, but as stated by the late Dr. URE, by an unworthy artifice of Lord LAUDERDALE's, it was limited to seven years, with an understanding that the patent would be extended other seven years if at the end of the first period they could show that they had not been remunerated for their outlay. However, they were prevented from reaping the benefit of this arrangement by a standing order of the House of Lords, subsequently placed on their journal, which allowed an extension of a patent only to the original inventors. Messrs. FOURDRINIER being thus prevented from reaping any advantage, or deriving any remuneration in return for the capital expended, became involved in difficulties, which led to their bankruptcy.

To show the advantage of this invention, Mr. FOURDRINIER in 1806 published a statement, showing the cost of working a machine capable of doing seven vats' work, compared with the cost of working seven vats. He shows the cost of the latter to be two thousand six hundred and four pounds sterling per annum, which would now be considerably increased by the higher wages paid to workmen; the cost of the machine doing equivalent work he calculated at seven hundred and thirty-four pounds sterling per annum, and this, on the contrary, would now be diminished, owing to the improvements which have been made, and the greater quantity of paper produced in the same time. But taking his own figures, he thus demonstrated a saving, by his invention, of one thousand eight hundred and seventy pounds sterling upon seven vats in one year. The cost of making paper by vat he showed to be sixteen shillings per hundredweight; by machine only three shillings and ninepence; and in 1807 he offered to make such machines at from seven hundred and fifteen to one thousand and forty pounds sterling, according to their width. He also points out as another advantage of the machine, that of relieving the

manufacturer of all difficulties arising from combinations among workmen.

It is a lamentable fact, remarks the late Dr. URE, that the attention required to mature this valuable invention, and the large capital which it absorbed, led ultimately to the bankruptcy and ruin of this opulent and public-spirited company; after which disaster no patent dues were collected, though twelve suits in Chancery were instituted; these being mostly unsuccessful on account of some technical objections made to their well-specified patent by that unscientific judge, Lord TENTERDEN. The piratical tricks practised by many considerable papermakers against the patentees, are humiliating to human nature in a civilized and *soi disant* Christian community. Many of them have owned, since the bankruptcy of the firm removed all fear of prosecution, that they owed the company from two thousand to three thousand pounds each for patent dues!

PRESENT PAPER MACHINE.—When the pulp is properly prepared, it is emptied into the stuff-chest—in which an agitator revolves for the purpose of keeping the pulp and water at an equal consistency—and is thence drawn as required to suit the machine. Before describing the latter apparatus, it may be necessary to state that an important desideratum in paper is *uniform thickness*, and this can only be obtained by a uniform supply of pulp and a regular speed of machine. Formerly, this uniformity depended entirely on the care and attention of the workman; but in drawing the pulp to supply the machine by a pipe from the chest, the pressure was always varying and making irregular paper, and the workman could scarcely regulate his valve or supply-cock to the exactness required. When an engine of pulp was emptied into the chest or reservoir, the pressure on the valve was increased, and the workman, by his own judgment, had to lessen the orifice of discharge; but, however attentive he might be, he could not regulate the valve with perfect certainty, or in precisely the same ratio as the increase or decrease of pressure in the chest.

To overcome this irregularity in thickness, papermakers tried various methods, but the two modes in general use are by a pump and a pulp meter.

Pumps and Pulp Meters.—When pulp is delivered to a machine by a pump, the latter is applied to pump the pulp from the large chest into a small one placed above it, in which is an overflow, so that if the supply to the machine be rapidly stopped, the pulp will immediately flow back into the large chest. A regular quantity of pulp is thus kept in the small one, to which the supply-pipe is attached, and a uniform pressure is in this way obtained.

The other mode by *pulp meter* was introduced by Messrs. COWAN from OECHELHAEUSER, the foreign inventor, and consists in making the pulp, which is kept at an equal density, flow into a cistern, in which a box constantly dips, lifting an exact quantity of pulp. The capacity of this box can be increased or diminished, to correspond to the different thicknesses of paper required. The writer has seen this pulp meter work for twelve hours, and the workman in attendance never require to touch it, while the paper produced would not vary in weight one half pound per ream.

Lifter Wheel and Sand Trap.—From the pump or pulp meter the pulp flows into the *lifter wheel*, and is further diluted with water. This is a wheel composed of buckets, into which the *save-all* water flows, and is by them lifted to its former level for the purpose of being used again. The pulp and water are both lifted and discharged on to a *sand trap*, which is a long flat box from twenty to forty feet in length, and only four or five inches deep. The pulp flows over this surface, and allows sand to settle on the bottom. From this the pulp flows into the strainer.

The Strainer is a brass frame, of which the bottom is composed of brass plates finely perforated, and through which the pulp has to pass longitudinally, thereby keeping back all knots and impurities. A quick, vertical motion is given to it; the pulp flows in on the top, and percolates through the bottom by suction; it then passes into the vat. A great variety of these strainers are in use; but the best which the writer knows of is made by EASTON and AMOS of London. Their strainer is a fixture, and below it is a piston, which is made to work vertically against the bottom of the strainer, without touching it. A rapid motion is given to this piston, and the suction thereby created carries the pulp through. This patent strainer is a great improvement on the old one. While the latter has to be cleaned every twelve or twenty-four hours, this will work for sixty or seventy hours without cleaning.

The Wire.—From the strainer the pulp flows by two pipes into the vat, which is a large box for containing a supply of pulp, and from this it passes to the *wire*. The latter, which constitutes a most important part of the mechanism, is generally an endless web of fine wire-cloth, of three thousand six hundred to five thousand meshes in each square inch. It is about thirty feet in length, and is made to revolve on two rollers—always presenting a level surface of twelve or fifteen feet to receive the pulp. To admit this liquid to the wire, a slit or opening runs along the front of the vat, by which the depth of pulp is regulated. The latter flows through this opening upon an apron or delivery board, and from thence to the wire, beneath which is placed a box called a *save-all*. The lateral motion of the wire shakes the fibre of the pulp together, while the water passes through the meshes of the wire-cloth into the *save-all*, and thence into the lifter wheel, to be used over again.

The fibre being left on the surface of the wire, gradually becomes firmer and more compact; and is regulated in width by *deckel* straps or bands, which form ledges at or near the sides of the web, and prevent its flowing off the wire. These bands or deckels are made of a number of layers of cotton, gummed and sewed together, being about one inch in width, and half an inch thick; sometimes they are made entirely of vulcanized india rubber. They travel along with the wire, one on each side, and by their flexibility keep the pulp to any required width. They are guided by a frame which stretches across the machine, resting on its framework; and the breadth of pulp is regulated by widening or narrowing the frame.

The Dandy Roll.—Travelling with the wire, the

pulp passes to the dandy roll, which is simply a cylinder, the two ends of which consist of brass hoops fixed on a shaft, and having wires extended between them; or it is sometimes formed of perforated copper, and is covered with fine wire-cloth. It is generally seven inches in diameter, and usually corresponds in length to the width of the wire upon which it rests. The journals of this roll turn in slits in two upright stands; one behind the machine frame and the other in front of it; but, as the roll actually rests with its whole weight on the wire, it revolves by the progressive motion of the latter, while the stands prevent it from participating in the lateral motion. This roll, by running on the surface of the pulp, presses out a great quantity of water, and renders the paper finer and closer in texture.

The dandy roll appears to have been invented by Mr. JOHN WILKS, an English mechanist, for the purpose of pressing out some of the superfluous water. This object was afterwards more effectually accomplished by the pump-box, but the dandy was still found to be a valuable invention for closing the pores of the paper. It is also by this part of the mechanism that the water-mark and the lined appearance which laid paper presents are impressed.

Suction Boxes.—Beneath the dandy roll, and across the machine, two suction or pump boxes are placed, having their upper sides open. As the wire travels over these boxes, the action of the pumps with which they are connected draws the wire upon them with a pressure sufficient to make them air-tight, thereby extracting a large portion of the water which the pulp at this point still retains, and giving to it such a degree of consistency as fits it to bear without injury the pressure of the couch rolls. Before this apparatus was introduced, the pulp often came too wet to the couch rolls, causing the paper to be water-galled.

The Couch Rolls.—The web of paper being regulated in width by the deckels, rendered closer in texture by passing under the dandy roll, and made drier and more compact by passing over the suction boxes, now arrives at the couch rolls. These are two large rollers covered with felt; the under one revolves inside the wire, and gives the motion to it; the upper rests on the lower, and thus both wire and web of paper pass through between them, receiving a gentle pressure, which renders the paper still more compact.

At this point the paper leaves the wire, and is received on a soft woollen blanket, or endless web of felt, which revolves continuously on rollers, and is about twenty feet in length. This endless web carries the paper between two heavy iron rollers, called press rolls, which still expel a large quantity of water. The paper can now bear its own weight, and may be handled gently without injury.

Steam Drying.—For many years after the introduction of the paper machine, the paper, after passing through the press rolls, was wound on reels, cut into sheets by hand, and then hung up in the loft to dry. But in 1821 a very useful improvement was added to the machine by T. B. CROMPTON, who invented and patented a new mode of drying by heated cylinders, and a cloth or felt. According to Mr. HERRING, the

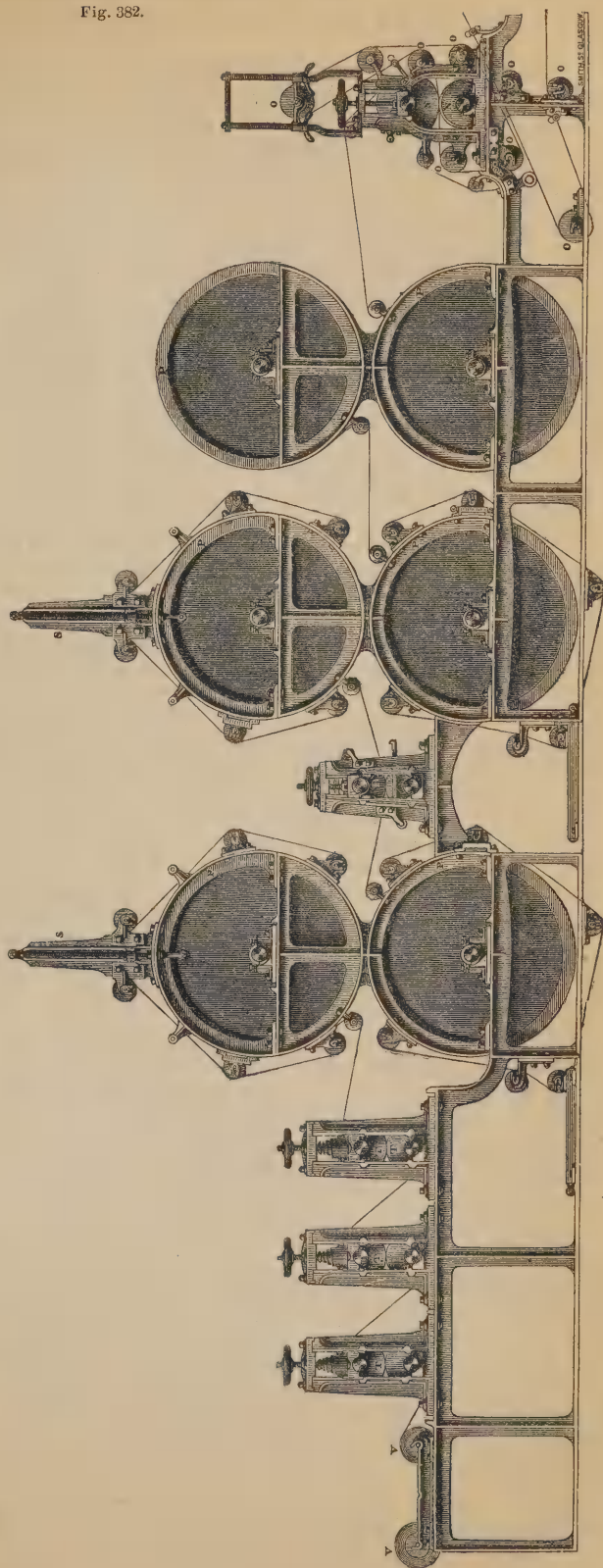
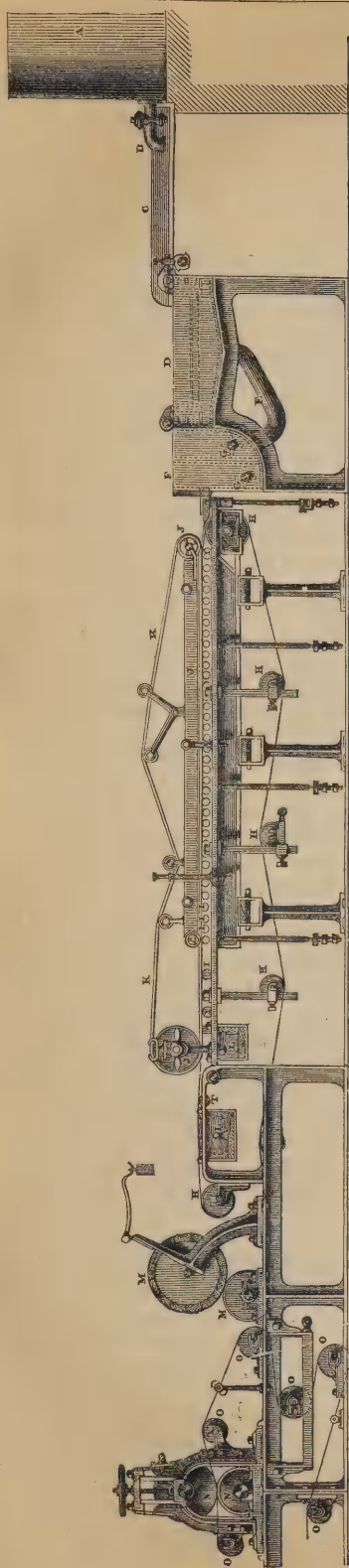
first experiment for drying paper by means of heated cylinders was made at GELLIBRAND'S calico-printing factory, near Stepney, a reel of paper in a moist state having been conveyed thither from Dartford in a post-chaise. The experiment, which was made in the presence of the patentees of the paper machine and Mr. DONKIN the engineer, proved highly satisfactory; and the adoption of copper cylinders heated by steam was thenceforth considered indispensable. But copper cylinders were soon superseded by cast-iron ones. The former, being thin, did not retain the heat any length of time, and were rapidly heated or cooled by the least variation of pressure on the steam. The cast-iron drying cylinders at present used are made thicker, and although not so quickly heated, retain their heat longer; while any irregularity in the pressure or temperature of the steam does not so easily affect them. The number of cylinders in a machine varies from three to fourteen; they may be placed in a great many different ways, and are used of different sizes. But the best way to arrange them, is to set them in pairs, one over the other, leaving a few inches between the two surfaces.

The paper, after passing through the press rolls, and thereby parting with a quantity of water, is much firmer; but from the circumstance that the pressure on one side is exerted against the felt, it is rougher on that side than on the other; and to equalize the sides a second pair of press rolls and a short felt have been introduced. The paper passes from the first pair of rolls, presenting its rough surface to the smooth roll. It then passes on to the first drying cylinder, which should only be slightly heated; the second is heated a little more, and so on, each of the series of cylinders successively increasing in heat. By this means the paper is dried gradually, and is found to be much stronger when dried in this way than when passed over one or two very hot cylinders.

Papermakers have paid too little attention to the drying power of their machines; and in many places, while the speed of the machine has been greatly increased, the number of drying cylinders has remained the same; consequently, a great degree of heat has to be kept up, while the paper, nevertheless, is not so well dried; and in making printing paper, or paper sized in the engine, this high temperature and its quick application cause a great quantity of size to evaporate, leaving the paper imperfectly sized. Enterprising and scientific papermakers have now remedied this defect by increasing the number of their cylinders. Over a few of the cylinders is a felt web, which revolves with the cylinder, and the paper runs between cylinder and felt. The object of the felt is to dry the paper equally, and keep it from *cockling*.

In well-arranged mills, the cylinders are differently adjusted on machines for making writing and those for making printing papers. On a writing paper machine, the paper is only passed over a number of cylinders to dry it, then wound on reels. On machines for making printing paper, the paper passes over three or four cylinders, then between a pair of smooth, well-polished metal rolls, to give it a surface, and which is best done when the paper is a little moist; from these,

Fig. 382.



called *nipping rolls*, the paper passes over three or four additional cylinders.

Calendering.—The paper is now thoroughly dry, and from the last drying cylinder it passes through between one or two sets of calender rolls, to bring up the surface required. These calender rolls are often five in number—one large roll, with four small ones placed above it. The paper passing in at the top circulates to the bottom, and thence proceeds to the reel, on which it is wound. These rolls are very difficult to keep in order, and are giving place to another arrangement, which consists of two or three pairs of rolls, with springs on the top of the bearings of the uppermost roll. The rolls are placed in sets; two rolls in a set, and three sets on a machine, thereby bringing up a fine surface.

Having thus described the several parts of the paper machine, and followed the course of the paper from its first appearance in the shape of unsightly rags until it is wound on the reel, it will be necessary to add a connected and complete view of the entire mechanism, to render it thoroughly intelligible to the reader. With this view, the Editor gives in Fig. 382 an engraving of one of the most improved paper machines, recently designed and erected by Mr. GEORGE BERTRAM of Edinburgh, who is known throughout Europe for the durability and excellence of his paper machinery. Machines from his establishment are working in Sweden and Russia, as well as in all parts of Great Britain. In this figure, A denotes the pulp chest; B, valve for regulating the supply of pulp; C, spout for conveying pulp to strainer; D, strainer; E, pipe for conveying pulp from strainer to vat; F, vat; G G, small agitators for keeping the pulp of equal thickness; H H H, rolls for wire revolving on; I I I, small tube rolls for supporting wire; J J J, deckel frame with pulleys for regulating width of paper; K, deckel strap; L L, pump boxes between which the dandy roll is placed; M M, couch rolls; N N, first and second press rolls; O, rolls for felt revolving on; P, drying cylinders; R, nipping rolls; S, guide frame for dry felt; T, calender rolls for improving surface; V, reel filling with paper, and reel full.

Laid Paper and Water-mark.—When the machine was invented, only wove paper could be made by it, and it was then supposed that it would never be possible to make laid paper by it, or introduce a water-mark; but the invention of the dandy roll and pump box have removed this supposed insurmountable difficulty. It has been already stated, that when the wire passes over the pump box a large quantity of water is immediately extracted from the pulp. This gives it such a degree of consistency that any impression made on it at this point remains, owing to its passing instantly from a partially fluid state to one of greater consistency.

A dandy designed to make laid paper is covered with fine wire, laid longitudinally, leaving very small spaces between the wires. When a water-mark is required, whether a name or device, the figure or letters are made of fine wire and sewed on the surface of the dandy roll.

CUTTING MACHINE.—Previous to the introduction of cutting machines, the paper was uniformly wound on a reel, the diameter of which could be diminished

or enlarged, according to the size of sheet required. When the reel was filled, an empty one was put on, and the paper was cut off the full reel by the hand. This method of cutting occasioned a great deal of waste; many attempts were therefore made to produce a machine which would cut the paper into sheets as it issued from the machine, or as it was wound off a reel; but most of the plans, after repeated trials had been made and considerable cost incurred, were laid aside as impracticable. Mr. J. B. CROMPTON of England appears to have been the first who produced a really useful cutting machine. About 1821 he secured a patent for cutting paper into suitable lengths by a pair of shears, as it issued from the machine; and in 1828 he again obtained a patent for cutting paper lengthwise by revolving circular blades fixed on a roller parallel to a cylinder. Finally, in 1849, AMOS and CLARK patented a cutter which obviated the difficulty that arose from the constantly increasing velocity of machines, causing the sheets to be cut into irregular lengths; and this cutter is the best yet in use.

The first operation of this cutter is to cut the paper lengthwise into such widths as may be required. To effect this object, there are placed across the machine two shafts, armed with circular blades, which may be moved along the shafts to adjust them to any required width. These knives revolve at a much greater speed than the paper, which, as it issues from the making machine, or is wound off the reel, passes between the two shafts, and is cut by the knives very exactly. It may be stated that the knife on the upper shaft is larger in diameter than that on the lower, and as they revolve in contact, the action produced is similar to that of a pair of scissors.

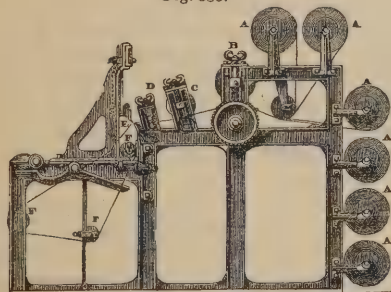
The web being thus cut lengthwise, proceeds over a large drum for the purpose of being cut across into the lengths required for the sheets. From the velocity with which the paper travels, this is a difficult operation, and requires the paper to be momentarily arrested in its course, at regular intervals, to admit of the sheet being cut square. With this view, the drum is so contrived as to have an alternating motion; at one time bringing the paper forward the required length, and then returning. This effect is produced by a crank arm, which can be adjusted at pleasure to regulate the length of the sheet. In front of this drum, at the point where the paper leaves it, is placed a solid board or wooden block, over which is suspended a movable board or presser. The paper passes between these, and when the drum has brought forward the required length of sheet, the presser, by a particular movement, is made to descend against the block, and holds the paper fast, while at the same instant a combined motion of rolls and levers brings a movable knife against a fixed knife, and the paper is cut in the same manner as by a pair of shears. The sheets immediately on being cut are caught by boys, and laid straight in handfals. The drum, after bringing forward the required length, immediately retrogrades, while the pressers prevent the paper from being pulled back along with it. Three rolls covered with felt are placed on the top of the drum to assist in bringing forward the paper, and the moment it is held fast in the

pressers these rolls are raised by a lever and connecting rods, so that the paper is left loose on the drum, which by this arrangement can turn back without dragging the paper. The latter is continuously passing between the knives, and while the drum is making its backward motion, a *dancing roll* takes up the slack of the paper.

This cutter is invaluable in cutting laid paper on which is a water-mark. As this water-mark requires to be in the centre, from which it sometimes deviates, a portion of the machinery can at any time be stopped by hand, and a small part of the sheet cut off, thereby bringing the water-mark again to its proper place.

In addition to the cutter just described, and which is certainly the best in use for cutting paper with water-mark, there is another which also has its advantages, and of which the annexed engraving—Fig. 383—has been kindly furnished by Mr. GEORGE BERTRAM. This machine is generally used for cutting wove paper, printing paper, and newspapers, and cuts six webs at once. Six reels turn on bearings in a frame, and the web from each, passing round a smaller roller, is received

Fig. 383.



on a small drum. All the six webs, passing round this drum, are collected on a pair of small rollers, called *gathering rolls*, and by these they are simultaneously subjected to the action of the circular knives, which cut the paper lengthwise, forming the required width of sheet. By a wheel and lever, which regulate the motion, the requisite length of paper is then brought under a movable upright knife, which immediately descends on a fixed or bed knife, and severs the sheets from the webs. The sheets are then carried forward on a revolving apron to boys, who pile them carefully in handfuls; after which the paper is taken to be overlooked and finished. This description will be easily understood by the figure, in which A represents the six reels of paper on cutter frame; B, gathering rolls; C, circular knives for cutting paper longitudinally; D, feeding rolls; E, movable and fixed knives for cutting paper from web, usually called *cross-cutting knife*; F, endless apron for carrying paper to boys. This cutter has the advantage of being capable of performing about double the work of the one previously described, and is therefore used in mills where the water-mark is not put on paper.

SIZING.—Inferior sorts of writing paper, and all continental writing paper, are sized in the pulp, by the same method as printing paper; but to produce a good writing paper, it is necessary to size it with animal size after it is made.

Size is generally made at the mill from the parings of skins, called *scrolls*. Formerly the scrolls were boiled until the gelatin they contain was extracted, but the size had often a turbid appearance, and injured the color of the paper. About 1840, the Messrs. PIRIE of Stoneywood, Aberdeen, obtained a patent for an improved method of making size. Their process consists in steeping the scrolls in stagnant water until putrefaction has commenced; the scrolls are then beaten with a mallet, well cleansed, and steeped in water strongly impregnated with sulphurous acid, which acid has the property of both arresting putrefaction and bleaching the scrolls. By this process the gelatin is much more easily extracted, and the scrolls do not require to be boiled. They are put into a large wooden vessel or tub, which is set inside a cast-iron one, and between the sides of these vessels there is a space of about one inch all round. This space is filled with water, into which steam is admitted, and by the heat thus communicated the gelatin is extracted; but unless the heat is kept considerably below the boiling point the size will not be pure. When drawn off, a quantity of alum is dissolved among it for the purpose of preserving it. By this method a fine pure size is obtained, which does not injure the color of the paper; but the process is complicated, and the gelatin contained in the scrolls is liable to be injured by allowing putrefaction to proceed too far when the scrolls are being steeped. It has now, however, been found that a part of this process may be omitted, and that copper instead of wooden vessels may be used without detriment to the size.

The sizing of paper by hand-dipping was a tedious process, and occasioned a great deal of waste. Many attempts were therefore made to size it in the web, which for a considerable time were unsuccessful. About 1840 several mills succeeded in attaining this object, but with some little diversity in their methods. The mode adopted by Messrs. ALEXANDER COWAN and SONS at their mills, is to pass the paper over two rolls, about a foot in diameter, half immersed in size. Behind these rolls is a frame fitted with small rolls set at an angle. Paper, when undergoing the process of wetting, expands considerably, and these rolls have the effect of keeping the web of paper stretched to its full width, thereby preventing it from getting into creases as it passes to the press rolls, where the superfluous size is pressed out. Another and simpler method is to pass it under a drum about two feet diameter, half immersed in size, and then forward to the press rolls.

The sizing of paper is an important but difficult process. If the paper is very porous, it is also generally weak, and then the sizing occasions a good deal of waste. If again the paper has been blued with ultramarine, a strong and offensive smell is often communicated to it. The best remedy for this is to use a size which has not been long kept, to allow the paper to lie some time after being made, and after sizing to dry as quickly and as perfectly as possible. If it still retains any offensive smell, this may be partially removed by hanging it up in a place where it can be exposed to a very dry atmosphere.

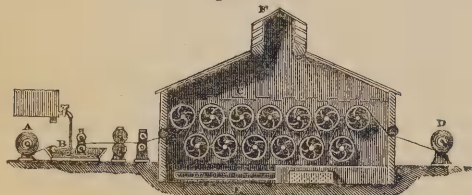
DRYING.—Manufacturers having succeeded in sizing in the web, the next desideratum was also to dry it in

the same form, which, after many unsuccessful attempts, was accomplished.

The drying machine is a large frame of cast-iron, about ninety feet long and nine wide. In this frame are laid two and sometimes three tiers of skeleton drums or cylinders, three feet in diameter. A shaft passes through the centre of each drum, and to the shaft inside of the drum are fixed two arms called fans. The shaft is driven by a separate arrangement of the machinery, and is independent of the motion of the drum. The paper travels over the drum at the rate of from forty to sixty feet per minute, while the shaft is making about one hundred and eighty revolutions per minute, thereby producing a considerable agitation in the atmosphere around the dryer. Six sets of narrow bands, about one inch wide, pass over the drums from end to end of the dryer, for the purpose of conveying the paper from one drum to another. In some mills the paper passes at once from the sizer over the dryer; but generally it is wound on a reel at the sizer, and allowed to stand a few hours until the paper has cooled a little, and absorbed the size which is lying on the surface when it comes from the sizer. To convey the paper over the drying drums the end of the web is placed between the bands—three of the sets being above the paper and three below. It generally takes about fifteen minutes to travel over the dryer, and by the time it has reached the opposite end it should be quite dry and ready for the cutter.

Fig. 384 is a sectional view of the sizing and drying apparatus, where A represents the reel of paper to be

Fig. 384.



sized; B, the size cisterns and press rolls; C, drying drums with fans inside; D, dried reel of paper; E, heating apparatus; F, ventilator.

The drying machine is of great advantage to the paper manufacturer in regard to economy of time, but not otherwise. Paper when drying has a natural tendency to contract, and this is counteracted by the tension at which it must be kept when drying on the machine. Paper so dried is, therefore, not so tough as it would have been by the old method of hanging it on ropes. To meet this defect a much stronger size has to be used.

FINISHING.—The finishing, or smoothing the surface of printing paper, is now performed at the machine. After it is cut it does not require much labor. The first process is overhauling or overlooking. This is done by women, who turn over and examine every sheet, and lay aside all that are imperfect, or which have any small defect; these are called *retree*. Sheets seriously damaged are called *broken*, and when sold bring about half the price of sound sheets. The paper

is then counted into *quires*, each quire consisting of twenty-four sheets; and twenty quires, or four hundred and eighty sheets, constitute a *ream* of printing, wrapping, and colored paper. The reams are then subjected to heavy pressure before being put into covers. An excise label is pasted on the cover of every ream, and in this form it is set aside until wanted for the market.

Before being sent from the mill the excise-officer weighs the paper and writes the weight on it. He also requires the manufacturer to write or print the weight on each ream, and to put a progressive number on each. He further compares the weight on the ream with the gross weight, and if it exceeds or falls below the allowed per-centage, the paper is liable to be confiscated. Formerly the law required paper to stand twenty-four hours after being charged with duty; but this is now modified, and by complying with certain regulations paper may now be sent off a few hours after being charged with duty.

In finishing writing paper, a large amount of both labor and machinery is required. After it comes from the cutter it is pressed in strong hydraulic presses, and then rolled or glazed. The operation of rolling and glazing consists in subjecting the paper to a heavy pressure between highly-polished sheets of copper or brass. This part of the work is chiefly performed by women, who take one sheet of copper and another of paper, alternately, until they have about forty of each, which is called a *handful*. This quantity is then passed between a pair of rollers about fourteen inches diameter, set in a strong iron frame, and driven by steam or water power, working under a pressure of upwards of twenty tons. When the handful has passed through the rollers, the machinery is so constructed that the motion can be reversed, and by this means the handful is made to pass forwards and backwards several times, according to the smoothness or gloss of surface required. Highly-finished paper called *glazed*, and sometimes known as *satín* paper, is produced by simply repeating or prolonging this operation until the desired finish is obtained. To the manufacturer it is a somewhat costly process; for besides the expense of labor, which is considerable, injury to some of the paper is unavoidable, and the smallest flaw or speck in the sheets is brought strongly out by the high finish. It is evident, therefore, that writing paper which has to be highly finished, requires great care both in the preparation of the pulp, and in the manufacture of the paper.

The smoothing or finishing of the surface was formerly accomplished by placing the sheets of paper between glazed pasteboards. The boards, intermixed at intervals with *heated* iron plates, were then put into a press and subjected to heavy pressure—a process which is well known by the name of *hot-pressing*. It was very beneficial to the paper, as it took out any superfluous moisture, and made it handle firmly.

After the surface is smoothed, writing paper goes through the same process as that intended for printing, so far as regards the overhauling and making into reams. The standard quantity in a ream of printing paper is four hundred and eighty sheets, but paper is often put up with five hundred sheets in the ream, and

sometimes five hundred and sixteen, and also five hundred and twenty-eight, but in all these cases the number of sheets must be marked on the ream. The standard quantity for a ream of writing paper is four hundred and thirty-two sheets of whole, and forty sheets of broken, twenty of which must be above and below the whole.

VARIETIES OF PAPER.—The name *paper* comprehends a great number of kinds, differing very widely both in the mode of manufacture and in the purposes to which they are applied. They may, however, be all classed under four heads, namely, white paper, grey and brown paper, colored paper, and pasteboards of all kinds.

White paper includes two kinds, writing and printing, and of these there are various qualities. *Writing paper* stands at the head of this class, and the best quality is of a pure uniform color, strongly sized, and highly finished. There are many sorts of writing papers; but it will be sufficient to enumerate such of them as are best known by name to those who are unacquainted with the trade—such as cream, blue, and yellow, in color; laid and wove, in texture.

Cream is as nearly as possible a pure white. Writing shows always to most advantage on this color; but it has the defect of being more transparent than any other hue; and the high finish generally put on it increases the transparency. A small quantity of ultramarine and rose-pink improves the purity of this tint.

Blue is a fine shade, and has not the defect of transparency. It was formerly obtained by mixing a quantity of smalt with the pulp; but since the introduction of ultramarine smalt is not much used; ultramarine gives a much finer color, and is not so costly; and except in the sizing, where it occasionally causes some inconvenience, there is now no difficulty in employing it. When put among the pulp, both it and rose-pink should be well mixed in hot water, and strained twice either through a serge bag or the finest wire sieve, and should be put into the engine as soon as the chlorine is neutralized.

Yellow is simply a bluish shade given by using a smaller quantity of ultramarine than for blue; generally about a fourth or fifth part.

The old names given to paper are still retained, and also the sizes; but as the machine can make paper of any length, printing paper is generally cut to whatever size is most suitable for the printer.

The kinds of grey and brown paper used for wrapping are extremely numerous, and the varieties of colored paper are almost endless; but further details would be tedious to the reader, and would occupy too much space.

Formerly, paper manufacturers put a device, called the water-mark, on all their paper, and the old names, some of which are rather odd, are supposed to be derived from these devices. A jug or pot was put on paper of a small size; hence it still retains the name of *pott*. The fool's cap-and-bells was also one of their devices, and, although another mark has long been substituted, paper of that size also retains the name of *foolscap*. In like manner, *post* is supposed to have

been so called from the post-horn, which was at one time a common device. Besides these there were a great variety of marks, many of them of a fanciful kind, but which are now only interesting to the antiquarian.

Water-marks have frequently been of essential service as the means of detecting frauds in dating deeds, *et cetera*; and they are very useful on bank notes, cheques, and receipts. Those who are curious on this subject will find some amusing information in Mr. HERRING's work on papermaking.

The following is a list of sizes of writing and printing paper. In a few cases there are two sizes in use, and both are given:—

	Inches.
Pott,	12½ by 15
Foolscap,	17 by 13½
Foolscap—writing,	16½ by 13½
Post,	18¾ by 15½ or 19 by 15½
Copy,	20 by 16
Large post,	20¾ by 16½
Medium post,	18 by 23 or 18 by 22½
Sheet and third foolscap, ..	24½ by 13½ or 22 by 13½
Sheet and half foolscap, ..	13½ by 25
Double foolscap—printing, ..	27 by 17
Double foolscap—writing, ..	16½ by 27
Double pott,	15 by 25
Double post,	30½ by 19
Double crown,	20 by 30
Demy—writing,	20 by 15
Demy—printing,	17½ by 22½
Medium demy,	22 by 17½
Medium demy—printing, ..	23 by 18½
Royal—writing,	24 by 19
Royal—printing,	20 by 25
Super-royal—writing,	27 by 19
Super-royal—printing,	21 by 17
Imperial,	30 by 22 or 30½ by 22
Elephant,	28 by 23
Atlas,	34 by 26
Columber,	34½ by 23½
Double elephant,	26¾ by 40
Antiquarian,	53 by 31

The following is a list of coarse papers, such as grey and brown:—

	Inches.
Tient cap,	21 by 18
Bag cap,	19½ by 24
Havon cap,	21 by 26
Imperial cap,	22 by 19
Double two pounds,	17 by 24
Double four pounds,	21 by 30
Double six pounds,	19 by 28
Middle hand,	22 by 16
Lumber hand,	19½ by 29

Of purples there are—

Copy loaf,	16¾ by 21¾
Powder loaf,	18 by 26
Double loaf,	16½ by 23
Single loaf,	21½ by 27
Lump,	23 by 33
Hanbro,	16½ by 23
Titler,	29 by 35
Prussian, or double lump, ..	32 by 42

PAPER DUTY.—It would be out of place here to enter largely into the duty levied on paper; but any article on papermaking would be incomplete without some notice of it. It is usual to commence remarks on this subject by describing the annoyance and hindrance which the collection of this duty imposes on the paper manufacturer. On this point the Editor will not enlarge. The Honorable Board of Inland Revenue has for some years shown a more favorable disposition towards manufacturers than formerly; and has removed

and modified all restrictions complained of, so far as is consistent with the collection of the revenue and the protection of the honest trader. The officers of excise, also, generally give every facility in their power, and accommodate the manufacturer so far as their duty will permit. But the labor and much of the annoyance caused by the collection of this duty can only be removed by its total repeal.

This tax was first imposed in the year 1711. The law imposing it, and the regulations for its collection, have undergone many changes and alterations, which it is not necessary to particularize. When the duty was first imposed it was easily and to a great extent evaded; and manufacturers were not over scrupulous about the means of doing so. This naturally created a good deal of bad feeling between the manufacturers and those officers who acted honestly in the discharge of their duties. The expedients to which many manufacturers in former times resorted, and the indirect bribes which were given to excise officers, form a dark page in the history of papermaking; and it is a somewhat remarkable fact, that all those who resorted to these unworthy expedients have been ruined, and nearly all have been driven from the trade.

About the year 1800, the laws imposing the duty were revised, and paper was divided into three classes:—The first class comprised all paper made from rags, the duty on which was threepence per pound; the other two classes comprised all paper made from tarred ropes and all pasteboards, the duty on which was three halfpence per pound. In 1836 these laws were again revised; the division of paper into classes ceased, and a uniform duty of three halfpence per pound was imposed. A few years after this five per cent. was added to the duty; and under these laws the tax is still levied. This addition of five per cent. on the duty has been a heavier burden on paper manufacturers, and has been more complained of than the duty itself. It is a well-known fact that no corresponding advance was obtained upon the price of paper at that time. The additional five per cent. was, therefore, virtually a direct tax on paper manufacturers; and to show that this is not a mere trifle about which there should be no complaint, it may be stated that at a moderate computation a paper machine makes annually about seven hundred and fifty thousand pounds of paper, the duty on which is upwards of four thousand six hundred pounds sterling; and five per cent. on this sum amounts to upwards of two hundred and thirty pounds sterling. But with the exception of this sum the duty on paper is a burden on the consumer; and were the community alive to its baneful effect in diminishing the demand for labor it would have been repealed long ago. The Editor believes that all politicians now admit the impropriety of taxing the raw material of any manufacture. But paper is the raw material upon which a large portion of the population of the country is employed. Were it possible to trace it from the time it was a piece of dirty rag until it appeared as a highly-finished book, or an ornamented piece of papier maché, or an embossed envelope, it would be found very difficult to name any other material on which a greater amount of labor is bestowed.

The Editor conceives he is warranted in assuming that the repeal of the duty would greatly increase the consumption of paper, from the fact that the trade doubled itself in fourteen years after the duty was reduced to three halfpence per pound. This reduction took place, as already stated, in 1836. Now, in 1835, duty was paid on seventy million, six hundred and fifty-five thousand, two hundred and eighty-seven pounds; in 1850, on one hundred and forty-one million, thirty-two thousand, four hundred and seventy-four pounds—a great impetus having been given to the publishing trade, and to all those manufactures in which paper is used, which undoubtedly contributed to the prosperity of the country; nor should the fact be overlooked, that the reduction of the duty brought the means of obtaining useful information and rational enjoyment within the reach of the humblest classes of the community.

But, like all other evils, this duty has found defenders. One of the most plausible of their arguments is, that the excise regulations—which require that the weight to within five per cent. on paper above twenty pounds, and to within ten per cent. on paper below twenty pounds per ream, be written or printed on each ream—*gives security to the purchaser that he is not imposed on by a false weight.* One would suppose that a ream of paper could be weighed as easily as any other article, and any fraud of the kind at once detected. But the argument is altogether fallacious. Paper is sold not by the weight marked on the ream, but by the real weight; and if it exceeds the required weight, paper manufacturers lose the excess, and this is to them a source of considerable loss.

Another objection urged to the repeal of the duty is this—it is so small that its repeal would benefit only the paper manufacturers and printers, while the community generally would never derive any advantage from it. Let it be admitted that it would be a boon to papermakers and printers—it might be supposed that this would be an argument for and not against the repeal. It is difficult to see any justice in subjecting these classes in particular to an onerous burden, to which other merchants and manufacturers are not liable; and although the repeal of the tax would not lessen the expenditure of those who buy few books and no paper, yet even they and the entire community would be benefited by the increased demand for labor which would undoubtedly follow the extinction of this most impolitic impost.

STATISTICS.—IMPORTANCE OF THE PAPER TRADE.—The introduction of FOURDRINIER'S machine, and the application of steam power, with other improvements, have effected a complete revolution in the art of making paper, and have placed the trade among the staple manufactures of the United Kingdom.

Formerly paper-mills were spread nearly over the whole country, especially in England. Wherever there was a good stream of water, a paper mill was almost invariably to be found. These mills were generally small; *one machine will now make as much in one hour as some of them made in a day.* At that time, too, the trade was in the hands of a few wealthy firms, chiefly located in London, on whom paper manufacturers were to a great extent dependent. The exten-

sion of the trade, and the large amount of capital now invested in it, have to a considerable extent broken up that system; and the Editor believes that the firm of ALEXANDER COWAN and SONS, Valleyfield Mills, where the paper on which this work is printed is manufactured, was the first to adopt means to free itself from this virtual monopoly. In the year 1810 their mill there was one of the largest in Scotland, yet there was not produced then more than one thousand pounds of paper per day, or about fifty reams, whereas above four hundred reams are now made, the half of which is highly-finished writing paper. Some idea of the extent of these works may be formed from the fact, that there is made at an average every day forty miles of paper, five feet wide, or as much as would cover above twenty-four acres. The space required for finishing the paper covers nearly one thousand three hundred square yards, or something more than one-third of an acre, and above seven hundred people are employed.

There has, perhaps, in no locality been a greater extension of the trade than on the river Esk, on which these mills are situated. At the close of the French war, in the year 1815, twenty-six vats were in operation, the produce of which would not exceed four thousand five hundred pounds of paper per day, and the number of people employed could not be more than four hundred; there are now on that river fifteen

machines at work, the produce of which is not less than thirty thousand pounds per day, and the number of people employed amounts to about two thousand.

The subjoined statement, derived from sources of undoubted veracity, will show the extension of the trade generally. In the year 1784 the value of paper made in the country was estimated at eight hundred thousand pounds, the duty on which was forty-six thousand eight hundred and sixty-seven pounds sterling; in the year 1856 there were charged with duty, one hundred and eighty-seven millions, seven hundred and sixteen thousand, five hundred and seventy-five pounds sterling. The duty on this would amount to one million, two hundred and thirty-one thousand, eight hundred and eighty-nine pounds; assuming the value of paper at an average to be about three times the amount of duty, the value charged with duty in that year would amount to three millions, six hundred and ninety-three thousand, six hundred and sixty-seven pounds sterling. The number of people employed in the direct manufacture of paper is supposed to be about thirty thousand; but, besides this, there are thousands who find occupation in making and repairing the machinery used, and also in preparing the chemical substances required in the manufacture.

The annexed table exhibits the quantity of paper in the United Kingdom charged with duty, exported, and retained for home consumption during ten years:—

	1847. Pounds.	1848. Pounds.	1849. Pounds.	1850. Pounds.	1851. Pounds.
Charged with duty,	121,965,315	121,820,229	132,132,660	141,032,674	150,903,543
Exported,	5,852,979	5,180,286	5,966,319	7,762,686	8,305,590
Home consumption,	116,902,336	116,639,943	126,166,341	133,269,988	142,597,943

	1852. Pounds.	1853. Pounds.	1854. Pounds.	1855. Pounds.	1856. Pounds.
Charged with duty,	154,469,211	177,633,009	177,896,224	166,776,234	187,716,575
Exported,	7,328,886	13,296,874	16,112,020	11,110,924	14,798,979
Home consumption,	14,710,325	164,336,135	161,784,204	155,665,310	172,917,596

The following table shows the quantity of paper charged with duty in England, Scotland, and Ireland,

respectively, during the years 1855, 1856, and nine months of 1857:—

	1855.	1856.	Nine months of 1857.
England,	123,552,869	139,752,062	109,660,884
Scotland,	35,932,985	40,100,234	31,925,920
Ireland,	7,290,380	7,864,279	6,081,269
Total,	166,776,234	187,716,575	147,668,073

These figures prove the expansion of which the trade is capable; but however important the paper manufacture may be as a source of national industry, it is justly entitled to a higher place than that which belongs to it merely in this material aspect. There is no article so intimately connected with *mind* as paper—none upon which the development of the moral and intellectual nature of man is so dependent; and mankind is now learning how much the welfare of the race depends on the right cultivation of the mind. It is now universally admitted that in a densely-populated country there is no permanent security for life, property, and progress, unless the whole mass of society is leavened with the rudiments of knowledge and the principles of morality. For this purpose paper is essentially requisite. It would be vain to speculate with regard to the future, but it is evident that paper must

be the medium of diffusing the blessings of knowledge and Christianity throughout the world, and is destined to be one of the most powerful agents, under Divine Providence, in renovating the human family.

PERFUMERY.—*Parfumerie*, French; *parfümerien*, German.

By nature's swift and secret working hand
The garden glows, and fills the liberal air
With lavish odors.—*Thomson*.

The distinction between perfume and odor is substantial as well as critical—the former designating those volatile emanations which are usually considered agreeable, while the latter, in its general signification, is applicable to every scent, irrespective of its nature. GREMIO, in *The Taming of the Shrew*, directs that the papers he sends to BIANCA may be *well perfumed*, for she is *sweeter than perfume itself*; while, in *King John*,

SHAKSPERE makes CONSTANCE call death *thou odorous stench*. Of the five senses, that of smelling is the least valued, and, as a consequence, is the least tutored; but from this one must not conclude that it is of insignificant importance to the welfare and happiness of mankind.

By neglecting to tutor the olfactory nerve, one is constantly led to breathe vitiated air, and thus poison the body by neglecting the warning given at the gate of the lungs. Persons using perfumes are more sensitive to the existence of a vitiated atmosphere than those who consider the faculty of smelling as an almost useless gift.

HISTORICAL NOTICE.—There is no delicate luxury which has held its influence so long and so uninterruptedly upon refined society as that of perfumes; and their annals comprise the history of the folly, voluptuousness, and extravagance of past ages. The antiquity of their use is very great, and one is almost lost in searching for their origin.

Perfumes seem to have been first imported from Elam, now called Persia, and they were important articles of commerce between that country and Egypt. The distant deserts were often traversed by camels laden with *odors of sweet scents*; and when the Ishmaelitic merchants, to whom JOSEPH was sold, were going to Egypt, they were wending their way with *spices and balm and myrrh*. At a later period, but long before the time of CONSTANTINE, the Turks were accustomed to lubricate their persons with fragrant unctions, to complete the gratefulness and value of their baths. MOSES was commanded to speak unto the children of Israel, that in the offerings of the tabernacle they should bring *sweet spices, and anointing oil, with sweet incense*; and that they should make of the former *a perfume, a confection after the art of the apothecary, tempered together, pure and holy*.

Indeed, perfumes were considered among most of the ancients as necessities of life, and entered into nearly all their ceremonies of a religious or social nature. They were used both at feasts and at funerals, and were burned as well in honor of the living as of the dead. The priests of Memphis offered them as incense, daily, to the sun; and the Egyptians, by their aid and with resins, have transmitted their illustrious dead, in mummies, through thousands of years to living generations.

As in the Mosaic days, spices and frankincense were held as sacred offerings to the Lord of Hosts, so in the new era of religion the practice was not discontinued, and CHRIST after crucifixion was embalmed in spices; but at first, it seems, that certain spices were devoted only to religious uses, for EZEKIEL accused the Jews of profanity in applying to their own purposes the odors which were reserved for sacred things; and ISAIAH reproaches them as faithless to God, and as like a spouse painted and perfumed to please strangers.

The present mode of introducing flowers at repasts was common among the Grecians and Romans. Rich perfumes and precious ointments were among the treasures found by ALEXANDER in the camp of DARIUS, and thus, possibly, the Greeks borrowed the example of their use from the Persians. The violet was most grateful to the Athenian taste, but every part of the

body had its appropriate perfume; the oil extracted from the palm was thought best adapted to the cheeks and the breasts; the arms were refreshed with balsam mint; sweet marjoram supplied an oil for the hair and eyebrows; and wild thyme for the knee and neck. Perfumes, in time, became very common among them. The *nardus* and *malobathrum* were held in much estimation, and were imported from Syria. The *baccaris*, the *brenthium*, the *psagda*, the *plangonium*, and the *sagdas*, made principally of the general constituent of all the ancient ointments, *videlicet*, myrrh, had their respective eulogists. The saloon, where any entertainment was given, was generally perfumed by burning myrrh or frankincense in it. A nice distinction divided perfumes into two kinds: the first were of a thicker sort, and applied more as salves, or wax; the latter were liquid, and poured over the limbs. To indulge in the liquid ointment was considered as effeminate and voluptuous, but the sober and the virtuous were permitted to use the thicker variety without any impeachment of their good qualities. The supplies of perfumery occupied a considerable place in the stock of those artisans who contributed to the embellishment of a Grecian lady of fashion. The article itself bore a high price, but this did not hinder voluptuaries using it profusely, not, however, without an occasional admonition from the grave men of the mischief arising from its abuse. The old people referred to a statute of SOLON, forbidding the sale of perfumery, at least by the male sex; SOPHOCLES significantly described VENUS as sprinkled with perfume, and looking in a mirror; and PALLAS, the goddess of wisdom, as moist with olive oil, and practising the exercises of the palaestra. SOCRATES objected to the use of perfumery altogether. There is the same smell, said he, in a gentleman and a slave, when both are perfumed. In his opinion, the only odors worth cultivating were those arising from honorable toils and the smell of gentility.

A knowledge of perfumes soon extended from Greece to Rome; and the abuse in the employment of them was such that PLINY lamented their introduction into the camp. NERO is said to have consumed in the funeral pile of his wife, POPPÆA, more incense than could have been produced from the whole of Arabia in a year; and under the consulate of SUCINIUS CRASSUS, in order to secure a sufficiency for church purposes, a law was necessary to restrict the use of them to that and a few other special objects.

With the decline of the Roman Empire, the European commerce in perfumery diminished; and in the disastrous epoch of Vandalism, when floods of barbarians inundated the capital of the world, refined taste took its flight, and perfumes became obsolete. In modern days, however, civilization revived, and brought back with it this one of its concomitants, which was soon nurtured into a vigorous growth, upon the institution of a new era of gallantry and elegance. The supremacy of woman's influence being thus re-established, perfumes, as aids to beauty, were in constant and extravagant demand.

In the reign of LOUIS the Fifteenth, the ladies at court indulged most freely in perfumes, and fashion ordained an ever-varying routine; so that the royal

apartments were one day fragrant with the scent of the tuberose, and the next with that of amber and cloves; and so on, consecutively, each succeeding day bringing a change of the reigning odor. In that luxurious age, the personal use of perfumes was not confined to the fair sex, but the effeminate gallants and *petit-maitres* of the day gloried in perfuming themselves with the favorite scents of their mistresses or of presiding belles; so that allegiance was recognized, not, as in more chivalrous times, by the knight wearing the colors of the fair one who had enslaved him, but by his smelling of the particular odor which she had consecrated to herself.

Pathologically considered, the use of perfumes is in the most eminent degree prophylactic; the refreshing qualities of the citrine odors to an invalid is well known. Health has often been restored when life and death trembled in the balance, by merely sprinkling the essence of cedrat in a sick chamber.

Throughout all civilization, from the dim early ages to the enlightened days of the present—through every ramification of society, and in all the sacred ceremonies of life—flowers and perfumes have ever borne a conspicuous part, and by their graces and freshness, touching allegories and seducing sweetness, blended themselves with the pleasures and hopes of mankind; sometimes typifying transient images, but still, *also*, appearing as the beautiful symbols of those affections and principles which are *most enduring*.

SOURCES.—Perfumes are derived from a variety of natural sources; a few being of animal origin, and the remainder emanating chiefly from the vegetal kingdom. In their primitive state of isolation, they may be termed *simple*, in contradistinction to the *compound* odors, which are made up by combinations of the former, varied according to the taste and skill of the manufacturer. In this way an infinite variety of scents may be obtained. But the art of the perfumer is not wholly restricted to the preparation of odors; it extends also to the fabrication of pomades, aromatic vinegars, washes, tooth powders, cosmetics, fine soaps, and all appliances of the toilet which by their tonic, emollient, or cleansing properties, will improve the health and beauty of the skin, hair, and teeth. In some of the preparations, certain *mineral* matters enter as ingredients to impart color or consistence; and but rarely for any purpose otherwise connected with the efficiency of the product. In all instances, however, the smell is most important. When the perfume does not exist in a free state, it is then manufactured from the raw material by mechanical or chemico-mechanical means; as, for instance, by expression, distillation, maceration, infusion, and enfleurage, as will be more fully explained hereafter in treating of the essential oils, extracts, fats, waters, *et cetera*.

In enumerating the raw materials used in the manufacture of perfumery, it will not be possible here to give more than the striking properties and characteristics of each. These will, however, suffice to convey the necessary information for making a judicious selection; and it is only necessary to add that the purity of the *stock*, and the manner in which it has been gathered and kept, have an important bearing upon the quality and quantity of the products to be obtained from it.

ANIMAL SUBSTANCES.—The *perfume*-materials of this class are only three, and each is an animal secretion: namely, musk, civet, and ambergris.

Musk.—This exists in the excretory follicle behind the navel of the adult *male* of the *moschus moschiferus*, or musk deer, of Siberia, Thibet, China, and other mountain ranges. These bags, or *Pods*, as they are termed in commerce, contain from two to three drachms of musk. When separated from the sack, it is called *grain musk*. Tongva musk outranks all others in quality, and that from Russia is the most inferior. Thibet musk is of intermediate quality. The high price of this substance renders it liable to adulteration with dried blood, brown earth, *et cetera*. The finer grades are frequently weighted by the fraudulent introduction of pieces of lead into the pods. To test the quality of musk, plunge into the pods a wire which has been rubbed with garlic, and then note the odor. If the garlic odor is disguised by the musk, the latter may be considered of good strength.

Musk, from its pleasantness and permanence, becomes a general basis-odor; and from these, and its diffusibility, it may be called the wings of the perfumes, as, besides carrying with it the other fragrances, it survives to pronounce their departure and illustrate its own durability. It requires, however, to be very much diluted, in order that it may not prevail too much in the scents which may contain it as an ingredient.

Civet.—The secretion of the civet cat, or *viverra civetta*; also, of the *viverra zibetha*. It is scraped out from the glandular receptacle near the anus, and sent to market in small bags made of the skin of the animal. The supply comes mostly from Malabar and Bassord. It is of a pale yellow color, and has a musky odor of such intensity as to be offensive, except in a highly diluted state. Its admixture in small proportions with other perfumes gives agreeable modifications, and imparts strength and permanence.

Ambergris.—So called from *amber-gris*—grey—because of its having been considered by some of vegetal origin, and analogous to amber. It is more probably a bezoar from the whale, and may be a product of disease. It is found floating on the sea, near the coasts of China, Japan, Coromandel, Brazil, Ireland, and America. It is in small irregular masses of scaly fracture and grey color, with yellow, and sometimes black streaks. It emits a very peculiar and diffusive smell of great power, and is largely used in admixture with more feeble and less persistent odors.

Spermaceti.—A beautiful, pearly-white, dry, inodorous fat, found in the bony receptacles of the head of the white whale—*physeter macrocephalus*. It is obtained by subjecting the head matter of the whale to hydraulic pressure, for the separation of the oily portion. Unless entirely freed from oil, it is liable to become rancid. It may be purified sufficiently by subjecting it repeatedly to hot pressure; or, more expensively, by dissolving out the oil with boiling alcohol. Its structure is scaly, and it may readily be crystallized in plates. When pure, it melts at 120°. *Solar spermaceti* is the popular name of an admixture of true spermaceti with palmitic acid.

Spermaceti has eminent emollient properties, and is

used in perfumery as an ingredient of pomades, creams, cosmetic pastes, and the like.

Wax.—This is the solid portion of the honeycomb, produced by the hive bee—*apis mellifica*. In its native state it is yellow, or brown-yellow, and sometimes grey; but it can be bleached perfectly white by chemical means, or by exposure, in thin ribands, to the combined action of light, air, and moisture. It is the white wax which is most generally used by the perfumer; and that bleached by the latter method is the best, as it is purer, firmer, and drier; moreover it is tasteless. Pure wax melts at 149°. It is often adulterated with earthy matters and stearic acid. The first shows itself when, on melting the wax, an infusible and insoluble substratum remains. The last is known to be present if effervescence and a gelatinous solution are produced by boiling some of the wax in distilled water, containing one-fiftieth of its weight of carbonate of soda. There are also several kinds of vegetal wax assimilating to beeswax in physical character, but they have not yet been employed in the art of the perfumer.

Suet.—As found in commerce, suet is generally a mixture of beef tallow and mutton fat. It is *rendered* by heating the *rough fat*, and pressing it, to separate the membranous matters. When of good quality it is firm, and does not melt below 98°.

Suet and lard form the body of pomades; and that the quality of these latter may be unexceptionable, the fat material must be perfectly fresh, inodorous, and pure. The rendered suet being almost always more or less deficient in those respects, it must, therefore, be subjected to a purifying process, in order to fit it for use in perfumery. This is done by melting the fat by the heat of a saline or steam bath, in an enamelled iron vessel, and adding to it, gradually, powdered alum and chloride of sodium, in the proportion of one ounce of the former, and two ounces of the latter, to every fifty pounds of fat under treatment.

The heat is to be continued above 212°, until scum ceases to rise to the surface, which contains all the organic and other impurities, and must be removed with a skimming ladle as fast as it is formed. The fat is then to be strained through bolting cloth into clean stone jars, and there left to cool. It is next to be spread upon a circular stone slab, with its top surface slanting from the centre, over which a stone roller is made to move by suitable gearing. As the roller, or muller, as it may be called, revolves over the fat, cold water is allowed to trickle upon it, and this latter acts by dissolving out the saline and organic impurities, and in flowing off carries them away. This treatment is continued until the fat is free from foreign matters, after which it is to be melted, and heated, as before, until all retained water has been expelled by evaporation. When cold, the fat will be found to be very white and pure, and in a condition to preserve its sweetness. In this deodorized state it is suitable for use with the most delicate odors. An apparatus like that described under DYEING, Vol. I., page 703, will be very suitable to carry out the process just described.

Lard.—This is the fat of the common hog, and that kind commercially known as *corn-fed lard* should be selected, as it is superior to other grades in many

respects. Though fine and white, it is softer and more fusible than suet. It melts at 81°. The lard used for perfumery should be pan-rendered, over an open fire, or by *dry steam*; for if *wet steam* is used, and under pressure, as is most generally the case, then it contains foreign organic matters in solution, which give it a tendency to decomposition, and cause it to emit a disagreeable smell. Moreover, it is then granular, instead of being smooth in body. To give it a condition suitable for the perfumer, it must, however, be carefully rendered, and undergo purification in the same manner as directed for suet.

Both lard and suet are used as *body* for pomades; the former constituting *soft body* for winter climates, and the latter *hard body* for summer temperatures.

Suet and lard are described also in Vol. I., page 413, to which the reader is referred.

Bears' Grease and Beef Marrow.—The fat of the common bear is soft, and not unpleasant in odor when carefully rendered. It is a favorite grease for the hair, and for that purpose, as well as to cheapen it, is often mixed with marrow obtained from the *marrow bones* of beef cattle.

COLORING MATTERS.—It is often desirable, as a matter of taste, to tinge these bodies; and the process to be followed for them, and also for other fats, whether solid or fluid, is as follows:—

Alkanet root is the coloring matter for imparting a *pink* shade, and four ounces are required for every pound of fat. The fat having been melted over a water bath, the bruised root is then added, and the whole digested at a moderate heat for several hours. The mixture is then strained through bolting cloth, and the clear fluid fat, now colored deep pink, allowed to cool; and this may be termed the tinctorial substance. One ounce of this highly-tinged body will suffice to impart a hue to a pound of fat; and the manipulation consists in simply melting the two together, by gentle heat, in an enamelled pot. *Yellow* coloring body is similarly made with annotta, in the proportion of one ounce to the pound of fat. To give a *green*, fresh walnut leaves may be used. A *brown* shade may be obtained by merely adding a few drops of *caramel* to the melted fat, and continuing the heat until the water which held the caramel in solution has evaporated. Color may be imparted also by the addition of pigments in powder, but these latter are objectionable for pomade body, hair oils, and creams.

Cochineal.—This is a small wrinkled insect—*coccus cacti*—indigenous to Mexico and New Spain, which feeds upon several species of cactus. After having been scraped from the leaves, it is scalded, and then dried in the sun. The best is that which presents a silvery white exterior. Cochineal gives a brilliant crimson powder, and is used in that way as a coloring matter. A *liquid scarlet* may be made from it by boiling, say one ounce in eight ounces of distilled water, for fifteen minutes, and then adding thirty grains of powdered alum, and then reboiling for three minutes, and straining through bolting cloth. *Carmine*, the brilliant red used so extensively as a finer color for rouges, powders, *et cetera*, is made from cochineal. It is soluble in aqua ammonia, and, thus treated, it forms the solution called *liquid carmine*, or carmine ink, which also has a wide

range of application in the manufacture of perfumery. Carmine is prepared on a large scale by the practical chemists, and of various qualities. French carmine is considered the best.

VEGETAL SUBSTANCES.—The art of perfumery is almost wholly dependent for its existence and success upon the botanical kingdom; as the simple odors, with very few exceptions, come exclusively from that source. The only peculiarity in this respect is, that the plants growing in tropical latitudes are more prolific in odor than those of Northern climes. The East Indies, Ceylon, Peru, and Mexico, afford rich supplies of their indigenous stock; and nearer home, the South of France, bordering on that part of the Mediterranean between Toulon and Nice, is almost entirely cultivated for the production of perfume materials. Grasse and Cannes are the two principal flower gardens; and the genial, equable climate of this region renders it peculiarly favorable for the purpose to which it is devoted. To the enterprise and skill of their inhabitants the world is indebted for many of the finest and best perfumes, and they in return derive a large revenue from the trade.

The odor of a plant is due to a highly volatile matter, which is most generally an oil, called the essence or essential oil. In some instances, however, the odor is a very delicate and ethereal principle, and, therefore, not in a tangible form, though very evident to the sense of smell. In this latter case it is extracted and fixed through the agency of a medium substance, as will be explained under the head of pomades. The odors, though every odor is not necessarily fragrant, exist already formed in the living plant, or else are generated, as in the instance of bitter almonds, by some reaction between the elements, which takes place during fermentation or distillation. It is generally secreted in little sacs or vesicles, and so well confined that it does not escape in many cases even during the drying of the plant, if it be carefully done, whilst in other plants again, the aroma is being constantly produced at the surface, and as constantly exhaled at the moment of formation. The organism of the plant, and its vital force, are the creating power.

The aroma exists in every part of plants, but not in all portions of the same plant. Sometimes it is obtained from the root or wood, then from the bark, and again from the flowers, leaves, fruit, or seeds. Some few plants yield odor in all their parts. The orange gives three distinctive odors—*oil of neroli* from the flowers; *essence of Portugal* from the rind of the fruit; and *oil of petit-grain* from the leaves; and thus it appears that the oil may also differ with the part of the plant whence it is obtained.

The resinous and balsamic exudations of plants, such as benzoin, and myrrh, and the like, are often impregnated with the aroma of the plant.

The scents of plants are extracted in the form of oils, or attars, extracts, fragrant waters, *et cetera*; and the skill and taste of the perfumer render them capable of being infinitely extended and diversified by combination. In this way the great variety of *bouquets* have their origin.

There are many substances of vegetal nature also used largely in the art of perfumery for other purposes than as scents. For obvious reasons the Editor must

restrict the notices to those which are the most important; and for the better understanding of the subject, will classify them into roots, woods, leaves and flowers, seeds, balsams and resins.

1. ROOTS.—These yield their aroma by distillation with water, in the form of essential oil, or scented waters. They may also be used in powder.

Angelica—from the garden, or *a. archangelica*. The tops of the flowers are also serviceable. The root is spindle-shaped, greyish-brown, and much wrinkled externally, and whitish and spongy within when dried. Its fragrance is due to a volatile oil.

Calamus, or *Sweet Flag*—is the root-stem of the *acorus calamus*, and comes in long, slender pieces, with a yellowish-brown and wrinkled exterior. It is white in the interior, and gives off an aromatic odor, which may be obtained in the form of volatile oil.

Ginger.—The root of the *amomum zingiber*, growing in the East and West Indies, and Mexico, enters into the combination of many aromatic waters, and several kinds of dentifrice. The *white* ginger of Jamaica is considered the best, being the selected roots deprived of their epidermis. It gives a yellowish-white powder, and emits a penetrating aromatic odor. A volatile oil may be separated by distillation, but this property is generally and more readily extracted in the form of a tincture, by macerating the root in alcohol.

Orris, or *Iris*.—The white, fleshy part of the root of the *iris florentia*, which is native to Italy, and cultivated in the South of Europe. It comes in pieces of irregular form and size, which, being brittle, are easily reduced to powder. It emits an odor assimilating to that from violets, but very much inferior. The powder enters largely into the composition of tooth and sachet powders, for the purpose of giving volume as well as odor. Its tincture, made by digesting one pound of the powder in one pint of alcohol for two weeks, and filtering, is used to give body to more feeble perfumes, and improve the fragrance of those which are deficient in that property.

Souchet.—The root of the *cyperus longus*, and emits an agreeable, violet-like odor. It is generally macerated in acetic acid, then dried and reduced to powder.

Vitiver, or *Kus-kus*.—The fleshy part of a species of dry grass from India. It has an aromatic odor, and is used in the same manner as *orris* root. The tincture or extract of *vitiver* is made by digesting one pound of the dried root in a quart of alcohol for two weeks, and filtering. This tincture was formerly much used in bouquet combinations, and was an important ingredient in the once celebrated preparations of that kind called *mousseline des Indes*, *bouquet du roi*, *et cetera*. By distillation, it yields about one per cent. of volatile oil called *otto of vitiver*, and resembling, according to PIESSE, the *otto* of santal.

2. WOODS.—Those which are used as scents yield their odors by distillation with water, or by digestion in alcohol or other solvent. They are also used in powder, and several of them merely as coloring matters.

Aloe.—There are three varieties of this wood, and all come from China; namely, first, *calambac*; second, *agalochium*; and third, *aigle* or *garc*. The first is very rare and high-priced, being used only for fumiga-

tions in temples; is brownish-red, resinous and heavy, and emits in burning an aromatic odor. The *agal-lockium* is orange-colored, has a waxy fracture, and an odor less myrrhine than the calambac. This is the kind usually found in commerce. The *aigle* or *garç* wood differs from the other two in having a greenish-yellow color and musky odor, and also in not being bitter. It is fibrous, sometimes spongy, and, when burned slowly, eliminates an agreeable aroma. The latter two are used as ingredients of fuming pastilles.

Brazil.—The chipped wood of the different species of the *casalpinia* growing in Brazil and the West Indies. That from Pernambuco is the hardest and best. When freshly cut it is light reddish-brown, but on exposure becomes of a brighter tint. It is used as a cheap tinctorial matter, and forms the material whence the lakes are made. Its color may be extracted in soluble form, by boiling four ounces of the wood in a quart of water containing one drachm of chloride of tin, and filtering.

Cascarilla.—The bark of the *c. gratissimus*, as well as that of the *c. fragrans* and *c. fragilis*, are used as ingredients of fuming pastilles. The first is a component of the *eau à bruler*, for perfuming apartments, and is the most fragrant and valuable of the three kinds. Its leaves, according to PIÈSSÈ, are gathered by the Koras of the Cape of Good Hope as a perfume.

Cassia.—The outer bark of the *cinnamomum cassia*, and the Chinese cinnamon, from Canton. It yields, by distillation, about three-fourths of one per cent. of volatile oil, of aromatic rather than flowery odor, and much used for mixing with other perfumes, and for scenting soaps.

Cedar.—The wood of the cedar emits an agreeable odor when burned, and on that account is sometimes made into sticks for lighting lamps. In a finely-ground state it may be employed as a body for sachet powders, for it is said to keep away moths. It gives on distillation a fragrant volatile oil, occasionally used for scenting toilet soaps. The wood forms a crimson-colored tincture with alcohol, and may be thus employed to tinge and scent tooth-powders.

Cinnamon.—The bark of the *laurus cinnamomum*, and that from Ceylon is the best. It is very thin, brownish-red, and has an agreeable aromatic flavor. The cassia, which it resembles closely, is thicker, rougher on the surface, and comes in larger rolls or quills. The first is often sophisticated with the latter, and sometimes even a part of its volatile oil is abstracted by infusion in alcohol. This latter fraud is detected by the feeble smell and taste of the cinnamon. The finely-ground bark is used for pastilles, sachets, and tooth-powders. Its aroma may also be extracted in the form of tincture, by alcohol. By distillation, it yields an essential oil of powerful odor, which is largely used in combination with oil of cloves and other strong essences.

Clove.—This bark, known also by the name of *cannelle giroffée*, and *bois de crabe*, is brought from the West Indies. It comes in concentric cylinders of about two feet length and an inch diameter, and has a dark-brown color. Its aromatic flavor, though similar to that of cloves, is much weaker.

Guaiacum.—This wood is imported from the West Indies. It is hard, compact, and resinous, and when burned or rubbed emits an agreeable odor. It enters into the composition of odontalgic liquors.

Rhodium.—Called also *rose wood* and *cyprus wood*; and incorrectly, by the French, *jacaranda*. It is the wood of the *convolvulus scoparius*, and has a pale-red color, and slightly bitter taste. It emits an agreeable perfume, and is used when ground for sachet powders. When distilled it yields a sweet-smelling oil, but this latter is seldom used, being superseded by the oil of geranium.

Santal.—This grows in the island of Timor and the Santal Wood Islands, and is improperly called *sandal* wood. It is extensively employed by the Brahmins, Hindoos, and Chinese, as incense in their religious ceremonies. Its strong, agreeable, and peculiar odor is very offensive to ants, and renders it a good material for cabinet ware. By distillation, it yields attar of santal, which is dense and oily, and has a dark straw color. It is often used in the form of extract, or tincture, made by dissolving one ounce of the attar in three pints of rectified alcohol, and adding four ounces of essence of rose. CAMERON writes of this scent as follows:—

The santal tree perfumes, when riven,
The axe that laid it low.

Sassafras.—The bark of the *laurus sassafras*, and is used in the form of tincture made by digesting it in alcohol. It also affords a volatile oil, but its odor is not delicate. It is employed for perfuming the coarser grades of transparent soap, and for admixture with other strong and common odors, to modify and improve their intensity.

3. LEAVES AND FLOWERS.—The leaves and flowers are when in a fresh state, of much greater advantage than after being dried. Indeed, very many are not serviceable for the extraction of their perfume, except when recently harvested. Drying is only resorted to with certain kinds for exportation, and this process must be carefully conducted in air chambers, to which the sun has access in summer. In winter, a gentle heat is necessary. The flowers or leaves are placed upon wicker waiters, and require to be stirred occasionally, in order that new drying surfaces may be presented, and fermentation hindered. In Grasse and Cannes the harvest is gathered by itinerant agents, called *commissionaires*, in the employ of the growers, and through them the product is sold to the distiller and perfumer. The harvest takes place at the flowering time of the plant, in a dry season, and towards the noon of the day, after the dew has evaporated.

Balm.—The leaves of this herb—*melisia officinalis*—yield, by distillation, a volatile essence, sometimes called the oil of melissa. It has a peculiar, fragrant odor, but is seldom used. The leaves lose their fragrance, in a great measure, when exsiccating.

Cassie.—The flowers or buds of the *acacia farnesiana* yield a very intense, but delightful odor, resembling that of violets, and much used in compounding fine scents for the handkerchief. The process of infu-

sion must be employed for its extraction and preparation. It is cultivated extensively at Cannes. DRYDEN, in his *Virgil*, thus alludes to it:—

The short narcissus and fair daffodil,
Pansies to please the sight, and *cassie* sweet to smell.

The *Wattle*, a plant of the same genus as the foregoing, and which grows luxuriantly in South Australia, yields, according to PRESSÉ, a very similar perfume.

Citron.—The flowers of this plant—*citrus medica*—give, by distillation, a fragrant oil, which is much in demand for the manufacture of Cologne-water.

Citronella.—This is supposed to be one of the grasses of the *andropogon* genus. The oil comes from Ceylon and the East Indies, and its odor resembles that of the oil of citron fruit. It is comparatively inexpensive, and forms the perfume of the so-called honey soap.

Elder.—The flowers of this plant—*sambucus nigra*—have a peculiar sweetish odor, and are used for preparing, by distillation, the elder flower-water. This latter enters into the composition of several cosmetic creams, milks, and oils.

Fennel.—The common fennel herb—*feniculum vulgare*—has an aromatic odor due to the existence of a volatile oil, which is used in combination with other oils for scenting soap. The herb itself, when dry and ground, is used in certain sachet powders.

Geranium.—The leaves of the rose geranium—*pelargonium odoratissimum*—are very largely cultivated in Grasse and Cannes for their essential oil, which is obtained by distillation. The plant also grows abundantly in Turkey. The odor of the oil is very agreeable and rose-like, and the color varies from white to brownish, and sometimes greenish. The oil of the *andropogon nardus*, cultivated in the Moluccas, is often used, according to PRESSÉ, for adulterating the oil of rose-geranium. The delightful odor of the true oil of geranium renders it a useful perfume. It is also used extensively for adulterating ottar of rose, than which it is much less costly.

Heliotrope.—The aroma of this plant—*h. peruvianum* and *h. grandiflorum*—resides in the flowers, and is obtained either by infusion or enfleurage. The flowers must be subjected to treatment in their fresh state, and immediately after being gathered. The odor is suggestive of that given by almonds and vanilla combined; and its exquisite fragrance adapts it to the production of the finer kind of compound scents.

Honeysuckle.—This flower, also called woodbine—*caprifolium perfoliatum*—is of luxurious growth, and yields a delicious odor by the process of enfleurage. The poet COWPER thus speaks of it:—

Copious of flower, the woodbine, pale and wan,
But well compensating her sickly looks
With never-cloying odors.

Jasmine.—This plant—*jasmine grandiflora*—is the *yasmyn* of the Arabs. The jessamine flowers in July and August, and is extensively cultivated in the Southern part of France. The essential oil may be obtained by distillation; but as its production is very costly, and the yield very small, resort is generally had to the process of enfleurage for the extraction of the

aroma. This odor is peculiar, but richly fragrant, and enters into the composition of many of the finer scents for the handkerchief. The poet says—

Luxuriant above all,
The jasmine throwing wide her elegant sweets.

Jonquil.—The flowers of this plant—*narcissus jonquilla*—give out an agreeable odor, which may be extracted by the process of enfleurage.

Lavender.—This plant, the common lavender—*lavandula vera*—is one of the most renowned of antiquity, being the spikenard of the ancients. It was then only less employed as a medicament than as a perfume. It is still an ingredient of some few medicinal preparations. Its extensive use in washing and bathing is the origin of its present name, from the Latin word *lavo*, to wash. The plant grows in the Southern parts of Europe, and is largely cultivated at Mitcham in Surrey. The British lavender is the most fragrant, and brings four times the price of that from the continent. By distillation, the flowers yield an essential oil, and also *lavender water*. The sweetness of this perfume and its abundance render it very serviceable.

The French lavender—*l. spica*—also yields a fragrant oil and water by distillation; but they are very far inferior to those from the preceding species. The oil of this latter plant is called the *oil of spike*.

Lemon Grass.—A species of grass, said to be *andropogon schoenanthus*, which grows abundantly in India, and is largely cultivated in Ceylon and the Moluccas. By distillation, the plant yields an essential oil, assimilating in odor to that of the oil of lemon, and sometimes called *oil of verbena*. This perfume is very agreeable and economical, and well adapted for extensive use, either alone or in combination with other scents.

Lilac.—The flowers of this shrub—*syringa vulgaris*—are very fragrant, and yield a perfume by the process of enfleurage, resembling that from the tuberose.

Lily.—The lily of the valley—*lilium candidum*—bears flowers which emit a peculiar and powerful fragrance. This aroma may be extracted by the process of enfleurage; but eight or ten repetitions, with the same fat or bearsoil and fresh leaves, are required to obtain the requisite strength.

Magnolia.—The flowers of this plant—*m. glauca*—are strongly and gratefully odorous. It abounds in the swamps of the Middle and Southern states of South America; and is sometimes called white bay, sweet bay, *et cetera*. The aroma is extracted by the process of infusion or enfleurage.

Marjoram.—A species of thyme—*origanum marjoram*. This herb yields, by distillation, a strong scented essential oil, much used for perfuming soaps. It is called *oil of orangeat* by the French.

Meadow Sweet.—This plant—*spirea ulmaria*—affords a sweet-smelling oil by distillation.

Mignonette.—This plant—*reseda odorata*—is widely cultivated in Grasse and Cannes for its flowers, which are characterized by a peculiar and very delicate fragrance. The odor is extracted by the process of enfleurage; and to give it consistency, the extract is generally mixed with a little violet.

Mint.—The herb—*mentha viridis*—called spearmint, yields, by distillation, a strong-smelling aromatic oil, which is much employed in mouth-washes; and also as an ingredient of compound perfumes for soaps.

Myrtle.—The flowers and leaves of the common myrtle—*myrtus communis*—yield, by distillation, a very fragrant oil. Myrtle-flower water is sold in France by the name of *eau d'auge*.

Neroli.—There are two species of the orange; the Portugal or sweet orange—*citrus aurantium*—and the bitter or Seville orange—*citrus bigaradia*. The flowers of both give very fragrant essential oils and waters by distillation; but those from the latter are the most costly and best esteemed. The oil is called oil of neroli; the water, orange-flower water. The leaves and unripe fruit of the bigaradia also give a volatile oil by distillation, known as essence of petit-grain. The essential oil distilled from the rind of the fruit of the sweet orange, is called essence of Portugal.

All the neroli products are highly esteemed for their delightful odor, and enter largely into the composition of perfumes, particularly that of the savine Cologne water, and other fine bouquets for the handkerchief. The essence of petit-grain is mostly used for scenting toilet soaps; and orange-flower water is very popular as a flavoring material. A few drops of this latter added to ice water, sweetened with white sugar, makes a refreshing summer drink. The odor obtained from the bitter orange flowers, by the process of infusion, is much more natural and delicate than that obtained by distillation.

Patchouly.—This herb—*pogostemon patchouly*—growing extensively in India and China, affords, by distillation, a dark-brown essential oil of very powerful and peculiar odor, which is agreeable when diluted. It enters into the composition of certain bouquet scents. The dry and powdered herb is used for sachet powder, on account of its property of keeping moths out of clothes.

Pea.—The flowers of the sweet pea or chick vetch, *lathyrus odoratus*, as it is also called, eliminate, by a process of infusion, a very grateful odor.

Pink.—The clove pink flower, *dianthus caryophyllus*, gives out a delightful aroma, which may be extracted by the process of enfleurage.

Rose.—This plant, *rosa centifolia provincialis*, is largely cultivated throughout Turkey, at Ghazepore in India, and in the Southern part of France, and also at Mitcham in England, for the manufacture of *rose water*, and *otto* or *attar of rose*. This latter is the essential oil of the flowers; and that made at Grasse takes the precedence of attar from all other countries. The bulk of supplies, however, comes from Turkey and India. The rose water made at Provence is distinguished for its very superior quality. Both it and the attar are obtained by distilling the flowers; two thousand roses yielding little more than a drachm of the latter. The odor may also be extracted by infusion or enfleurage; and thus obtained, it is much more natural and fragrant than that made by distillation. In Asia Minor, the attar is made by distilling the rose buds, without water, by the heat of a saline bath.

The odor is very popular, but must be used in a diluted state.

A fictitious rose water, which, according to WAGNER, might be used in perfumery, is made by decomposing the volatile oil of gaultheria—salicylate of oxide of methyl—with caustic potassa, and distilling. The distillate is the required product, and possesses an odor closely resembling that of the rose. This odor characterizes the products of the spontaneous decomposition of salicylate of potassa.

It has a very general application in the several branches of the art of perfumery.

Rosemary.—This plant—*rosmarinus officinalis*—gives, on distillation, a thin essence, with a characteristic aromatic and stimulant odor. It is generally employed, in combination with other perfumes, as an ingredient of *Hungary water*, *Cologne water*, and certain Bath waters.

Sage.—The leaves of this plant—*salvia officinalis*—are sometimes used, when dried and ground, for scenting soaps; and as an ingredient for sachet powders. The odor is strong, aromatic, and fragrant.

Spike.—This perfume has already been described under the head of *Lavender*.

Syringa.—This plant—*philadelphus coronarius*—is the *mock orange* of America. Its flowers emit an intense odor, very similar to that from orange blossoms; and which may be extracted by the process of infusion or enfleurage.

Thyme.—The lemon thyme—*thymus serpyllum*—yields by distillation an oil of herby, rather than flowery odor; and it is, therefore, rarely used as a perfume. The dried and ground plant is sometimes used in sachet powders. Thyme oil is generally sold as oil of origanum; but the odor of the two is widely different—that of the latter, when genuine, being more like peppermint than thyme.

Tuberose, or *Tubereuse*.—This is a very fleeting perfume, obtained by the process of enfleurage, from the flowers of the *polianthes tuberosa*—largely cultivated for that purpose at Grasse. Its rich and exquisite smell makes it a valuable agent in compounding the finer kinds of bouquets. A little extract of orris or vanilla must be added to impart permanence to it.

Verbena, or *Vervain*.—This is the scented species of the plant, *aloesia citriodora*. By distillation, it affords an odor of rare fragrance, which is seldom to be met with in commerce. The oil of lemon grass, diluted with alcohol, which is closely assimilated to it, is generally vended for it. It is used in *court bouquet*, *Portugal water*, and a number of the finer scents.

Violet.—From the flower of the *viola odorata* is obtained an odor, which, in its genuine state, is of the choicest fragrance. There are few perfumes more highly esteemed. The flowers are largely cultivated at Nice, Grasse, and also in the vicinity of Florence, where they are subjected to the process of infusion, in order to extract their delicious aroma. The essence thus obtained is of a beautiful green color, and has a perfectly natural smell. Tincture of orris root is a base imitation frequently sold for the genuine substance.

Volkameria.—This odor is supposed to be derived from the flowers of the *v. inermis*, which grows in

India. Little is known of it, and PIÈSSÉ gives the following recipe for the composition sold under the name of *essence of volkameria*:—Esprit de violette, and esprit de tubereuse—each one part; esprit de jasmine, four fluid ounces; esprit de rose, eight fluid, and essence of musk, two fluid ounces.

Wall-Flower.—The flowers of this plant—*cheiranthus cheiri*—emit a very delightful aroma, which may be extracted by the process of infusion. It is not much used, and deserves a more general application.

4. FRUITS AND SEEDS.—The materials under this head are not all used for their perfume; indeed, the majority of them serve different, though no less important purposes.

Almond.—This perfume has been much esteemed for many ages. VIRGIL speaks of it in the following lines:—

Mark well the flowering almond in the wood;
If odorous blooms the bearing branches load,
The gibe will answer to the sylvan reign—
Great heats will follow, and large crops of grain.

The kernel of the bitter almond—*amygdalus amara*—gives, on expression, a fixed oil; and the pressed cake which remains, on being macerated in water and distilled, exhales the volatile oil of bitter almonds, which does not exist ready formed in the nut, but is generated by the reaction which takes place between two of its constituents, *emulsin* and *amygdalin*, under the circumstances just mentioned. This golden yellow oil is of a pungent agreeable odor, but is highly poisonous, and must be handled and used with caution, as it always contains more or less hydrocyanic acid. This acid, which averages eight to ten per cent., may be removed by prolonged agitation with a large quantity of milk of lime and caustic potassa, and redistilling. The pure oil is hydride of benzoyl, with some benzoic acid; and it owes its peculiar odor to the former of these components. By judicious use, alone or in combination, it is very serviceable; particularly for scenting pomades, soaps, shaving and cosmetic creams, and meets with general appreciation. The *essence of mirabane*, which is frequently sold as the genuine substance, is an artificial product, known chemically as nitrobenzole. Its odor, however, only approximates to that of the oil of bitter almonds; nevertheless, it is largely employed for scenting soaps. Peach-kernels, by the above process, also afford a volatile oil, which is often palmed off as the genuine oil of bitter almonds. This latter is used for flavoring, as much as for scenting. The kernels or nuts of the sweet almond—*amygdalus dulcis*—do not yield any volatile oil, unless they are mixed with bitter almonds; but they give by expression a very mild fixed oil, which is much esteemed for making cosmetic pastes, creams, and the like. It is called oil of sweet almonds.

Ben.—This plant is the *mohringa optera* and *oleifera*, indigenous to Arabia and Syria, but growing also in the West Indies. By expression a fixed oil results, which is colorless, tasteless, and inodorous. The oil, after repose, separates into two portions; one of which is thick, and the other very fluid, even at low temperatures. The obstinacy with which it retains its neutrality, and resists the rancifying action of prolonged

exposure, combined with other desirable properties, render it an admirable vehicle for the extraction of certain delicate odors. It is, therefore, much in vogue in the process of infusion and enfleurage.

Bergamot.—The rind of the fruit of the *citrus bergamia* gives the well-known oil of bergamot by expression. Its odor is mild and eminently agreeable; and when mixed with other odors, greatly enriches their sweetness. The oil should be kept in tightly-stopped bottles, else its scent will become impaired.

Caraway.—The seeds of this plant—*carum carui*—yield, by distillation, the oil of caraway, much used for perfuming soaps, and particularly that kind known as *old Windsor*. It also enters into the composition of cheap essences. The seeds, in a ground state, are employed in certain sachet powders.

Cedrat.—The rind of the citron fruit—*citrus medica*—yields the oil of cedrat, both by expression and distillation. Its odor is lemon-like. This oil is expensive, and is mixed only with the finer perfumes.

Cloves.—The perfume from this plant, *caryophyllus aromaticus*, is one of the most ancient and useful. Every part of this plant contains aromatic oil, but the flower-buds are the most prolific portion. The oil may be obtained by expression, but much more economically by distillation, which is the mode generally followed. Its odor is strong and fragrant, and renders it a prominent ingredient of a very numerous variety of perfumes.

Cocoa.—The kernels of the cocoa palm, *cocos nucifera* and *butyracea*, growing in Brazil, Ceylon, and Bengal, when ground and subjected to hot-pressure, part with a white butyraceous fat, which has a disagreeable odor, of which it may be relieved by melting it with powdered benzoin, and afterwards straining. It has a limited application for common pomades, and as fat-stock for certain kinds of toilet soap.

Dill.—This plant, *anethum graveolens*, is cultivated in all the countries of Europe, and bears a strong smelling aromatic fruit or seed which, on distillation, eliminates a volatile oil, and a pleasant-smelling water, called *dill water*. This latter, mixed with rose water, is used, according to PIÈSSÉ, as a cosmetic for clearing the complexion. The oil may be employed in combination with others for scenting soaps.

Lemon.—The rind of the lemon fruit, *citrus limonum*, by expression evolves the well-known essential oil of lemons, which comes principally from Messina, and has a delightful odor. By time and exposure it becomes altered, and loses fragrance; it must, therefore, be used fresh. It enters largely into the compound perfumes and Cologne waters, but will not answer for scenting greases, as it promotes their rancidity. Like bergamot oil, it is often adulterated by the dealers with oil of turpentine.

Mace-Nutmeg.—Ground mace is sometimes to be found in sachet powders. It is the reticulated membrane investing the kernel or nutmeg of the *myristicha moschata*. The nutmeg emits by distillation, a fine fragrant volatile oil. It also yields, by expression, a fixed oil, called oil of mace. It is concrete, yellowish, and of an agreeable aromatic odor. Its application in perfumery is very limited.

Orange.—The *essence of Portugal*, heretofore de-

scribed under *Neroli*, is obtained by expression and distillation from the rind of the sweet orange. It is a very agreeable and popular perfume, and the prominent ingredient of many fragrant waters.

Palm.—The palm fruit, *avoira elais*, on being boiled with water, sends to the surface a butyaceous orange-colored fat of a violet-like odor. It is met with chiefly in admixture with tallow to make fine palm soap, and in small quantities for coloring pomades. The odor of the oil may be extracted by infusion in alcohol.

Tonquin.—The tonka or *coumarouma* bean, is the seed of the *dipterix odorata*, a plant growing in Guiana. It emits a strong, agreeable, aromatic odor, which may be extracted by infusion in alcohol. The tincture thus made is used in small quantities in a large number of compound scents, and particularly the *bouquet du champ*, on account of its assimilating in odor to new hay. The bean itself, when ground, forms an ingredient of many sachet powders.

Vanilla.—The pod or bean of the *vanilla planifolia* or *aromatica*, a plant of the West Indies, Mexico, and South America, emits a very fragrant and peculiar odor, which may be extracted in the form of tincture, by infusion in alcohol. It enters largely into the composition of bouquet odors, hair washes, *et cetera*, and is also a favorite material for flavoring confectionary.

5. BALSAMS AND RESINS.—The balsams used in perfumery are, the *Peru balsam*, from the myroxylon peruiferum; *tolu balsam*, from the myroxylon toluiferum; *balm of gilead* or *mecca balsam*, from the amyris opobalsamum; *labdanum*, from the cistus creticus; *storax*, from the liquidamber styraciflua; *benzoin*, from the styrax benzoin; and *myrrh*, from the balsamodendron myrrha. Some are in the form of fluid resins, while others are concrete, as labdanum, myrrh, and benzoin. All are exudations from plants, flowing out naturally, or else produced by incisions. Most of them are of oriental origin, and the supplies of all come from abroad. Their odors are aromatic and agreeable, that of labdanum being amber-like. Myrrh has a peculiar fragrance, and is more used for odontalgic preparations than as a perfume. This class of substances impart their aroma to alcohol in the form of tincture, and in that state are valuable adjuncts to the perfumer. They constitute the *foundation* or less volatile portions of many compound odors, and give consistency to the scent, and fix those ingredients which are more delicate and fleeting. They must be used judiciously, and in small quantities, as directed for the odors of musk, vanilla, and the like. Benzoin is also employed in a powdered state, as an ingredient of certain sachet powders.

The subject of BALSAMS is fully considered in Vol. I., pages 222-35, of this Dictionary. There are two other materials, neither of which belong properly to any of the classes enumerated, and as one of them is of prime importance in the art of the perfumer, they are entitled to an independent paragraph.

ALCOHOL AND CARAMEL.—*Alcohol*.—The manufacture and rectification of alcohol have already been described in Vol. I., pages 48-149. The Editor will only remark, that for the purposes of perfumery it should be wholly free from the odor of fousel oil, which is

peculiar to rye and corn spirit. In that respect, the French grape spirit is peculiarly adapted for the delicate perfumes, as it has rather a grateful aroma itself, which assimilates well with that of the scent substances. The grain spirit, on the contrary, is preferable as a solvent for the strong odors. HYDE proposes to remove fousel oil and analogous matters, by distilling the alcohol—eighty-five to ninety per cent.—with half a per cent. of manganate of potassa or soda, dissolved in a small quantity of water. The valerianic and other acids thus generated from the fousel and associate oils, combine with the alkali of the manganic salt, and remain fixed, while the alcohol passes over, pure and inodorous.

Caramel.—This useful coloring matter is made by heating brown sugar to 400°-430°, dissolving the product in water, and precipitating with alcohol. The blackish brown deposit is pure caramel, readily soluble in water; and it may be separated from the liquid by straining. A commoner article is the heated sugar merely dissolved in water and strained, the subsequent precipitation being omitted.

MINERAL SUBSTANCES.—This class comprises only a few materials, which are used rather as *body* or coloring matters. *Subnitrate of bismuth* is the *pearl white* for the complexion. A less objectionable preparation would be a mixture of *native sulphate of baryta* and *prepared chalk*—precipitated carbonate of lime. These latter two, while being as white as the former, are not, like it, discolored by the sulphur fumes in the atmosphere, nor so particularly injurious to the skin.

Mineral Talc.—A smooth, greenish-white earth, forms the *body* of tinted rouges. The different colored ochres are also sometimes used as pigments for soaps.

EXTRACTION OF SIMPLE ODORS.—*By Distillation*.—This process is necessary for the preparation of nearly all the essential or volatile oils, the fragrant waters, and more particularly Cologne waters. The apparatus consists of a metallic still and its appliances, for general purposes; but in certain cases, such as the distillation of vinegars and other substances that might act upon metal, glass or stoneware retorts are the proper implements. These latter, it should also be remembered, are better applicable for small and nice operations.

Essential Oils.—These so-called oils are misnomers, as they have none of the chemical or physical properties of true oils. They should be more properly designated by the title of *attars*. They differ from the fat or fixed oils in not being saponifiable, or greasy to the touch. They are, moreover, volatile; and being the odorous principle of the plants, each is consequently characterized by a scent. In specific gravity they range from 0.759—attar of coriander—to 1.094—attar of sassafras. They have, generally, an acid burning taste, and while many are colorless, some are yellow, red, or brown, others green, and a few blue. They burn with a brilliant flame and much smoke, and by prolonged exposure become thick and resinified. In ultimate composition they are chiefly hydrocarbons; but some few contain oxygen, and a certain class sulphur as a constituent. Their proximate components are *elaopten* and *stearopten*, the former of which is more fluid than the latter,

and may be separated by pressure when the oil is congealed.

The purity of essential oils is all-important, as they are used solely for their perfume. Those found in commerce do not always have that quality, but are frequently debased with alcohol, spirit of turpentine, resin, balsam copaiva, or some oil of inferior price. The detection of the latter fraud is very difficult—in most cases the specific gravity being the only test. The presence of resin or balsam is elicited when a drop of the suspected oil, heated upon a piece of paper, leaves a greasy spot.

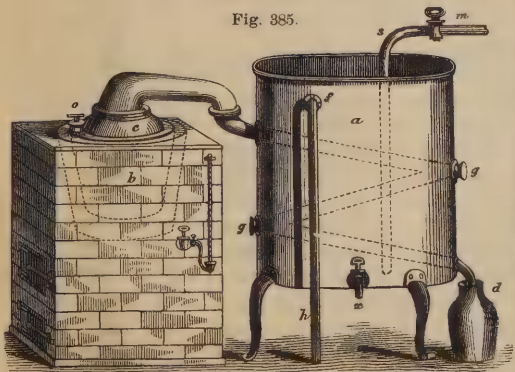
Alcohol is to be tested for, by placing a lump of perfectly dry chloride of calcium in a test-tube containing the suspected oil, and shaking it well. If the attar is pure, the chloride of calcium will remain unaltered; but if it contains alcohol, the lump will dissolve and form a dense substratum.

Spirit of turpentine is often used to cheapen the strong-scented attars, such for example as the attar of lavender. MERO has proposed an excellent method for its detection. It consists in placing one drachm of the attar with an equal volume of oil of poppy in a test-tube, and heating them in a water bath. If the attar does not contain spirit of turpentine, the mixture remains turbid; but if, on the contrary, it be present, the poppy oil is dissolved, and the menstruum becomes clear.

Attar of roses is often mixed with attar of geranium; but the presence of this latter may be ascertained by means of nitric acid, which imparts an apple-green hue to the latter, while it tinges the rose dark yellow.

The still used for the oils should be constructed so as to serve for all the distilling operations of the laboratory, and must, therefore, be set for use either with the naked fire or steam heat, as may be desired. MORFIT, in his *Chemical Manipulations*, describes an excellent arrangement, the whole of which is shown in front view by Fig. 385, just as it appears when in operation. The brickwork in which it is set abuts

Fig. 385.



against the chimney and connects with the flue, through the furnace of the still. This furnace, instead of being in front to inconvenience the operator with its heat and dust, is placed at the side, the lower door being the entrance to the ash-pit, and the upper to the furnace or fire-hole. The refrigerant or cooling-tub, α , has its position to the right of the brickwork.

The lower portion or body of the still, b , is made of heavy sheet-copper tinned interiorly. The head, c , is cast wholly from pure block-tin. Projecting from the inside of the still, near the bottom, is a tinned copper tube d , which passes forward through the brickwork and ends in a stopcock fixture, from which rises a glass tube e . The tap serves to shut off communication between the still and tube, as may be necessary in case of accident to the latter; and the tube itself, graduated into inches, presents a scale which will at all times indicate the height of the liquid. This indicator is protected by a half-casing of metal, in which it rests against the front wall of the brickwork, a clamp or two serving to keep it steady. There are two supplementary parts in the still, one of which is a colandered lining of block-tin, shown by Fig. 386, and the other by Fig. 387, a perforated false bottom of the same material. The first is made to fit to the mouth of the still in such a manner that the same head will adjust with both the inner and outer vessel equally well. The latter is intended as a support for organic or other matters alterable by contact with highly-heated surfaces, and is more particularly adapted for distillations with the naked fire. As it may be necessary frequently to remove this bottom, for the purpose of cleansing it, or dispensing with its use in some operations, it is constructed of two parts, connected by hinges in the centre, so as to form a fold which will pass through the mouth of the still.

Fig. 386.

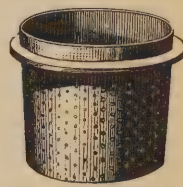


Fig. 387.



The block tin colander, exhibited in the drawing of the still by dotted lines, is designed for use in the distillation of bulky substances, particularly those of vegetal origin, by a direct current of moist steam. It allows, in a degree, the application of the displacement principle in distillation; for, as the current of steam enters, it passes upwards through the holes, thence through the mass of matter supported in the colander, and the first portion of the distillate reaches the condenser saturated with the volatile parts of the substance under treatment, and without mixture of any light, solid particles driven over mechanically, as would otherwise be the case. The process effects filtration at the same time that it constantly renews the surface of the solid matter to the solvent action of succeeding relays of fresh steam, while it also affords the means of determining when the former is exhausted, and the distillation should be stopped.

The steam-pipe is introduced through the opening, o —Fig. 385—and leads to within an inch of the bottom, where it takes an angular bend, and ends in a rose, which is a perforated copper ball, with a screw-cut shoulder, by which it is attached to the steam-pipe. The latter is so adjusted in the opening, by means of a shoulder and coupling-nut, as to form a tight joint. When the still is to be used with the naked fire *alone*, this pipe must be removed, and the opening closed with a screw-plug provided for the purpose. It should be remarked that this opening serves also for the entrance of a funnel—

tube through which to introduce fresh additions of liquid as may be required, to maintain a supply in the still, without the necessity of stopping the operation or removing the head.

The distillate, in passing from the still-head, goes into a worm, *g g*, firmly fixed in the cooler, *a*. The worm is a series of block-tin tubes, as shown by the dotted lines. The mouth of the first joint receives the beak of the still-head, and that of the last joint empties, through a bent nozzle, into the receiving-vessel, generally a glass or stone jar, as seen at *d*. To facilitate the cleansing of the joints, they are fitted at the ends, *g*, with screw-plugs, which being removed, allow free access to the interior with a cloth and ramrod.

The cooler is made of galvanized iron, or, still better, of tinned copper; and in order to accommodate the long joints of the worm which is soldered to it, its form is oval. The pipe through which it receives cold water is close to the side, and extends nearly to the bottom, as shown at *s*. A connection with the hydrant is made by a branch-pipe and tap, as shown at *m*. The opening for the exit of the warm water is seen at *f*, and leads into another pipe, *h*, running down the outside of the cooler into the drain or gutter. A tap, *x*, serves for draining off sediment, as it accumulates by deposition from the water.

When it may be desired to use dry steam, then the block tin colander, Fig. 386, must be replaced by one which is close and not perforated. There will then have to be an opening and tube opposite to *o*, for carrying away excessive steam.

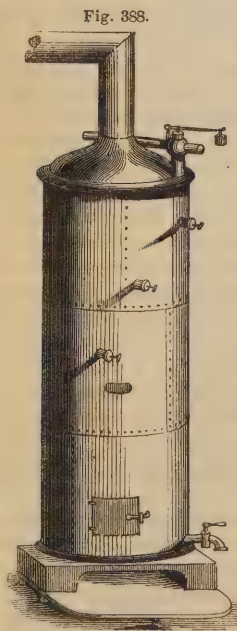


Fig. 388.

The jacket thus formed gives the convenience of using it also as a water or saline bath, when operating with fire direct, instead of steam. The water or saline solution is, of course, placed in the outer case or body of the still proper, *b*, and thus surrounds the inner vessel, containing the matter to be distilled. Steam may be supplied from a small portable generator, such as are now made for purposes of this kind, and here shown by Fig. 388. Great care is requisite in cleaning the several parts of the still arrangement at every change of operation.

In the distillation of roots, woods, barks, flowers, seeds, *et cetera*, the best heating medium is steam, as it allows a better regulation of tem-

perature than can be accomplished in the use of the naked fire. Moreover, it removes all liability of scorching the materials. A current of steam passing from the generator under a pressure of fifty pounds to the square inch, has a temperature of 280°, which

is much higher than is needed for any material under present consideration.

The part of the plant yielding the odor, after having been bruised or cut into small pieces, is to be placed in the colandered vessel, or on the perforated bottom, with as much water only as is necessary to drench the material; and when the oil to be obtained is heavier than water, the density of the latter must be increased by nearly saturating it with table salt, which also raises its boiling point from 212° to 220°. The head of the still—Fig. 385—is then put in place, and the joints closed. Steam is next let on through the pipe, *o*, and the current continued until oily distillate ceases to come over.

If the quantity of water is too much in proportion to the amount of material to be distilled, then a portion of the oil remains dissolved therein, and does not separate. The same result occurs when the oily constituent is in limited quantity. In all such cases cohobation is necessary. That is, the distillate or liquor first passing over must be poured back repeatedly, upon the same or fresh material, and as

often redistilled. Indeed, in all distillations where fresh relays of water are used, the last running, which is of feeble strength, should be reserved as the first water for the next operation with fresh material. In this way the small portion of oil which it may have contained is economized. As the volatilization of the water is coincident with that of the oil, the two must be received together, as they condense, in a vessel which will admit of the ready separation of them by reason of their different specific gravities. Fig. 389 represents the Florentine receiver, which is used for the lighter oils. The oil, accumulating at *a b*, retains its supernatant position throughout the distillation, while the water beneath flows out at *c*, as fast as it runs from the still. When the oil is denser than the water, a different arrangement, as shown at Fig. 390, is required. The denser oil is drawn off, by opening the tap of the barrel, as fast as it separates and subsides from the lighter water.

It is very necessary that the water in the refrigerant should be replaced by cold water as fast as it becomes warm; except for those oils, such as anise and rose, which thicken readily. The temperature of the water must be regulated in accordance with that property.



Fig. 389.

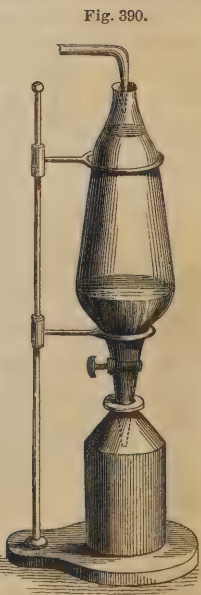


Fig. 390.

Scented Waters.—All substances which yield essential oils, give at the same time a scented water of superior excellence; for example, *orange flower water*; and the difference in the density of the two products permits their separation in the manner just described. There are some materials, again, which are too feeble in odor to give an attar, and may yet be made to impart their scent to water. In either of those cases, and also when it may be desired to obtain only a water from those substances which would yield an essential oil, the quantity of water employed must be much larger than for the oil distillations. And for the reason, that now the object is to obtain solution of *all* the essential oil in water, and not to promote the separation of the two, as before directed.

The process and manipulations are the same as just described for distilling the essential oils, except that only the first three-fourths of the distillate are preserved. A little rectified spirit may be advantageously added, before setting aside the scented water for preservation. Wet steam is by far the preferable means of heating. The flowers should be as fresh as possible, and free from stems. *Double distilled rose water* is made by distilling over two gallons from a mixture of twelve pounds rose leaves, and two and a half gallons water. In the same way, nine pounds of elder flowers and four gallons of water give three gallons of *elder flower water*.

By Expression.—This method is adapted only for those substances which are very rich in essential oil; as examples, the rinds of the lemon, orange, citron, and some other fruits. The chief implement is a powerful press. The material is either inclosed in hair bags, or a tinned metal box—Fig. 391—

Fig. 391.

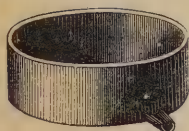


Fig. 392.



Fig. 393.



resting upon the bottom of the press. The box must be lined with a perforated cylinder—Fig. 392—having perpendicular ribs on the exterior circumference. These latter, projecting against the inner sides of the box, form channels by which the flow of the expressed oil is facilitated, and its free passage into the receiving vessel maintained. Being in two parts, connected by a hinge and movable pin, it can be conveniently emptied and refilled, as becomes necessary. The follower—Fig. 393—being directed forcibly downwards upon the contents of the box by the mechanism of the press, crushes

the oil vesicles, and drives out the oil, and along with it some water and mucilage, and foreign matters, which may be separated by sufficient repose and straining.

By Infusion or Maceration.—This process is mostly used for those substances, the odor of which is too delicate for distillation, such as the flowers of the cassie, bitter orange, and violet; and sometimes also the rose and the like, the natural perfumes of which it is desired to obtain in the maximum state of perfection.

The infusion medium is a mixture of beef or mutton

suet, and lard, refined in the manner already directed. The necessary apparatus is one of the steam pans heretofore referred to, but it must be tinned or enamelled interiorly, and fitted with a tight cover. The fat body having been melted, the flowers or odoriferous material are wholly immersed in it, and left for a day, care being taken to stir the mixture occasionally with a wooden stick. In this time the flowers have become exhausted of their perfume by the fat, and must, therefore, be separated by remelting, straining through a fine hair-cloth sieve, and pressing the marc. The spent flowers are then replaced by a fresh charge; and so these renewals are continued until the fat has sufficient odor. In this way various strengths may be obtained, and are generally designated by numbers, according to the number of infusions which the fat has undergone. After the last straining and pressing, the expressed matter should be allowed sufficient repose to clean itself. The darker substratum which thus deposits may then be removed from the clear upper portion, and sold as an inferior quality.

In this manner the finer sorts of French pomade are prepared. Sometimes oil of ben takes the place of suet as the infusion medium, and then the products have the name of *huile antique*.

By Enfleurage.—There are certain flowers, the odors of which are so delicate that they will not bear even the little heat used in the preceding method; and for these the process of enfleurage or absorption is employed. Jessamine, mignonette, tuberose, and similar flowers, belong to this category.

HANBURY thus describes the operation as conducted at Grasse and Cannes. The apparatus required is merely a number of shallow wooden frames of about eighteen by fifteen inches, inclosing at half their depth a sheet of glass. The edges of the frame rise about an inch above each surface of the glass, and, being flat, the frames stand securely upon one another, forming often considerable stacks. The technical name for the frames is *chassis*; those just described are called *chassis aux vitres*, or *chassis aux pommades*, to distinguish them from a different form, which is used where oil has to be submitted to the process of enfleurage. The process in the case of pomade is thus conducted: the unscented fat is weighed into portions, each sufficient for one side of the sheet of glass of a *chassis*. It is then spread over the glass with a spatula in a layer hardly a tenth of an inch thick, care being taken, by employing a little inner frame during the spreading, that the fat does not come in contact with the wood-work of the *chassis*. One surface of the glass having been thus coated, the other is covered in like manner, and the *chassis* is ready to receive the flowers. These are now thinly sprinkled, or rather laid, one by one, upon the surface of the fat, where they are allowed to remain until the next day or day after, when they are dexterously removed with nippers, so as not to soil the fat, and fresh flowers supplied. The *chassis*, charged with fat and flowers, are stacked one upon the other, forming, in fact, a number of little rectangular chambers, the upper and lower surfaces of each of which are of glass, covered with a thin layer of fat sprinkled with flowers, the sides being of wood. In one manufactory

which the Editor inspected, only one surface of each *chassis* was coated with fat, the jessamine flowers being placed in an abundant layer upon the other surface. In another establishment the flowers of mignonette were being similarly treated. In this arrangement the flowers do not, of course, come in contact with the fat, but the latter is simply suspended above them to receive and absorb their odor. The flowers require changing, either daily, or every other day, for a month or two, before the pomade is sufficiently impregnated with their odor. It is of paramount importance that all flowers employed in this process should be collected during warm weather.

After the last impregnation, and when the fat is sufficiently fragrant, the pomade is removed with a spatula, and put into close cans.

By Alcoholic Solution.—The extraction of odors by means of alcohol from scented fats, will be more fully explained under the head of *Extraits*. The Editor will here limit himself to the description of essences and tinctures.

ESSENCES.—These, in the language of perfumery, are nothing more than solutions of essential oils in deodorized alcohol. The proportion of oil varies from two drachms to two ounces, and the manipulation consists in merely mixing and shaking the two together. Sometimes they are subsequently distilled with a little water, and then they are called *distilled aromatic spirits*. Cologne, lavender, and similar waters are thus made. For example, SMYTH makes his famous *essence of lavender* by mixing together—English attar of lavender, four ounces; deodorized alcohol of ninety-five per cent., five pints; rose water, a pint; and distilling off, five pints.

As examples of essences by simple mixture may be named—

	Essential Oil.	Deodorized Alcohol of 95 per cent.
Essence of lemon,.....	one fluid ounce.	a quart.
“ bergamot,.....	—	a quart.
“ rose—triple,...	one ounce and a half.	two quarts.
“ thyme,.....	two drachms.	two quarts.

Tinctures.—When both of the substances are fluid, as in the case of certain balsams, then the spiritous solution is made by merely mixing the two together as before, in suitable proportions. For instance—

	Tolu balsam.	Alcohol.
Tincture or essence of tolu,....	three drachms.	a quart.

There are, however, many solid substances which are treated with alcohol, for the extraction of either their odor or coloring matter. These menstrua may

be made by merely macerating the substance in alcohol for ten days, and filtering off the clear tincture; but the shorter and more efficient, as well as economical method, is that known as *displacement*. To explain the operation intelligibly, let one suppose that benzoin is under treatment. The apparatus, made wholly of glass, having been arranged as shown by Fig. 394, and a plug of raw cotton dropped loosely at *b*, the benzoin in coarse powder is then poured into the tube portion, *A*, until it reaches the line *c*. Alcohol, of 66° Twaddell, is next added, until it rises to the line *d*. As soon as the first portion sinks into the benzoin, a fresh addition must be made; and thus the succeeding relays go on displacing those which preceded them, without mingling with them. Each stratum becomes more and more charged with soluble matter as it descends; and when it reaches the bottom of the mass, under the pressure of the superincumbent liquor, it runs out saturated. When, by successive additions of fresh alcohol, the benzoin has become exhausted, the liquid passes through the mass, and falls into the receiver, *B*, as tasteless and colorless as when first poured in. This indicates the completion of the process. As atmospheric pressure is an important element in the operation, it will not answer to shut it off by closing the top of the displacer, without making some compensating arrangement; and, therefore, a communication between the upper and lower vessels is established by means of a latent-tube arrangement, *D*. In this manner the apparatus is kept close, and the evaporation of alcohol prevented, while the pressure produced is distributed throughout the vessel, and thus rendered uniform. As the runnings are clear, filtration is rarely necessary. The quantity of alcohol thus consumed need not be more than sufficient to exhaust the material; and the resulting tincture must therefore be diluted to the proper strength. Deodorised alcohol must be always used.

The following are the proportions employed for the most important tinctures or essences:—

		Troy.	Alcohol.
Tincture or essence of vanilla,.....	vanilla bean—rasped,.....	eight ounces,.....	eight pints.
“ “ musk,.....	grain musk,.....	two drachms,.....	eight pints.
“ “ frangipani,.....	powder a la frangipani,.....	one pound,.....	six pints.
“ “ rhodium,.....	rhodium wood—rasped,.....	one pound,.....	two quarts.
“ “ civet,.....	civet, orris root,.....	half an ounce,.....	two quarts.
“ “ tonquin,.....	tonka bean,.....	one pound,.....	eight pints.
“ “ orris,.....	orris root,.....	seven pints,.....	eight pints.
“ “ alkanet—red color,...	alkanet,.....	half an ounce,.....	a quart.
“ “ turmeric—yellow,...	turmeric,.....	half an ounce,.....	a quart.

POMADES.—The *fine*, and *extra fine* or *double* pomades are made by the processes of maceration and enfleurage, which have been already described at page 671. The

body must be of fat purified as previously directed. Almond paste, peeled and bruised almonds, may also be scented in the same manner here directed for fats.

Fig. 394.



Pomade à l'Acacia.—Cassie leaves, fifteen pounds; body, fifty pounds, consisting of thirty-five pounds lard body, and fifteen pounds of mixed beef and mutton suets. The infusion must be repeated ten times, and each time with a fresh quantity of fifteen pounds of flowers.

Pomade à la Rose.—One pound of body and twelve infusions, and each time with one pound of fresh rose leaves.

Pomade à la Fleur d'Oranger.—Equal parts of flowers and body. Eight infusions give the required strength.

Pomade à la Vanille.—One pound of vanilla in shreds, and twelve pounds body. Infuse for twelve days; remelt, and infuse for ten days longer; melt again, and strain through a fine sieve.

Pomade à la Tubéreuse.—The enfleurage must be repeated with fresh tuberoses flowers, six or more consecutive times.

Pomade aux Jasmin.—The jessamine flowers must be renewed ten times.

Pomade à la Jonquille.—The jonquil flowers need only five or six renewals.

Pomade à la Jacinthe.—The hyacinth flowers require to be renewed eight or ten times for a highly-scented pomade.

COMPOUND OR BOUQUET POMADES.—These are made by a judicious mixture of the single pomades, of which the preceding are some examples.

Pomade aux Fleurs d'Italie.—Pomades à l'acacia, à la tubéreuse, à la jacinthe, à la jonquille, each one pound. Pomades à la fleur d'oranger and au jasmin, each two pounds. Pomades au reseda and à la rose, each eight ounces. Melt together over a water-bath, color as may be desired, and strengthen the perfume with a mixture of tincture of musk, six drachms; tincture of amber, three drachms; essence of bergamot, three drachms; and essence of cloves, one ounce.

Pomade à la Frangipani.—Plain body, and pomade aux jasmin, each four pounds. Pomades à la fleur d'oranger, two pounds. Pomades à l'acacia and à la rose, each one pound. Melt together over a water-bath, and as the mass begins to cool, stir in a mixture of tincture of vanilla, four ounces; balsam of peru, one ounce; essence of bergamot, two ounces; essence of cloves, half an ounce; and tinctures of amber and musk, each four ounces. Color brown.

The name FRANGIPANI belongs to a very ancient and illustrious Roman family, and certain popular preparations are so called in honor of the grandson of MUTIO FRANGIPANI, one of its scions, who originated many agreeable combinations of perfumes during the time of LOUIS XIII. of France.

The perfume called after the above, as found in commerce, is a compounded scent, and not, as supposed, a simple extract of the *plumeria alba*, a fragrant plant of Antigua, originally named the FRANGIPANI shrub, after its discoverer.

Pomade Impériale.—Pomades à l'acacia, à la jonquille, au lilas, au réséda, à la tubéreuse, each eight ounces; pomade au jasmin, four pounds; pomade à la fleur d'oranger, one pound. Melt together over a water bath, taking care to add the pomade au lilas and

pomade au jasmin last. When nearly cool, stir in a mixture of essence of bergamot, and tincture of vanilla, each one ounce; tinctures of musk, amber, and fenugree, each two drachms; color green.

The common grade of pomades are composed of the unscented body used for preparing fine pomades, which is extemporaneously perfumed by merely stirring in the essential oils, singly or in *bouquet*, according to the odor it is desired to impart. Beef marrow, or bears' grease, are scented in this manner. White wax is to be added for *stick pomatum*.

Pomade à la Graisse d'Ours.—Bears' grease, purified, six pounds; pomade à la rose, one pound; melted together, and perfumed with essence of rose, one ounce; tincture of vanilla, one ounce.

Pomade de Moelle Bœuf.—Purified beef marrow, eight pounds. Melt, and perfume with tinctures of musk and benzoin, each two drachms; essence of portugal, one ounce; essential oil of lavender, two ounces; extract of jasmin, one ounce; and attar of roses, half an ounce. Color with a portion of unscented body, in which fresh walnut leaves have been infused.

ANTIQUÉ OILS.—These oils are prepared as already directed for the process of maceration and enfleurage; and they correspond with the pomades, except that olive or ben oil is used for the body instead of solid fat.

Huile Antique de la Rose de Provens.—Oil and rose leaves, each one pound. Infuse seven times, with as many relays of fresh flowers.

Huile Antique au Chevre-feuille.—Honeysuckle flowers and oil. Infuse eight to ten times, with as many relays of fresh flowers.

COMPOUND OILS.—These are judicious mixtures of the single oils. One example will suffice.

Huile Antique de Millefleurs; ou, de Bouquet Composée.—Oils au jasmin, à la rose, each eight ounces; oils à l'acacia, à la fleur d'oranger, à la tubéreuse, each four ounces; oils à la jonquille, à la jacinthe, à la vanille, each two ounces. Mix together.

The inferior qualities of the above oils are made from olive oil alone, or mixed with lard oil, scented, extemporaneously, with essential oils; for example:—

Huile à la Bergamot.—Essence of bergamot, two ounces; added to one pound of olive oil.

Huile de Neroli.—Essential oil of neroli, four ounces; and olive oil, one pound.

SINGLE EXTRACTS OR EXTRAITS.—These preparations are made by treating with alcohol the highly-scented pomades, or antique oils, obtained by the processes of maceration or enfleurage. In this way the aroma absorbed from the flowers by the fat is dissolved out. These spiritous infusions are of much more delicate odor than the so-called *essences* or *solutions* of volatile oil in alcohol. Indeed, they represent in themselves the primitive odor, in liquid form, of those plants which do not yield any volatile oil.

The scented pomade is placed in a stone vessel, and one pint of deodorized spirit added to every pound of pomade. The whole is then heated for three days over a water bath, and frequently stirred in the interval; after which the alcoholic liquor is drawn off from the fat, and put through the same operation repeatedly, with fresh quantities of pomade, until it has acquired sufficient

strength of odor. A revolving churn may be substituted for the digesters and water bath; and this arrangement has the advantage of eliminating the perfume in a state of great integrity, there being no heat used. The churn may be barrel-form, and placed horizontally, so as to facilitate the turning of the crank which imparts motion to the dash-paddle in the interior.

The liquors thus obtained are simple extracts of the most superior quality and natural odor, and form the bases of the compound extracts or *bouquets* so popular as perfumes for the handkerchief.

The pomade or oil, after treatment, still retains some odor, and is, therefore, valuable material for the stick and common pomades, or as fat stock for new treatment with fresh flowers.

Extrait de jasmin, Extrait de violette, Extrait de tubéreuse, are examples of preparations made according to the preceding directions.

COMPOUND EXTRACTS OR BOUQUETS.—*Extrait de bouquet.*—Extraits de jasmin et violette, each two pints; extraits d'acacia, rose, œillet, et des fleurs d'oranger, each one pint; flowers of benzoin, two drachms; tincture of amber, four ounces. Mix and filter.

Bouquet d'Amour.—Extraits de rose, jasmin, violette, acacia, each one pint; tinctures of musk and ambergris, each half a pint. Mix and filter.

Jockey-club Bouquet.—Extraits de rose et tubéreuse, each one pint; extrait de cassie, half a pint; extrait de jasmin, four ounces; tincture of civet, three ounces. Mix and filter.

Bouquet des Millefleurs.—Extrait de rose, one pint; extraits des tubéreuse, jasmin, fleur d'oranger, cassie, et violette, each half a pint; essence of cedar, four ounces; tincture of vanilla, ambergris, and musk, each two ounces; essence of rose, half a pint; attar of bergamot, one ounce; attars of almonds, neroli, and cloves, each ten drops. Mix, leave to repose for a week, and filter.

Bouquet de la Reine.—Extraits de rose et violette, each one pint; extrait de tubéreuse, half a pint; extrait de fleur d'oranger, four ounces; attar of bergamot, two drachms. Mix and filter after a week's repose.

Bouquet Royal.—Extrait de rose, one pint; extraits des jasmin et violette, each eight ounces; extraits d'acacia et verveine, each two and a half ounces; essence of rose, half a pint; attars of lemons and bergamot, each two drachms; tinctures of musk and ambergris, each one ounce. Mix, and after eight or ten days' repose, filter.

Bouquet of Spring Flowers.—Extraits de rose et violette, each one pint; extrait d'acacia and essence of rose, each two and a half ounces; attar of bergamot, two drachms; tincture of ambergris, one ounce. Mix, and after ten days, filter.

There are certain *bouquets*, of fine odor, which may be compounded direct from the volatile oils; as an example, there is—

Bouquet de Rondeletia.—Attar of lavender, two ounces; attars of cloves and bergamot, each one ounce; attar of roses, three drachms; tinctures of musk, vanilla, and ambergris, each four ounces; deodorized alcohol, one gallon. Mix, and after a month's repose, filter.

COLOGNE AND OTHER FRAGRANT WATERS.—These preparations are mostly solutions of *bouquets* of essential oils, or extracts, in alcohol, improved by distillation. For common kinds distillation is omitted.

Eau de Cologne—Dorocherau's.—Inodorous alcohol, one gallon; attars of portugal and bergamot, nine drachms; attar of neroli, ten drachms; attar of petit-grain, twelve drachms; attars of lemon, lavender, and rosemary, each one ounce; rose, jasmin, and orange-flower waters, each two ounces. Mix by shaking, and after two weeks' repose distil, and set aside for a year.

Eau de Cologne—Double.—Inodorous alcohol, three gallons; attar of bergamot, twelve ounces; attars of cedrant, lemon, and portugal, each two ounces; attar of lavender, one ounce; attars of neroli and rosemary, each two and a half ounces; attar of thyme, one drachm. Mix, and after a week's repose, distil, and then dilute with orange-flower water until the liquor marks.

Eau de Cologne.—Spirit from grape, sixty over proof, six gallons; attar of neroli petale, three ounces; attar of biggasade, one ounce; attar of rosemary, two ounces; attar of orange peel, five ounces; of citron peel, five ounces; and of bergamot peel, two ounces. Mix with agitation, then allow it to stand for a few days undisturbed, filter and bottle.

Eau de Rondeletia.—French alcohol, one gallon; attar of lavender, two ounces; attars of cloves and bergamot, each one ounce; attar of roses, three drachms; tinctures of musk, vanilla, and ambergris, each four ounces. Mix, and leave to repose for a month, then filter and bottle.

COSMETICS.—The preparations under this head are designed to soften the skin and beautify the complexion. We annex recipes for the more important. The heating medium in the manufacture of them must be either a water or steam bath.

Amandine.—Put into a large marble mortar two ounces gum arabic, and six ounces white honey, triturate, and when the mixture has been rubbed into a thick paste, add three ounces perfectly neutral almond shaving paste. Then continue the trituration until the mixture has become homogeneous. Two pounds of fresh cold-pressed sweet almond oil are next allowed to flow from a can above into the water, but only as rapidly as the workman can incorporate it with the mass; otherwise, if it enters in too large quantities, the blending is imperfect, and the amandine becomes *oily* instead of jelly-like and transparent, as it should be when the manipulation has been skilful. In summer temperatures it will be difficult to effect a combination of all the oil; and, therefore, the flow should be stopped as soon as the mixture becomes bright and assumes a crystalline lustre. The perfume should be mixed with the almond oil, and consists of half a drachm of attar of bitter almonds to every pound of paste. A little attar of rose and bergamot may also be added—about one drachm of each. As soon as finished it must be put in close pots. A small quantity, say a lump of filbert size, gives with warm water a rich lather, which, when rubbed over the face and hands, imparts softness, and prevents chapping. It should be wiped off, while still in lather, with a dry towel.

Camphor Ice.—Melt together over a water-bath, white wax and spermaceti, each one ounce; camphor, two ounces; in sweet almond oil, one pound. Next, triturate in the manner directed for amandine, and allow one pound of rose water to flow in slowly during the operation. Then perfume with attar of rosemary, one drachm.

Crème de Cathay—Farina.—Melt together over a water-bath white wax and spermaceti, each two drachms; then add oil of sweet almonds, four ounces; and mecca balsam, three drachms; next, perfume with rose water, six drachms; and stir until cold.

Glycerin Cream.—This superior cosmetic is the well-known *cold cream*, with glycerin substituted for rose water. Melt together spermaceti, six ounces; and white wax, one ounce; in one pound of sweet almond oil. Then remove from the fire, and stir in PRICE's glycerin, four ounces; and when congealing, perfume with attar of rose, twenty drops. Other attars may be used as desired in place of rose.

Pâte d'Amande au Miel.—Rub together one pound of honey and the yolks of eight eggs; then gradually add sweet almond oil, one pound, during constant trituration; and work in bitter almonds—blanched and ground to meal—eight ounces; finally perfume with attars of bergamot and cloves, each two drachms.

Pomade Rosat—for the lips.—Melt together white wax, two ounces; oil of sweet almonds, four ounces; alkanet, three drachms. Digest for several hours, strain, and add twelve drops of attar of rose.

Crème de Psyché—for the lips.—White wax and spermaceti, each one ounce; oil of sweet almonds, five ounces. Melt together, and pour in mecca balsam, one drachm, and stir until the mass congeals, when add ten grains of powdered acetate of lead.

Lait Virginal.—Orange-flower water, eight ounces; and tincture of benzoin, two drachms. The former is added very slowly to the latter during constant trituration, so as to produce an opalescent milky fluid.

Milk of Roses.—Place over a water-bath, oil soap one ounce; and melt it in five or six ounces of rose-water; then add white wax and spermaceti, one ounce; and continue the heat until they have fused. Next take one pound of blanched almonds, beat them to meal in a clean marble mortar, with three and a half pints of rose-water, admitted portionwise, during the trituration. The emulsion of almonds, thus made, is to be strained without pressure through washed white muslin, and run very slowly into the previously-formed soap-mixture; the whole being blended at the same time by energetic trituration. Towards the end of this operation, two drachms of attar of rose, dissolved in eight ounces inodorous alcohol, is to be let into the mixture very gradually, and in a thin stream, during constant rubbing of the mass. This cautious manipulation is indispensable to the smoothness and perfection of the milk. The last operation is to strain; and after the liquid has had a day's repose, to bottle it.

Piessé's Milk of Cucumber.—Heat two pints juice of cucumbers to boiling, cool and strain; and make into milk, as above directed, with sweet almonds, four ounces; green oil and wax, and curd soap, each half an ounce; alcohol, eight ounces, and essence of cucumber,

four ounces. This latter is made by digesting twenty-eight pounds bruised cucumbers with two pints of alcohol of .837 specific gravity for twenty-four hours; and then distilling off one pint and a half.

Crème de Pistache.—Pistachio nuts, three ounces; green oil, palm soap, wax, and spermaceti, each one ounce; orange-flower water, three and a quarter pints; essence of neroli, twelve ounces; make as directed for the preceding milks.

PREPARATIONS FOR THE HAIR.—In addition to the various kinds of pomades and antique oils already described, there are other special preparations used for promoting the growth, health, and beauty of the hair. Annexed are formulæ for those most esteemed.

Philocomé.—This compound is made without heat. Equal parts of purified beef-marrow, oils of noisettes and sweet almonds are thoroughly mixed by trituration in an agate or marble mortar; and the whole is then perfumed by the addition of a sufficient quantity of a mixture of extracts of rose, acacia, jasmin, orange flower, and tuberose.

Macassar Oil.—Oil of ben, one gallon; oil of noisette, half a gallon; strong alcohol, one quart; attar of rose, two drachms; attar of bergamot, three ounces; attar of portugal, two ounces; and tincture of musk, three ounces; mix together, digest with alkanet root—for color—in a stoppered bottle for a week, then strain and bottle.

Morfit's Hair Tonic.—Scald black tea, two ounces, with one gallon of boiling water; strain, and add three ounces of glycerin; tincture cantharides, half an ounce; and bay rum, one quart. Mix well by shaking, and then perfume.

Shampoo Liquor.—This excellent wash for the hair is made by dissolving carbonate of ammonia, half an ounce, and borax one ounce, in one quart of water, and adding thereto two ounces of glycerin, New England rum three quarts, and one quart of bay rum.

The hair having been moistened with this liquor, it is to be shampooed with the hands until a slight lather is formed; and the latter being then washed out with clear water, leaves the head clean, and the hair moist and glossy.

PREPARATIONS FOR THE TEETH.—These preparations should be compounded of materials, which, while cleaning the teeth without injury to the enamel, will also be antiacid, antiscorbutic, and tonic in their action upon the gums.

Poudre Détersive Dentifrice.—Willow charcoal and white sugar in impalpable powder, each eight ounces; calasay bark in impalpable powder, four ounces; mix thoroughly in a mortar, sift through the finest bolting cloth, and perfume with a mixture of attar of mint, two drachms, attar of cinnamon, one ounce, and tincture of amber, half an ounce.

Camphorated Chalk.—Precipitated carbonate of lime, one pound; powdered orris root, three and a half pounds; powdered camphor, quarter of a pound; reduce the camphor to fine powder by triturating it in a mortar with a little alcohol; then add the other ingredients, and when the mixture is complete, sift through the finest bolting cloth.

Morfit's Dentifrice.—Powdered willow charcoal, four

ounces; cinchona bark and sugar of milk, in powders, each one pound; old transparent soap, in powder, four ounces; mix in a marble mortar, sift through the finest bolting cloth, and perfume with attar of orange flower, one ounce.

Rose Tooth-powder.—Precipitated carbonate of lime, one pound; powdered orris, half a pound; rose pink, two drachms. Mix together; sift and perfume with attar of roses, one drachm; and attar of santal, twenty drops.

Another Dentifrice.—Precipitated carbonate of lime, one pound; powdered borax, half a pound; powdered myrrh, four ounces; powdered orris, four ounces. Mix, and sift through finest bolting cloth.

Opiate Tooth-paste.—Honey, powdered orris, and precipitated carbonate of lime, each half a pound; rose pink, two drachms. Rub into paste with simple sirup, and perfume with attars of cloves, nutmeg, and rose, each half an ounce.

Eau Botot.—Tincture of cedar wood, one pint; tincture of myrrh and rhatany, each four ounces; attar of peppermint, five drops. Mix.

Violet Mouth-wash.—Tincture of orris, essence of rose, and alcohol, each eight ounces; attar of almonds, five drops. Mix.

Cologne Tooth-wash.—Eau de cologne, one quart; tincture of myrrh, four ounces. Mix.

Cachou Aramatisé.—These popular pastilles for perfuming the breath are thus made:—Dissolve three and a half ounces of extract of liquorice in four ounces of water, by the heat of a water-bath, and add of pulverized gum arabic half an ounce, and Bengal catechu, in powder, one ounce. Evaporate to the consistence of an extract, and then mix in, thoroughly, powdered mastic, charcoal, cascarilla, and orris root, each half a drachm. When the mass has been reduced to the proper consistence, it is to be removed from the fire, treated with attar of peppermint, thirty drops; tinctures of ambergris and musk, each five drops; poured out upon an oiled slab, and rolled to a very thin sheet. After cooling, blotting paper is pressed upon it to absorb any adhering oil; and the surfaces are then moistened with water, and covered with silver leaf. When dry it is to be divided into small bits of the size of a fenugree seed.

POWDERS.—Powders for the hair and skin have almost gone out of use. The basis of them is either powdered orris, or fine dry pearl starch. The perfume of the finest kinds is imparted by stratifying starch with fresh flowers, after the manner of enfleurage with fat. The flowers are subsequently separated by sifting. The simple perfumed powders thus obtained, by judicious admixture, form compound or bouquet powders. The tediousness and expense of this process prevent its general employment. The common mode is to scent by the direct addition of extracts or essential oils, or else to mix in powdered fragrant material with the orris or starch. The following formulæ will explain the manufacture of them.

Violet Powder.—Wheat starch, twelve pounds; powdered orris, two pounds. Mix together, and add attar of lemon, half an ounce; attars of bergamot and cloves, each two drachms.

Poudre d'Iris.—Powdered orris root, twelve pounds;

powdered bergamot, peel, and acacia flowers, each eight ounces; powdered cloves, half an ounce. Mix and sift.

Prepared Bran—for the hair.—Powdered wheat bran, one pound; powdered orris, two ounces. Mix and sift.

Poudre Noir—for the hair.—Starch and orris in fine powder, each eight ounces; charcoal and ivory black, in fine powder, each one ounce. Mix and sift.

Poudre Blonde—for the hair.—Finely powdered starch and orris, eight ounces each, as in the preceding, but with yellow ochre for the coloring matter.

Poudre à la Vanille Brune—for the skin or for sachets.—Powdered vanilla, rose leaves, lump storax, benzoin, rhodium, pallsandre and ebony woods, each one pound; powdered cloves, two ounces; powdered musk, two drachms. Mix together with three pounds of starch; sift, and add a few drops of extracts of tuberose and jessamine.

Poudre à l'Éillet Composée—for the skin or sachets.—Powdered rose leaves and orris root, each three pounds; powdered bergamot peel, one pound; powdered cloves and cinnamon, each six ounces; powdered acacia and orange flowers, each eight ounces; starch, three pounds.

ROUGES.—Paints or rouges are the means by which the natural color of the skin may be heightened or changed. They are, however, objectionable preparations, and the use of them extends very little beyond the theatres, where they are employed to produce stage effect.

French White.—This is the mineral talc, or French chalk, finely levigated and bolted. It forms the basis of the most harmless rouges. Perfume is added as may be desired.

Pearl White.—Pure oxide or subnitrate of bismuth in powder. This pigment darkens in atmospheres containing sulphide of hydrogen. One ounce triturated with four ounces of orange-flower water makes liquid white.

Pearl Powder.—Precipitated carbonate of lime, finely bolted and perfumed. The French add oxides of zinc and bismuth, each one ounce to the pound of chalk.

Carmine Rouge.—Finely bolted talc, four ounces; carmine, two drachms. Mix together with a little warm and dilute solution of gum tragacanth. For lighter shades, the proportion of carmine must be increased. For commoner pastes, rose pink replaces the carmine as coloring matter. It may be made into a pomade.

Bloom of Roses.—Powdered carmine of the best quality, two drachms, digested with strong ammonia, four ounces, in a tightly stoppered bottle for two days, at the ordinary temperature of the atmosphere. Then add rose water, one pint, and essence of rose, four ounces. After a week's repose, the upper stratum of clear liquid may be decanted from the subsident matter, and bottled.

Fard Bleu d'Azur.—Talc and ultramarine, finely bolted, equal parts, triturated with a solution of gum tragacanth into a stiff paste.

TOILET SOAPS.—To this class belong the finer kinds of scented soaps, which have emollient properties. They are rarely made direct by the perfumer, the body or basis being a well-selected white soap, subsequently

cleansed and purified. For the choicest grades, the body should be made of a mixture of olive and sweet almond oils, as the fat stock. Lard and beef tallow make the next best stock; and for palm soap a small quantity of bleached palm oil is to be added to them. Cocoa oil and pale yellow rosin saponaceous matters also enter into the composition of certain toilet soaps. These body-soaps may be obtained as wanted from any well-conducted soap factory. To be adapted to the purposes of perfumery they must be perfectly neutral, firm, free from unpleasant odor, and all tendency to *crust* in cold, or *sweat* in damp weather. They should, moreover, give a rich lather without wasting too rapidly in the water. Soaps, generally, in their original condition, are usually deficient in many of those points; and must, for the purposes of perfumery, undergo a refining process, which is as follows:—

The soap, as purchased in bars or blocks, being piled upon the shelf of the rasping machine, is next placed in the hopper, and as the wheel revolves, knives come against the soap and cut it into meal, which falls into the reception box beneath. It is now in a state fit to be melted readily, for which purpose it is transferred to the steam bath before mentioned at pages 669 and 670, and mixed with rose and orange-flower waters, each half a gallon, to every hundred pounds of soap. The steam being let on, and the containing kettle covered, its contents become gradually fluid, and in this state must be stirred with a *crutch*, which is a long stick having the form of an inverted T, until the paste becomes uniformly consistent and smooth throughout. It is then allowed to cool, again melted, but without fragrant water, and crutched as before. When the contents of the vessel comprise several kinds of soap, great care must be observed not to put in all at once, but to add and melt each successively, and to crutch constantly, so as to effect an intimate mixture. When the paste begins to cool, coloring matter as may be desired is then added; and subsequently the perfume, which is reserved to the last, to avoid any unnecessary loss by evaporation from the hot paste. A portion of glycerin might also be added at this stage, with great advantage to the soap, as that liquid imparts an eminent emollient property.

When extracts or bouquets are used, as for scenting the finest kinds of soap, they must be added to the compound in meal, and incorporated with the mass by kneading it with the hands; for the application of heat would impair the delicacy of the odor, as well as occasion loss by its evaporation. In large establishments, this is done by passing the meal repeatedly between marble rollers.

The soap is now ready to be put into the cooling frames, which is a rectangular well made of a series of wooden frames, resting successively one upon the other. In a day or two it is sufficiently hard to be cut into bars and tablets of the size of the sections of each frame, which are fitted by means of a piece of brass wire, which are set up edgewise, and left for several days to dry, and are then barred by means of a wire. The sections or *lifts* of the frame regulate the width of the bars, and the gages adjust their breadth—these latter being made so as to cut bars

or squares of four, six, eight, or any required number to the pound of soap. The bars are further subdivided into tablets, and subjected to pressure for the purpose of imparting solidity, and ornamenting the exterior with some appropriate device, or impressing upon it the maker's name. Moulds for this purpose are shown by Fig. 395, and they may be varied in form and inscription according to taste; but the character of the latter is generally floral or medallion. The press is of ordinary construction, with spiral springs to throw out the soap tablet from the die box as soon as it is pressed. The box is movable, so that the die may be changed at will. In some factories the pressure is more effectually accomplished by means of a steam-hammer, which is made to give three successive blows, directly vertical, to each tablet of soap. Savonettes, or soap balls, are shaped by rotating blocks of soap upon a soap-scoop made of brass with sharp edges.

Fig. 395.



Almond Soap.—This is a very white soap, which, when genuine, is made by the cold process hereinafter described, and from pure oil of sweet almonds. The kind, however, generally met with is made as follows: white curd soap, one hundred pounds, and cocoa-nut oil, fifteen pounds; purified as before directed, and perfumed with a mixture of attar of bitter almonds, one and a half pounds, and attars of cloves and caraway, each eight ounces.

White Windsor Soap.—The genuine old white windsor is made from a body of which a mixture of lard and olive oil is the fat stock; and attars of caraway, lavender, and rosemary, constitute the perfume. The modern windsor soap is made from fine white curd soap, one hundred and fifteen pounds; cocoa-nut oil soap, twenty pounds; perfumed with a mixture of attar of caraway, one and a half pounds; attars of thyme and rosemary, each eight ounces; and attars of cassia and cloves, each four ounces.

Brown Windsor Soap.—Curd soap, one hundred pounds; cocoa-nut oil, and pale yellow rosin soaps, each twenty-five pounds; color with caramel, eight ounces; and perfume with a mixture of attars of caraway, cloves, thyme, cassia, petit-grain, and lavender, each eight ounces. MORFIT'S oleic soap, of first grade, is peculiarly adapted as body for brown windsor soap, as it gives a rich lather, and is very smooth, and highly emollient. Moreover, it retains its normal moisture for a great length of time.

Savon au Miel—Honey Soap.—White curd soap, forty pounds; melted and crutched with white honey, ten pounds; storax, two pounds; and powdered benzoin, one pound.

An imitation honey soap is made by melting together pale yellow soap, one hundred pounds; soft soap, fourteen pounds; and perfuming with attar of citronella, one and a half pounds.

Frangipani Soap.—Curd soap, colored brown with caramel, seven pounds; perfumed with a mixture of attars of neroli and vitivert, each four ounces; attar of rose, two drachms; attar of santal, one and a half

ounces; and civet, two drachms. The latter is to be previously triturated with the attars.

Savon à la Rose.—Rose soap is made from a mixture of olive oil soap, sixty pounds; and curd soap, forty pounds; colored with one pound of finely bolted vermillion. The perfume consisting of attars of rose, six ounces; attars of santal and geranium, each one ounce; and tincture of musk, eight ounces; must be added to the cold soap in meal, and incorporated by kneading. The oil soap may be replaced by curd soap, but the quality of the rose soap will not then be so fine.

Savon au Bouquet.—White soap, sixty pounds, perfumed in the cold with eight ounces of an extract bouquet; or in warm paste, with a mixture of attar of bergamot, eight ounces; attars of cloves and sassafras, each half an ounce; attar of thyme, one ounce; attar of neroli, one ounce. The soap body must be previously colored brown with one pound of caramel. The soap scented with the attars is inferior to that having the extract bouquet as perfume. The perfume, and with it the title of the soap, can be varied according to the caprice of fashion.

Poncine Soap.—Curd soap, fifty pounds; cocoa nut oil soap, the same quantity, melted to paste and crutched with ten to twenty pounds of finely bolted pumice-stone powder. The perfume is a mixture of attars of thyme, cassia, caraway, and lavender, each one pound.

Spermaceti Soap.—The genuine spermaceti soap is superior to all others in emollient properties; but it is rarely made from pure stock, owing to the difficulty in saponifying it. As generally vended, it consists of white curd soap, fourteen pounds; perfumed with a mixture of attars of bergamot, two and a half pounds, and attar of lemon, eight ounces.

Palm Soap.—Curd soap, made of a mixture of one-half lard, one-third bleached palm oil, and the remainder olive oil or spermaceti, constitutes the body of palm soap. Its natural odor is that of the violet, which is sometimes stimulated by the addition of a little attar of portugal, with a lesser portion of attar of cloves.

Floating Soap.—All the hard soaps increase in bulk by mechanical batting of the paste; the loss of density thus produced gives them the property of floating in water. The batting or whipping is best accomplished by means of a churn-twirl, rotating on a pivot in the bottom of the melting-pan, and put in motion by a handle.

Transparent Soap.—This amber-looking soap is made by dissolving hard white soap, previously reduced to meal and thoroughly dried, in alcohol of 66° Twaddell. The steam-bath before described, fitted with a still head, makes a very appropriate containing vessel. The alcohol and soap are taken in about equal proportions; and as the solution proceeds, any spirit which may distil over must be allowed to condense in a worm, and collect in a receiver. The heat should not exceed 212°. After solution, the whole must be allowed repose for settling, after which the clear, supernatant fluid is to be drawn off from the sediment into wooden frames, or globular moulds of britannia metal, if it is desired to cast it in ball form. Previous to settling, it may be colored as desired—red, with tincture of alkanet; yellow, with tincture of turmeric;

orange, with a mixture of the two tinctures; green, with tincture of chlorophyle; and blue with tincture of indigo carmine. Transparent soap is rather translucent when first made, and does not clear until perfectly dry. The perfumes are the same as for the other soaps.

SOAPS BY THE COLD PROCESS.—All the foregoing soaps are made by boiling the fat stock with alkali; but toilet soap may also be made extemporaneously without much heat and the so-called little pan process. Many of the French and American perfumers manufacture their soaps in that way. The lies are necessarily very strong, and should be of 66° Twaddell. Cold soaps are very white, and also very hard, as they do not contain any excess of water.

White Soap.—Lard forty pounds, and caustic soda lie, of 64° Twaddell, twenty pounds. Melt the fat by a heat not exceeding 150°, and add, during constant stirring, ten pounds of the lie. After one hour's manipulation with the stirrer, the heat being continued all the time at a moderate degree, the remaining ten pounds of lie are to be added. When the paste has become smooth and uniform throughout, it is transferred to a cooling frame, perfumed, and left in a room of moderate temperature for a few days to set and ripen. It is then ready to be cut into tablets and pressed.

Almond Soap.—Genuine almond soap is made from oil of sweet almonds, fifty pounds; and soda lie of 66° Twaddell, twenty-five pounds, the latter being gradually added to the former at a temperature between 125° to 150°, and the whole stirred constantly until the mixture has a pasty consistence. It is then transferred to a cooling frame, perfumed with attar of bitter almonds, and then left for several days to set and ripen.

Soft Soaps.—These differ from the hard soaps in having potassa in place of soda as their alkaline base. They are all more or less pasty or gelatinous; and they may be made either by the boiling or cold process. Of the soft soaps used in perfumery, that known as *fig soap* is, however, the only one that is boiled.

Fig Soap.—The fat stock is chiefly oil—generally olive oil—with the addition of a little tallow to give it the granular appearance called *fig*.

Shaving Cream.—This saponaceous compound is made by melting twenty pounds of lard in the steam-bath, at a temperature of 212°, and then letting five pounds of caustic potassa lie, of 66° Twaddell, run in *very slowly*, during constant stirring and batting with a wooden paddle. The heat is continued all the time; and after a while, when the paste becomes thick, five pounds more of lie are added in the same manner. After several hours' stirring the paste becomes firm, and is then finished. It is then transferred to a mortar and triturated, until the soap becomes homogeneous throughout, and assumes a pearly appearance. Attar of almonds is the perfume for almond cream, and attar of rose for the rose cream, and they are dissolved in a little alcohol, and added during the trituration. The rose cream is colored at the same time with a little tincture of alkanet.

Rypophagon Soap.—This is a mixture of equal parts

of pale yellow rosin soap and fig soft soap, perfumed with attars of anise and citronella.

According to PRESSÉ, British India and Europe consume annually, at the lowest estimate, upwards of one hundred and fifty thousand gallons of perfumed spirit, under various titles, such as eau de cologne, lavender water, esprit de rose, *et cetera*. Some idea of the commercial importance of this art may be formed, when one of the large perfumers of Grasse and Paris employs yearly eighty thousand pounds of orange flowers, sixty thousand of cassie, fifty-four thousand of rose leaves, thirty-two thousand of jasmin blossoms, twenty thousand of violets, and sixteen thousand pounds of lilac, besides rosemary, mint, lemon, citron, thyme, and other plants in larger proportion.

The Editor cannot conclude this monograph without expressing his thanks to Dr. CAMPBELL MORFIT of New York for the valuable assistance he has rendered him during its compilation. Professor MORFIT is the author of one of the best books on this subject which has recently appeared; and being the first technological chemist in America, the Editor, although personally unknown to him, feels the more gratified for his having volunteered his aid in this article, which is sure to prove interesting to all readers, whether scientific or otherwise; for, as shown in the introductory notice, perfumes, in the early ages of the world, were in constant use, and had the high sanction of Scriptural authority.

PHOSPHORUS.—*Phosphore*, French; *phosphor*, German; *phosphorus*, Latin.—This truly remarkable substance is one of the elementary bodies. It occurs abundantly in both kingdoms of nature, not, however, in the free state, but always in combination, usually as phosphoric acid united to earthy and metallic bases. Its intense affinity for oxygen would not allow it to exist in nature in an isolated form; for on exposure to the air, even at the ordinary temperature, it undergoes a slow combustion, and is converted into phosphorous and phosphoric acid. At a very slightly elevated heat it takes fire, and is resolved entirely into phosphoric acid. Nor is phosphoric acid met with naturally uncombined, its powerful reaction upon the bases causing it to enter quickly into combination. Amongst phosphorus compounds, the most important are those which phosphoric acid forms with lime and magnesia, and these are widely distributed throughout nature. In this condition it is found in unstratified rocks, and in the lavas of more recent date. As these disintegrate, and crumble down into fertile soil, the phosphates pass into the organism of plants, and ultimately into the bodies of the animals to which these latter serve as nutriment. Phosphate of lime constitutes by far the greatest part of the hard matter of bones, and consequently fulfils a very important part in the structure of the animal frame, communicating stiffness and inflexibility to the bony skeleton. Phosphorus is also an ingredient, in some unknown form of combination, of animal and vegetal fibrin and albumen. It is likewise found in the brain, and in the soft roe of the carp, though in what particular condition it exists is uncertain. In the urine and excrements it is also invariably present. In the mineral kingdom, it

is found principally as phosphate of lime—known to mineralogists as apatite—as phosphate of magnesia, as phosphate of alumina, or wavelite, and as phosphates of lead and copper, *et cetera*.

The term phosphorus—derived from two Greek words signifying *light-producer*—was applied by the older chemists to every species of substance capable of becoming luminous without the application of heat. It is now retained only by the one simple substance under consideration.

HISTORICAL NOTICE.—Amongst the many important discoveries made by the alchemists in their pursuit of the philosopher's stone, that of phosphorus holds a very high position. It was first obtained, in 1667, by BRANDT, a tradesman of Hamburg, while engaged in prosecuting researches upon urine, with the view of extracting from it the mysterious agent that would effect the transmutation of the baser metals into gold. BRANDT partially explained the secret to KUNCKEL, a German chemist with whom he was acquainted, and who subsequently succeeded in obtaining it even more pure than had been done by BRANDT. He continued to prepare it, and it soon became known as KUNCKEL'S phosphorus, to distinguish it from other bodies possessing the property of luminosity. In 1676 KUNCKEL published a description of it, and was afterwards considered as one of its discoverers.

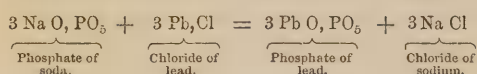
In England, the celebrated BOYLE, having seen phosphorus in the hands of KRAFT of Dresden, who had purchased the secret from BRANDT, and knowing that it was extracted from some matter appertaining to the human body, commenced his investigations, which, after a year's labor, were crowned with success. In 1680 an account of the new substance was published in the Philosophical Transactions, and it became known under the name of English phosphorus. BOYLE communicated his process to GODFREY HANKWITZ, who prepared it under his direction in London, in large quantities; and after the death of BOYLE and KUNCKEL, HANKWITZ was alone in possession of the secret and the trade in this substance. Up to this time it was extremely rare, being found only amongst the cabinet curiosities of the rich; and for the next fifty or sixty years its great price prevented its employment in any branch of art or manufacture. At last, in 1737, a stranger came to Paris, and sold to the French government a process for its preparation, which HELLOT, conjointly with GEOFFROI, DUFAY, and DUHAMEL, was charged to submit to the test of experiment. The process was successful, and a report of it was published in the Memoirs of the Academy for the year 1737. By this method, also, it was extracted from urine, and although the process succeeded it could never have been employed on the large scale. It was besides tedious and offensive. To understand the difficulties it will be sufficient to say, that, after a protracted series of operations, the above-mentioned chemists obtained from five hogsheads of urine, thirty-eight pounds of the residue on evaporation, the whole of which yielded only four ounces of phosphorus, and by means of four distillations.

Experiments were afterwards made by MARGRAAF, FOURCROY, VAUQUELIN, and others, to render the

process of extracting it from urine more easy, but this process was entirely relinquished when SCHEELLE and GAHN discovered the presence of phosphoric acid in the bones of animals. It is from bones that phosphorus is still extracted at the present day. It is prepared as an article of manufacture in large quantity in London and Paris. KANE has calculated that in the latter city alone, about two hundred thousand pounds are yearly produced. In Germany, also, it is manufactured on a large scale; one establishment at Carlsruhe—that of OTTO PAULI—producing annually, amongst a long list of other chemical substances, sixty hundred-weight of this one article. Its ready inflammability has always made it a subject of popular interest, while the singularity, importance, and variety of its compounds, have drawn to them no ordinary share of the attention of chemists. The introduction of lucifer matches has enormously increased its consumption; indeed, at least ninety-five per cent. of the whole quantity produced is absorbed by this manufacture.

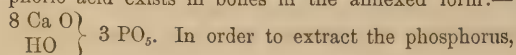
PREPARATION.—All the processes for obtaining phosphorus are founded upon the deoxidation of phosphoric acid— PO_5 —by means of carbon.

BRANDT and BOYLE evaporated urine to a thick creamy consistence. This was afterwards distilled, either *per se*, or after being mixed with sand or charcoal powder. In this process the carbon—either that which results from the charring of the organic matter contained in urine, or that which is added to it—decomposes the portion of the phosphoric acid which is in combination with ammonia, while that which is combined with the soda remains unaltered. MARGRAAF evaporated urine to the consistence of honey, then added one-tenth of chloride of lead, and half its weight of charcoal powder. The mass was afterwards thoroughly desiccated, and then distilled. In this case the chloride of lead and phosphate of soda mutually decompose, yielding phosphate of lead and chloride of sodium :—



GIOBERT precipitated urine, without previous evaporation, with a soluble salt of lead. The precipitate of phosphate, sulphate, and chloride of lead was collected, well washed, and mixed with a fourth of its weight of powdered charcoal. The mixture was then exsiccated and distilled. The great advantage in the processes of MARGRAAF and GIOBERT was, that an equal quantity of urine yielded nearly twice as much phosphorus as the process of BOYLE and BRANDT, in consequence of the decomposition of the phosphoric acid originally in combination with soda, and which in the process of the latter chemists would remain unaffected.

After the discovery of phosphoric acid in the bones of the vertebrata, the old methods of extracting phosphorus from urine were totally abandoned, and it is now obtained almost exclusively from bones. Phosphoric acid exists in bones in the annexed form :—



the bones are first thoroughly calcined, that is, heated to redness, with contact of the air, until the organic matter is entirely removed. The bone ash thus obtained is reduced to powder, and to every three parts are added two of concentrated sulphuric acid, and sixteen or eighteen parts of water. By this treatment a portion of the lime is separated as sulphate, and an acid phosphate of lime is produced, which dissolves in the supernatant liquid. After the separation of the sulphate by decantation and filtration, the phosphoric solution is concentrated by evaporation to a thick sirupy consistence. A quantity of charcoal powder, equal to one-fourth of its weight, is then added, and the pasty mass is exposed to a strong heat, nearly to redness, till perfectly dry. The desiccated mass is then transferred to a stone-ware or iron retort, connected by a wide elbow-shaped copper tube with a receiver containing water, into which the tube dips about a line. Another smaller tube, open at both ends, is attached to the receiver, to convey the uncondensed gases into the chimney. Heat is now applied, and is gradually increased to whiteness. The superphosphate of lime, in contact with charcoal, is decomposed, the lime retaining only the quantity of phosphoric acid necessary to reconstitute bone earth. The excess of acid, and the water still remaining in the mass, are deoxidised by the charcoal, and the results are carbonic oxide, hydrogen, and phosphorus. The phosphorus gradually rises in vapor, distils over, and is condensed in yellow drops in the water contained in the receiver, at the same time that the gases escape by the smaller tube into the chimney.

The theory of this operation is very simple, but in practice many difficulties occur, and the requisite precautions will be pointed out in the following detailed account of the process.

Preparation of the Bone Ash.—The bones usually employed in this manufacture are those of oxen, of sheep, or of horses. The bones of sheep are preferred, as the ash which they yield is less compact, and more easily attacked by an acid. They contain, besides subphosphate of lime, carbonate of lime, and a small per centage of other salts, as phosphate of magnesia, chloride of sodium, fluoride of calcium, *et cetera*; also a large proportion of animal matter, estimated at from thirty-three to fifty per cent., according to the kind of bone, and the age of the animal. The following analysis of the bones of the ox is by BERZELIUS :—

	Centesimally.
Animal matter soluble by boiling, and vascular substance,.....	33·30
Phosphate of lime, with a little fluoride of calcium,.....	57·35
Carbonate of lime,.....	3·85
Phosphate of magnesia,.....	2·05
Soda, and a little chloride of sodium,.....	3·45
	100·00

The object of the first operation is to cause a complete separation of the animal matter. This is usually effected by calcination. The process is conducted in a large reverberatory furnace as follows :—The fire is first well kindled; a quantity of bones are then introduced by the opening in the dome of the furnace. When these are well inflamed, a further supply is added until the furnace is about half filled. A strong

draught is created by placing on the cupola, surrounded by a cone, a stove pipe, more or less elevated, and which is directed into the chimney. The operation now goes on of itself, and the combustion is very complete. When concluded, the ash is drawn out at the furnace door, and a fresh charge introduced at the upper opening, being careful not to add a too great quantity at one time, and also to maintain the necessary draught, so that the operation may not be suspended. The calcination is effected at little expense, as the bones themselves yield the necessary combustible matter. When first heated, they become black, owing to the disengagement of hydrogen, oxygen, and nitrogen gases, and the consequent separation of charcoal. A considerable time is required to remove the whole of the charcoal from the osseous mass; and if, when the ash is drawn out, many black portions remain, they are returned to the kiln, and recalcined.

Very frequently bones are used in this manufacture from which the soluble gelatinous matter has been previously extracted. When these residues are collected in heaps, a rapid fermentation ensues, and they become heated and perfectly dried. They are afterwards burned in a reverberatory furnace, or one of similar construction. Before introducing the bones, the bed of the furnace is heated to redness. They are submitted to the action of the flame for the space of twenty hours, at the end of which time the incineration is usually complete.

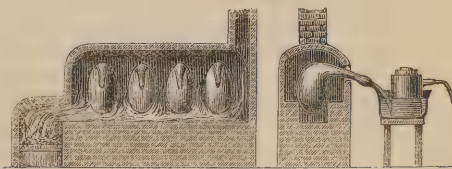
The incombustible residue of these operations consists of about eighty to eighty-two per cent. of a phosphate of lime— $6 \text{ Ca O} + 3 \text{ PO}_5$ —fifteen to seventeen of carbonate of lime, and two or three of sand, earthy matter, chloride of sodium, *et cetera*. According to GRAHAM, bone earth contains two distinct phosphates of lime, both tribasic, but in one of which an atom of lime is replaced by one of water. He gives as its formula— $2 (3 \text{ Ca O}, \text{PO}_5 + \text{HO}) + (\text{HO}, 2 \text{ Ca O}, \text{PO}_5 + \text{HO})$. The calcined bones are ground to fine powder and sifted. The powder is greyish-white, and almost tasteless.

Second Operation.—The object of the next process in this manufacture is to transform the insoluble calcareous phosphate into the soluble superphosphate. This conversion is effected by means of sulphuric acid, which separates a portion of the base in the form of the nearly insoluble sulphate of lime. The sulphuric acid also decomposes entirely the carbonate of lime present, producing the same difficultly soluble salt. The operation is effected in a leaden cistern or in a wooden tub lined with lead. To three parts by weight of the bone ash are added two of concentrated sulphuric acid, and from fifteen to twenty parts of water, constantly stirring with a wooden spatula. A lively effervescence ensues, owing to the escape of carbonic acid. When this has subsided, the whole is transferred to a copper boiler, heated to the point of ebullition, and to promote decomposition, continued at this temperature for twenty-four hours. The liquid requires to be constantly agitated, to prevent the concretion of the mass, which, if allowed, would protect a portion of the subphosphate from the action of the acid. When completely decomposed, the mixture is suffered to remain at rest

for ten hours, so that the sulphate of lime may subside. The supernatant liquid is afterwards drawn off by means of a leaden siphon, and conducted through leaden pipes to the filter, consisting of a conical linen bag of close texture, which retains the sulphate of lime, and allows the solution of acid phosphate to pass through. The residue itself is then thrown upon the filter and strongly pressed, and afterwards thoroughly washed with successive portions of boiling water. The filtrate is now concentrated, by evaporation in a copper boiler, to one-fourth of the original quantity, and again filtered to remove the portion of sulphate of lime which has become insoluble; the evaporation is then resumed till the liquid has a sirupy consistence. The sirup, which contains the acid phosphate of lime, the excess of sulphuric acid, and a little sulphate of lime, is gradually mixed with a quantity of powdered charcoal, about one fourth of the original weight of the bones. The mass, after being evaporated to dryness, is further dried in a cast-iron kettle, at a nearly red heat, and with constant stirring with an iron spatula. During this process, the greatest part of the water is disengaged; a portion of the excess of sulphuric acid is also set free; the remainder, by the action of the charcoal, is decomposed, and sulphurous and carbonic acids are liberated.

Distillation.—The perfectly dry mixture of acid phosphate of lime and charcoal is ground to fine powder in an iron mortar, and transferred as quickly as possible into the retorts. These, which are of earthenware, are arranged side by side in a reverberatory furnace, as shown in Fig. 396. The neck of the retort fits into the

Fig. 396.



tubulure of a copper receiver half filled with water, and furnished with a tube for the escape of the gas formed during the distillation. Each retort has its own receiver, and all the receivers are placed in a trough filled with water, at the temperature of about 110° , and kept at that temperature, in order that the phosphorus distilling over may not solidify and obstruct the tubulure. In performing the distillation, a very high temperature is required. The furnace should therefore be sufficiently capacious to hold a body of coke or charcoal piled above the retort. Earthenware retorts at a red heat become permeable to the vapor of phosphorus, and consequently require to be well and carefully luted externally. For this purpose a mortar, composed of clay and horse dung, may be applied, or, still better, a mixture of freshly slaked lime and solution of borax. This mixture should be laid on with a brush in two or three successive coats, and forms, according to BRANDE, an excellent vitrifiable lute. The copper tube opening into the receiver, and into which the beak of the retort is inserted, should be of considerable size, and so bent as to dip perpendicularly into the water, otherwise it will be apt to become plugged up by congealed

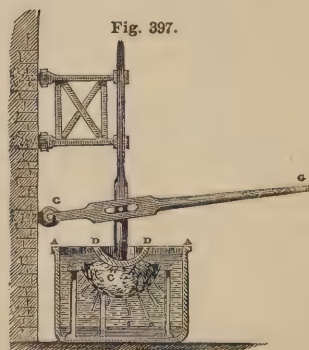
phosphorus. It must also dip so little, that by no condensation could the water be forced back into the retort. The heat of the furnace in which the retorts are placed should be very slowly raised, allowing at least three hours to heat to redness; afterwards it is urged vigorously till all disengagement has ceased, the process requiring from fifteen to thirty hours, according to the size of the retorts. The superphosphate of lime, although dried at a high temperature, retains chemically-combined water, which is liberated by the superior heat of the furnace. At first, therefore, a mixture of air and steam is disengaged; afterwards, when the charcoal becomes incandescent, a mixture of hydrogen and carbonic oxide, evidently proceeding from the decomposition of the water by the hot charcoal— $\text{HO} + \text{C} = \text{H} + \text{CO}$. When the retort has attained a bright red heat—that is, after the lapse of about four or five hours—the nature of the gaseous products is changed. The superphosphate of lime is decomposed into basic or subphosphate of lime, and phosphoric acid. This last, in contact with incandescent carbon, yields phosphorus, which rises in vapor, distills over, and condensing in the liquid form in the tubulure, flows down and collects under the surface of the water. The phosphorus is accompanied by a mixture of carbonic oxide and phosphide of hydrogen, the last inflaming spontaneously on contact with the air. These two gases continue to be produced during the whole operation. DUMAS considers it an unsettled question, whether the gas evolved is really phosphide of hydrogen, and if it is not carbonic oxide saturated with the vapor of phosphorus, as a small quantity always escapes condensation, and this is sufficient to render carbonic oxide spontaneously inflammable by contact with the air. The disengagement of gas enables one to trace the progress of the operation, and when it has entirely ceased, the process is terminated. In the retorts are found a subphosphate of lime—having precisely the same composition as the original bone phosphate, $6\text{CaO} + 3\text{PO}_5$ —and also the redundant charcoal. The lime of the phosphate acts a most important part in fixing the phosphoric acid, which, if not so combined, would distil over long before the heat was sufficiently high for decomposition.

The proportion of the various ingredients used in the production of phosphorus, is varied by different manufacturers. FUNCKE used, for one hundred parts of bone ash, ninety parts of concentrated sulphuric acid, and nine hundred and fifty of water. This mixture is digested for a considerable time in a leaden vessel, then transferred to a linen filter. The filtrate is afterwards evaporated to the consistence of sirup, mixed with twenty parts of charcoal powder, and dried. By distillation this mixture yields ten parts of phosphorus. NICOLAS used equal weights of bone ash and oil of vitriol. Various other methods have also been proposed for procuring phosphorus from bone ash. SCHEELÉ dissolved the ash in nitric acid, and precipitated the lime by sulphuric acid. The rest of the process is conducted as above. FOURCROY and VAUQUELIN prepared acid phosphate of lime according to NICOLAS' method, and precipitated its aqueous solution with acetate of lead. The resulting phosphate of lead was afterwards distilled with one-sixth of its weight of

charcoal. BERZELIUS dissolved bone ash in warm nitric acid, and precipitated the hot solution with acetate of lead. Native phosphate of lead may also be employed, provided it is free from arseniate.

Purification.—The phosphorus obtained by any of the above processes is never in a state of purity, as it passes into the receivers. The ordinary impurities are adhering charcoal, a reddish-brown phosphide of carbon formed during the process, and another reddish-looking substance, originally supposed to be an oxide of phosphorus, but ascertained by SCHRÖTTER to be phosphorus in an allotropic condition. Phosphorus, otherwise pure, generally contains a small quantity of this amorphous modification of the element. Arsenic is also frequently present, in consequence of the acid used in its preparation having been formed by the combustion of arsenical sulphur, or pyrites. WITTSTOCK found in one sample of phosphorus 0.76 per cent. arsenic. The same chemist examined a sample of phosphorus obtained from France, the coating of which was greyish-yellow instead of white. It appeared, when freed from this coating, of a dark-red color by transmitted light. Its fractured surface was almost black, and it retained this color when melted and slowly solidified. Besides arsenic he found it to contain bismuth, lead, iron, copper, and a large quantity of antimony.

Most of the impurities may be separated by simple fusion in hot water, and afterwards pressing through buckskin, or still better, chamois leather. The operation is effected in the apparatus represented in Fig. 397. The phosphorus is first agglomerated by melting it in a water bath at 140° . When it has again solidified by cooling, it is wrapped in a perfectly clean



and well-moistened chamois skin, *c*, which is then tied up, and immediately plunged into a copper colander, placed in the middle of another vessel, *A*, filled with water, heated to about 120° Fahrenheit. When completely fused, the bag of skin is pressed upon by a wooden capsule, *D D*, by means of the lever, *G G*, increasing the pressure very gradually. The melted phosphorus passes through the pores of the skin, and collects in the liquid form at the bottom of the vessel.

PAYEN gives a description of a process by which the purification is rendered more complete, obviating at the same time all danger in the manipulation. It consists in causing it to pass, when in a state of fusion, through granular animal charcoal. The apparatus consists of a cylindrical vessel provided with a false bottom,

pierced with small holes, on which is laid the charcoal in a layer to the height of six or seven inches. The cylinder is then filled to two-thirds with water heated to 140° Fahrenheit, and the phosphorus, as taken from the receivers, is introduced. Being quickly melted, it passes spontaneously through the charcoal filter, and collects under the false bottom. It is afterwards strained by hydrostatic pressure through chamois skin.

Several other methods have been followed to effect the separation of the red amorphous phosphorus. It may be removed by digestion for a considerable time, and with frequent agitation, in very dilute nitric acid, or in chlorine water, contained in a cask fitted with a gas delivering tube, which dips under water.

The redistillation of phosphorus is occasionally resorted to as a means of purification. On account of its excessive inflammability, the process demands great care and attention. DUMAS recommends for the distillation of phosphorus a double U-shaped tube, into the first curve of which the phosphorus to be distilled is placed, the other curve serving in place of a receiver. The arrangement is afterwards connected with an apparatus from which issues a current of perfectly dry hydrogen, or carbonic acid gas. The phosphorus, when submitted to heat, volatilizes, and distils over with the gas, and is condensed in the second curve of the tube, from which it is removed after being melted in hot water.

MOULDING.—Phosphorus, as usually met with in commerce, is either in the form of round sticks, or granular. The moulding into sticks is effected by allowing it when fused to flow into glass tubes. A method frequently adopted is simply to plunge a slightly conical glass tube into the phosphorus melted under water, and causing it to ascend the tube by drawing out the air by suction with the mouth, being careful to have a layer of water between the phosphorus and the mouth. When the required quantity has entered the tube, the upper end of the latter is closed with the finger, and the whole is immediately transferred to a vessel filled with cold water. The removal of the phosphorus from the tube may be accomplished by gently pushing with a stout wire through the narrow end of the tube.

A very simple, and at the same time very efficient, mode of forming phosphorus into sticks, has been contrived by SCHUBERT. By the old system, the glass tubes, into which the phosphorus was poured to solidify, were frequently broken in forcing the phosphorus out by means of wires, and the method was, moreover, attended with great loss of time. In SCHUBERT'S arrangement the melted phosphorus flows from a copper receiver into horizontal glass tubes, the one extremity of each tube being surrounded by water at a temperature above 111°; the other by cold water. By suddenly opening a stopcock, and again quickly closing it, a small quantity of phosphorus is allowed to pass through the glass tubes into cold water contained in a cistern, and in passing it closes the tubes, leaving a projecting rough piece of phosphorus, which forms an excellent handle, whereby to draw the sticks from the tubes. The operation thus commenced, the cock is again opened, and the phosphorus drawn alternately from either tube, cut off with a pair of strong scissors, and allowed to

fall into the cistern. By this method, from fifteen to twenty pounds of phosphorus may be formed into sticks in less than a quarter of an hour.

To obtain phosphorus in the granular condition, it is caused to fall in drops into cold water. SCHUBERT'S apparatus will also be useful in this operation. The cistern, is filled to about three parts with cold water, and upon the surface of this is placed a layer of water, heated to about 140° Fahrenheit, high enough to cover the glass tubes which convey the phosphorus from the boiler. This is done by pouring the hot water upon a wooden trencher, swimming on the surface of the cold water. The difference in the density prevents the cold water mixing with that at a higher temperature. The stopcock of the vessel containing the melted phosphorus is slightly opened, so as to allow it to exude in drops. These, falling through the mass of cold water, become solid, and collect in the granular condition at the bottom of the cistern. Phosphorus may also be granulated by shaking it, while in the fused state, with a warm liquid, till it solidifies. CASSARCA recommends for this purpose strong alcohol.

PROPERTIES.—Phosphorus at the ordinary temperature, when perfectly pure, is a soft solid substance, transparent and colorless. As generally found in commerce, it is of a light amber yellow color, or even reddish, much resembling in appearance imperfectly bleached wax. After rapid cooling it is yellow, and semi-opaque like horn, and has a waxy lustre. At 32° it is brittle and crystalline in its fracture. At a higher temperature it is soft and very flexible, may be several times bent in contrary directions without fracture, and is easily cut with a knife. The addition of an extremely small quantity of sulphur, even a three hundredth part, is sufficient to render it brittle. Being totally insoluble in water, it is tasteless; its solutions in other liquids have, however, an acrid disagreeable taste. Neither has it any smell, though on exposure to the air it gives off vapors, which, undergoing a slow combustion, have an odor somewhat resembling that of garlic, or of impure hydrogen. Its specific gravity at 60° is 1.77, and at 212° according to SCHRÖTTER 1.83. Its atomic weight, according to BERZELIUS, is 31.36. Many chemists, however, take it in their calculations at 32.

Exposed to heat it quickly melts. Its fusion commences at 108°, and in close vessels even at 95°. When melting it undergoes a dilatation of 0.0134 of its volume, according to GRAHAM, and immediately before fusion becomes transparent and colorless. It forms a transparent, oily-looking, colorless fluid, possessing a high refracting power. When completely fused, and allowed to cool slowly and without agitation, it remains liquid at 100°, or even at a lower temperature; and during solidification, the temperature rises to 108°. It begins to evaporate at 217.5°, and boils at 550°, forming a colorless vapor, the density of which DUMAS gives at 4.353, air being unity. Phosphorus volatilizes at temperatures considerably below its boiling point, and in small quantities even at ordinary temperatures, as well *in vacuo* as in the open air. Several gases, as oxygen, hydrogen, carbonic acid, nitrogen, *et cetera*, when placed in contact with phosphorus, become charged

with its vapor, and if boiled with water, it renders the aqueous vapor luminous.

Phosphorus is quite insoluble in water, but soluble—particularly if heated—in absolute alcohol, in chloroform, in fixed and volatile oils, in native naphtha, and most of the liquid hydrocarbons, in chloride of sulphur, sulphide of phosphorus, and in ether. Its best solvent, is, however, bisulphide of carbon, which dissolves one-fourth of its weight. Phosphorus crystallizes in regular octohedrons, and in rhomboidal dodecahedrons. Small octohedral crystals have been obtained by slowly cooling large masses of phosphorus. If a mixture of two parts of phosphorus and one of sulphur be melted under water, a compound is obtained, holding an excess of phosphorus in solution, and which is deposited in regular octohedral crystals on cooling. Its solution in sulphide of carbon, or in hot naphtha, when slowly evaporated in a current of carbonic acid gas, deposits regular dodecahedral crystals of considerable size.

SCHRÖTTER has carefully examined the boiling points of phosphorus under different pressures, and obtained the following results:—

Imperial inches.	Degrees.
4.72	329
6.81	338
8.03	356
10.40	392
13.30	408
14.10	424
15.40	439
20.20	446

When phosphorus is exposed to the air, even at ordinary temperatures, it undergoes a slow combustion, appears luminous, and diffuses white vapors, possessing a peculiar penetrating alliaceous smell. The phosphorous acid, PO_3 , hereby produced, attracting moisture from the air, condenses to a liquid, and taking an additional quantity of oxygen, is converted into a mixture of phosphorous and phosphoric acids, $\text{PO}_3 + \text{PO}_5$. This slow combustion is attended with a sensible evolution of heat, which gradually reaches the point at which phosphorus takes fire. It should therefore always be preserved under water. According to J. DAVY, the luminosity of phosphorus increases with the degree of rarefaction of the air, and is equally bright even in the vacuum of the air-pump. In air compressed to four atmospheres, phosphorus does not appear luminous till the temperature is raised. Nor does it shine below 32° degrees under the usual pressure, though at a few degrees higher it is distinctly perceptible. In oxygen gas, at the ordinary pressure, phosphorus does not shine unless heated to 80° , and may even be volatilized unaltered. The dilution of the oxygen with nitrogen, hydrogen, or carbonic acid causes it instantly to burst into the luminous condition.

The absorption of oxygen during the process of the slow combustion of phosphorus, may be proved by floating a small dish or watch-glass containing phosphorus on the surface of water, and covering with a bell glass. The oxygen gradually disappears, and water rises to fill the vacuum thus created. This oxidation of phosphorus in contact with the atmosphere, renders it a very useful agent for the determi-

nation of oxygen in the analysis of air, or other gaseous mixture. For this purpose, a ball of wetted phosphorus, fused upon the end of a wire, is introduced into the mixture of gases contained in a graduated tube, and standing over mercury. It is allowed to remain in contact with it as long as white fumes of phosphorous acid are visible round the ball. The vapors of phosphorous acid are ultimately absorbed by a ball of hydrate of potassa similarly introduced. The diminution in the measure of the gas shows the quantity of oxygen originally contained in the mixture.

The luminosity of phosphorus is so excellent a test of its presence, that if a drop of an extremely dilute solution of it in bisulphide of carbon be placed on a heated plate in the dark, the presence of one twelve-thousandth part is readily detected.

Owing to its powerful affinity for oxygen, phosphorus reduces the compounds of the noble metals, when placed in contact with their solutions, and quickly becomes covered with the reduced and precipitated metal. In contact with chlorine, bromine, and iodine, phosphorus inflames spontaneously, and without the aid of heat, producing respectively, chloride, bromide, and iodide of phosphorus. When heated in a copious supply of dry air, phosphorus burns with a brilliant white light, producing white fumes of anhydrous phosphoric acid, PO_5 , which, when condensed, much resembles snow.

Owing to the changes that take place in phosphorus on exposure to the air, it is necessary, to preserve it unchanged, to inclose it either in a gas free from oxygen, or in boiled distilled water. It is best preserved in stoppered bottles, completely filled with boiled water, and to exclude light, the bottle should be inclosed in a tin case, also filled with water.

Precaution.—In consequence of the great danger incurred in the handling of phosphorus, owing to its excessive inflammability, it is necessary, in all manipulations upon this substance, that a vessel, containing a mixture of chalk or magnesia and water, be placed in such a position as to be easily accessible to the operator. Phosphorus frequently, by simple contact with the warm hand, takes fire, melts, and continuing to burn, produces a painful and most troublesome sore, inflicting indeed, in some cases, frightful injuries. The danger is in a great measure prevented by immediately immersing the hand in the above mixture, as the earthy base neutralizes the strongly caustic acids formed during the combustion, and thus prevents further penetration. Phosphorus should always, if possible, be handled only under water, as the most gentle friction causes it to ignite.

AMORPHOUS MODIFICATIONS OF PHOSPHORUS.—Phosphorus, like sulphur, under the influence of apparently very trifling causes, assumes several allotropic conditions, some of which have been already alluded to.

White Phosphorus.—This modification is gradually produced whenever phosphorus under water is exposed to sunshine or ordinary daylight. The opaque crust is yellow at first, but afterwards turns white. Its specific gravity is 1.515. It smells like ordinary phosphorus, is luminous in the dark on exposure to the air, but turns red in daylight much more quickly than colorless

phosphorus. It retains its original appearance when dried over sulphuric acid, and sustains no diminution of weight. This variety of phosphorus was, until lately, considered to be a compound of phosphorus with water, or a hydrate of phosphorus, and the formula assigned to it by PELOUZE, was $P_2 \cdot HO$. Had such a compound been proved to exist, it would have been the first exception to a well-known chemical law, that element combines only with element, and compound with compound. MARCHAND proved that the supposed compound was not a hydrate; for after having dried it over concentrated sulphuric acid, he found that it retained only 0.4 to 0.7 per cent. of water; thus showing that the water, instead of being in chemical combination, was present only hygroscopically, or in mere mechanical mixture. MULDER observing that it became red in aerated water—doubtless owing to the action of light—considered it to be a compound of phosphoric oxide and phosphide of hydrogen, and to be produced by the decomposition of water. ROSE proved it to be pure phosphorus, differing from the ordinary variety only in its state of aggregation. GMELIN, because it is not produced under water in the dark, accounts for its production on the supposition that phosphorus, under the influence of light, decomposes water, producing phosphoric oxide and phosphide of hydrogen, and that, in the dark, these two compounds are again resolved into water and finely divided phosphorus. The latter theory is probably the correct one, as it is a well-ascertained fact, that phosphorus under water, by the influence of light, does actually decompose water, and that the results of the decomposition are the two above-mentioned compounds— $7P + 3HO = PH_3 + 3P_2O$.

Liquid Phosphorus.—Phosphorus, under certain conditions, after having been fused, retains the liquid form for some time after cooling, and, according to some chemists, even continues permanently in this condition. This variety of phosphorus has the appearance of a transparent oily liquid. It may be obtained by fusing ordinary phosphorus with an aqueous solution of hydrate of potassa. Under the solution it remains liquid for several weeks at ordinary temperatures, solidifies on being agitated, or by reducing the temperature to about 27° , and afterwards fuses at its ordinary melting point. Contact with a solid body, especially with solid phosphorus, also causes it to solidify. If poured upon bibulous paper, it becomes solid as soon as the adhering liquid has been absorbed by the paper, and with particular rapidity when touched with an iron wire. GROTHUS, by heating phosphorus with concentrated alcoholic solution of potassa, obtained it in the form of an oil which remained liquid on cooling, and when heated with water, evolved phosphide of hydrogen without acidifying the water. He, therefore, considered it to be a compound of phosphorus and hydrogen.

Black Phosphorus.—Another allotropic variety of phosphorus, distinguished by its black color, was discovered by THÉNARD. To produce it, phosphorus is melted at 150° , and while in a state of fusion, is poured quickly into very cold water. OSANN states that it may be obtained also by passing ozonized

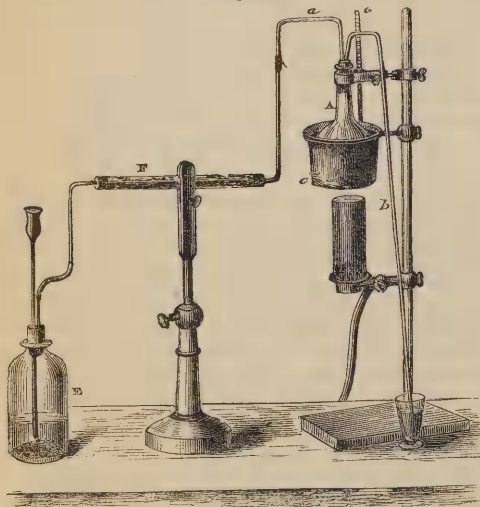
air over fragments of ordinary phosphorus for a considerable length of time; and also from the red oxide of phosphorus, procured by burning phosphorus fused under water with oxygen gas. The red oxide so obtained is boiled with concentrated solution of phosphoric acid. It thereby soon changes its color and bulk, and assumes a blackish-grey appearance. The boiling being continued, a black powder separates, whilst the mass becomes greyish-brown. OSANN, however, considered the peculiar color of this phosphorus to be owing to the presence of copper. The black variety of phosphorus is produced whenever fused phosphorus is suddenly cooled. The black color disappears, and it is reconverted into the ordinary condition by remelting, and slowly cooling.

RED PHOSPHORUS.—By far the most important allotropic modification of phosphorus is that known in commerce as the amorphous phosphorus of SCHRÖTTER, or *red phosphorus*. It was originally supposed to be an oxide, and its formation was attributed to the presence of moisture. BERZELIUS was the first who understood and described the precise nature of this substance. It was afterwards minutely investigated by SCHRÖTTER and others, who have shown in a variety of ways that the red substance is nothing but phosphorus in a peculiar state of aggregation. The latter chemist published in 1848 a description of it, and the method of procuring it. He placed perfectly pure colorless phosphorus, dried as completely as possible, in a glass tube, having a bulb in the centre, and passed pure and dry carbonic acid gas over it. The phosphorus was then gradually heated to 212° to drive off every trace of moisture, and the tube afterwards sealed hermetically, thus excluding every trace of oxygen. The phosphorus when exposed to light assumed a *red hue*, the depth of which increased in intensity the longer it was exposed to the light. The same results were obtained in hydrogen and nitrogen gas. Hence he concluded that the peculiar change of condition could not be ascribed to oxidation. SCHRÖTTER proved also that the alteration might be effected by heat. In a retort, to the neck of which a glass bulb was attached by fusion, he placed a quantity of dry phosphorus in the bulb as well as in the body of the retort. The extremity of the neck was connected with a glass tube thirty inches long, placed vertically, with its lower end dipped under mercury. The neck of the retort above the bulb was filled with chloride of calcium, and a thermometer inserted through the tubulure. The phosphorus in the bulb was then heated till inflamed, and all the oxygen contained in the retort was thus absorbed. The body of the retort was now heated to 212° , to expel adhering moisture, and then left to cool. Afterwards the phosphorus was gradually heated. At about 300° , sublimation commenced, but without change of color. At 439° , the phosphorus, after some time, assumed a carmine color; it likewise became more tenacious, and the color increased in intensity until perfect opacity was produced. This change was owing to the separation of a red powder, which settled to the bottom of the vessel, and rapidly increased in quantity till it extended throughout the whole mass. SCHRÖTTER afterwards obtained it in the coherent form, by exposure during several days in a

closed glass tube to an uninterrupted heat. This red phosphorus is obtained whenever ordinary phosphorus is exposed to light, either under water or alcohol, or *in vacuo*, or in hydrogen, nitrogen, carbonic acid, carbide of hydrogen, or any gas in which it cannot oxidise; and also by exposure to heat between 419° and 480° . The change takes place, though slowly, at 419° ; but it is most rapid between 464° and 480° . It is accelerated also by the action of light. By heat alone, under diminished pressure, the conversion is slower, and does not appear to be produced when the pressure is reduced below $15\frac{1}{2}$ inches. In direct light, the metamorphosis is very active, but is perceptible also with a faint diffused light.

The following process for preparing this variety of phosphorus is extracted from MILLER'S comprehensive work. It is effected in the apparatus shown in Fig. 398. A quantity of dried common phosphorus is placed in the flask, A, to the neck of which a long narrow tube, *b*, bent downwards, is attached, the open end of which dips into a little mercury. The

Fig. 398.



removal of the air from the flask is accomplished by means of a current of carbonic acid evolved from the bottle, E, containing marble and hydrochloric acid; the gas is dried by passing it over chloride of calcium, contained in the tube, F. The flask being emptied of air, the tube is closed by fusion at the narrow portion, *a*, and the apparatus evolving carbonic acid is detached. The flask is then heated by means of an oil bath, *c*; the phosphorus melts readily; and by regulating the heat steadily between 450° and 460° , by means of a thermometer, *t*, and maintaining it thirty or forty hours, nearly the whole will be converted into the solid amorphous variety. When the metamorphosis appears to be complete, the apparatus is allowed to cool. Any unaltered phosphorus is separated by digestion in bisulphide of carbon, in which amorphous phosphorus is insoluble. The latter is afterwards collected on a filter, and washed with bisulphide of carbon as long as anything is removed from it, which

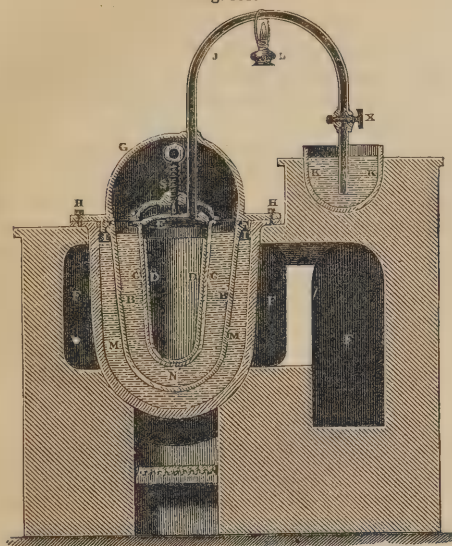
may be ascertained by evaporating a small portion in a watch-glass, when any dissolved phosphorus will remain behind.

The red powder obtained by the above process, if not quite free from ordinary phosphorus, inflames spontaneously, but if quite pure suffers no alteration by exposure to the air. To effect complete purification it should be boiled in solution of potassa of specific gravity 1.30, and then washed first with water slightly acidulated with nitric acid, and lastly with pure water. The color of this amorphous phosphorus is deeper the higher the temperature at which the transformation is effected; and in that of the finest specimens is more brilliant than vermilion. By heating the phosphorus more strongly during its preparation, the change may be effected much more rapidly; but the phosphorus then assumes the form of coherent flakes, which are difficult to purify, and are not easily detached from the vessel in which they are prepared. The process, however, requires great attention, and is not unattended with danger; as if the red phosphorus is heated to near 500° , the whole mass suddenly returns to the condition of ordinary phosphorus, with a copious disengagement of heat, succeeded by the sudden formation of a large volume of the vapor of phosphorus. Red phosphorus, therefore, appears to contain a large quantity of heat in the latent condition, which is liberated as it passes back into the ordinary vitreous state.

In 1848 a patent was granted to ARTHUR ALBRIGHT of Birmingham, for an invention communicated to him by SHRÖTTER of Vienna, for improvements in the manufacture of phosphorus, and in the apparatus to be used therein; and a Great Exhibition medal was awarded to him for the introduction of the prepared phosphorus as an article of commerce. By this process, red allotropic phosphorus is prepared on a considerable scale by Messrs. STURGE, also of Birmingham. A vertical section of the apparatus employed is represented in Fig. 399, and a view of it, as seen from above, in Fig. 400. AA is a cast-iron vessel set in brick-work, and having a fireplace underneath, with suitable flues, FF. From the inside of the flange of this vessel, a similar vessel, BB, of the same material, is suspended, and secured by means of the screw-pins, HH. The space between the two vessels contains a metallic bath, composed of a mixture of equal parts of tin and lead. G is a cast-iron cover to the inner vessel, B, fitting the upper edge by means of a groove, and fastened to the outer vessel, A, by the screw-pins, HH. A screw, S, passes through a three-armed iron holder, which is attached to a third movable iron vessel, CC, placed in a sand-bath, N. In the interior of this iron vessel, CC, another vessel of glass or porcelain, DD, is fitted, in which the phosphorus to be operated upon is placed. J is a curved pipe of iron or copper, passing freely through the cover, G, but screwed into the cover, E, and having an exit at the extremity into a detached vessel, KK. This contains water or mercury; if the latter be employed, it should be covered with water. The pipe, J, immersed in the mercury or water, serves as a safety valve, preventing the return of the atmospheric air into the inner vessel,

c c. The spirit lamp, L, is placed under the pipe, J, and is used, if necessary, to heat the curve, and prevent condensation of gaseous phosphorus, which, if allowed, would obstruct the passage. The stopcock, x, is used to prevent the ingress into c c of the contents of κ κ,

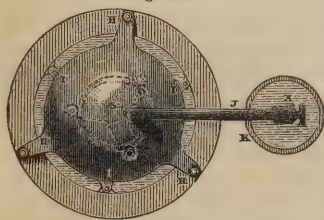
Fig. 399.



or of atmospheric air, and should be closed as soon as the operation is concluded, and before the apparatus in the furnace is allowed to become cool, or the vessel, κ κ, is removed. The cover, G, is not essentially necessary, its principal use being to prevent accidents. Between the end of the screw, s, and the cover, E, a small but strong concave disc or spring of steel is inserted, and so adjusted as to give a slight play to the

cover, E, in case of violent action arising in the interior, or the stopping up of the pipe, J, by condensed phosphorus. If the operation is conducted with proper attention, neither of these accidents is likely to occur.

Fig. 400.



The phosphorus to be converted into the amorphous state is to be previously melted and cooled under water, and afterwards dried as completely as possible. The mode of effecting the conversion is then as follows:—The phosphorus is deposited in the inner vessel, D D, and the covers, E and G, replaced. A fire is then kindled under the outer vessel, A A, and the temperature raised to such a degree as shall be sufficient to drive off the air and other gases that may be generated in the interior vessel; these will escape at the exit of the pipe, J, which dips into the mercury or water contained in the vessel, κ κ. When mercury is employed, it is desirable to cover it with a layer of water, so that any phosphorus which may distil over, and pass down the pipe,

J, may be covered thereby. The temperature is now to be gradually increased, until bubbles escape at the end of the pipe, J, which inflame spontaneously as they enter the air. When the gas has escaped freely for some time, the temperature may be further raised to 500°. To regulate the temperature, a thermometer is placed in the metallic bath before described. The length of time during which it is necessary to maintain the temperature, depends so much on accompanying circumstances that it can only be ascertained by experience. The heat should never be raised more than a few degrees above 500°. As soon as the operation is concluded, the vessel is allowed to become cool. The phosphorus is then taken out, to effect which it may be necessary to break the glass or porcelain vessel containing it. Should it be desirable to increase the pressure on the vessels, c c and D D, the vessel, κ κ, holding the mercury may be deepened, that it may contain a greater quantity, and thus a pressure of an atmosphere or even more may be gained. In this case, it will be necessary to remove the steel spring at the end of the screw, s, as soon as the steam and inflammable gases which arise in the first part of the process have ceased to issue from the pipe, J.

The phosphorus is then to be levigated under water, and drained therefrom by means of a bag or filter. If the operation has been successfully conducted, only very slight traces of unaltered phosphorus remain in the mass. The levigated phosphorus, still moist, should, in order to purify it, be spread thinly for convenient working on separate shallow trays of sheet-iron or lead. These trays may be so placed alongside each other as to receive the heat of steam, or of a hot water bath, or of chloride of calcium, or of sand, or of each consecutively in this order; but whichever be employed, the temperature must be gradually raised, and the phosphorus frequently stirred, until the disappearance of all luminous vapor shall show that the whole of the adhering ordinary phosphorus has become oxidised. The operator should have water at hand, to quench any fire that may arise before the whole mass was perfectly oxidised. The phosphorus is afterwards to be washed until the water running from it is perfectly free from all traces of acid.

The process of oxidation recommended by the inventor of the above-described apparatus, for the removal of unaltered phosphorus from the amorphous modification, is very unsatisfactory. A far better method, and one more quickly and more easily executed, is the application of an appropriate solvent, as bisulphide of carbon, oil of turpentine, or some other liquid hydrocarbon, by which the whole of the adhering unconverted phosphorus is readily and completely removed. This means of purification is also advantageous, inasmuch as the whole of the unaltered phosphorus obtained in solution may be recovered by simple distillation of the solvent, while in the process of oxidation the phosphorus, being converted into phosphorous and phosphoric acids, is lost, the acids being dissolved and removed by the subsequent washing.

Properties of Red Phosphorus.—Red amorphous phosphorus, in the state of powder, is lustreless, and destitute of crystalline structure. Its color varies from a scarlet to

a carmine red; sometimes also to a blackish-brown tint. When in the form of coherent masses, it is reddish-brown, exhibiting perfect metallic lustre and an iron-black fracture; sometimes the lumps are also of a bright scarlet color—usually, however, dark reddish-brown. It is brittle, very fragile, with a perfect conchoidal fracture. Its hardness is intermediate between calcareous spar and fluor spar; specific gravity at 60° is 2.14, exceeding that of ordinary phosphorus. Occasionally it has a porous appearance, resembling pumice-stone in structure, while some lumps are light enough to swim upon the surface of water. When heated in a liquid, it becomes darker in color, and after some time it acquires a deep violet. It is far less combustible than ordinary phosphorus, and is not luminous in the dark. When quite pure, it will bear a tolerably high temperature; but if it contains any unaltered phosphorus, is readily ignited by slight friction or percussion. It is not altered by exposure to the air at the ordinary temperature, but at 490° it takes fire, and if heated to from 490° to 500° in an inert gas, it passes into the state of ordinary phosphorus. Red phosphorus is insoluble in bisulphide of carbon, alcohol, ether, naphtha, chloride of phosphorus, and other solvents of ordinary phosphorus. In spirit of turpentine and other liquids which boil at a high temperature, it dissolves very sparingly during ebullition, but is deposited on cooling as ordinary phosphorus. It does not unite with sulphur until heated to 444°. It combines with chlorine with evolution of heat, but without any disengagement of light. The combination with bromine is attended with light. Concentrated sulphuric acid dissolves it when heated, with evolution of sulphurous acid, but is without action upon it in the cold. It is readily soluble in nitric acid with evolution of hypophosphoric acid, and formation of phosphoric acid. A boiling solution of potassa dissolves it, with disengagement of phosphide of hydrogen, not spontaneously inflammable, and it is at the same time converted into the black modification; indeed, according to SCHRÖTER, phosphorus always passes through the red state before conversion into the black modification. Red phosphorus decomposes many metallic oxides—for example, oxides of manganese, lead, silver, copper, mercury, especially if heated, sometimes with explosion. It detonates also when gently triturated with chlorate of potassa. If not perfectly freed from ordinary phosphorus, it ignites spontaneously when fractured, and also exhibits phosphorescence in the dark, and other properties of ordinary phosphorus. According to WÖHLER, red amorphous phosphorus may be rendered colorless and perfectly transparent, by fusing it in a concentrated solution of bichromate of potassa mixed with sulphuric acid. After this treatment it usually remains liquid after cooling, but solidifies instantly when touched by a solid body.

From a comparison of the properties of red allotropic phosphorus and the ordinary variety, it will be seen that the invention of SCHRÖTER is a great boon to those engaged in manufactories where phosphorus is largely used, and particularly to producers of instantaneous lights or lucifer matches, inasmuch as the red phosphorus is perfectly free from those pernicious

qualities which render the application of ordinary phosphorus to these purposes so destructive to health. In a commercial point of view it is also advantageous, as the red variety may be transported with perfect safety, while the carriage of ordinary phosphorus is attended with considerable trouble and risk, and consequent expense.

ESTIMATION.—Phosphorus is quantitatively determined as pyrophosphate of magnesia— 2 Mg O, PO_5 —or as basic phosphate of sesquioxide of iron, being first converted into phosphoric acid by the action of boiling diluted nitric acid.

To estimate as pyrophosphate of magnesia, a weighed portion is taken, and treated with nitric acid until entirely dissolved. The solution is mixed with a considerable excess of ammonia; chloride of ammonium is then added; and lastly, sulphate of magnesia, as long as a precipitate continues to be formed. The mixture is allowed to stand twelve hours; the deposit of phosphate of magnesia and ammonia is then collected by filtration, and well washed with dilute solution of ammonia, dried, and heated to intense redness, to expel all traces of ammonia. Every one hundred parts of pyrophosphate are equal to 28.15 of phosphorus.

To determine as phosphate of sesquioxide of iron, a weighed portion of the phosphorus is taken, and oxidised as above by dilute nitric acid. To the solution of phosphoric acid thus obtained, is added a measured quantity of sesquichloride of iron, and the whole is precipitated by ammonia. The mixture is allowed to stand some time at a gentle heat, the precipitate afterwards separated by filtration, washed and exsiccated at a gentle heat, which is afterwards gradually increased to intense ignition. This precipitate is a basic phosphate of sesquioxide of iron. From its weight is deducted the quantity of sesquioxide corresponding to that of the sesquichloride of iron added, and the remainder expresses the quantity of phosphoric acid contained in the solution.

IMPURITIES.—Phosphorus is rarely adulterated, and the only impurities contained in it are those derived from the acid used in its preparation. DUMAS considers flexibility as a characteristic of good phosphorus. Occasionally arsenic, antimony, bismuth, and some other metals have been found in it. If the acid used contained arsenious acid, or an oxide of antimony, these are reduced in the process of manufacture of phosphorus, and are found in it in the metallic state. A solution of phosphorus in dilute nitric acid should give no precipitate with sulphide of hydrogen, and the precipitate procured by a barytic salt should be entirely soluble in excess of nitric acid, proving the absence of sulphur. If arsenic is present, the solution in nitric acid deposits a black precipitate of metallic arsenic when submitted to evaporation.

PHYSIOLOGICAL EFFECTS.—Phosphorus introduced into the stomach of animals acts as a caustic poison. According to ORFILA, the corrosion depends on the formation of phosphorous acid, by the oxidation of phosphorus in the pulmonary canal, and the action of this acid upon the tissue with which it comes in contact. It is very rarely used in medicine, though it has been strongly recommended in cases attended with

great prostration of the vital powers, and also in some chronic diseases of the nervous system. In small doses its operation is stimulant. It becomes absorbed, and communicates an alliaceous smell to the breath. After absorption, it excites the nervous, vascular, and secreting organs, raises the temperature of the skin, and increases the frequency of the pulse. Its general effect is that of a powerful sudorific and diuretic. In large doses it operates as an irritant poison, producing inflammation of the stomach and bowels, terminating in convulsions, insensibility, and death. It is usually administered in solution in ether, chloroform, and in oils. The antidotes to be resorted to in cases of poisoning are chalk or magnesia diffused in milk, together with mild demulcent liquids in large quantity.

STATISTICS.—Previous to the year 1845, the whole of the phosphorus consumed in this country was imported principally from the Continent of Europe. The amount of duty paid in 1844 showed a consumption of about one hundred and twenty-five hundred weight. Since that time it has been manufactured to a considerable extent in England. In 1853 the conjoined English and French product of phosphorus was estimated at one hundred and thirty-four tons. Manufactories of phosphorus are now to be found in Prussia, Baden, Bavaria, Austria, and Sardinia. At the Great Exhibition of 1851, samples were exhibited by COIGNIB and SON of Lyons, OTTO PAULI of Carlsruhe, and by SELOPSIS of Turin and Brozzo, for which the former two received prize medals. The quantity fabricated in Europe probably exceeds three hundred tons annually. PAYEN estimated the annual consumption in the manufacture of lucifer matches in France at thirty tons. In England, the consumption in this branch of manufacture is far greater, one house, that of Messrs. DIXON, near Manchester, producing from six to nine millions of the finished article daily; this enormous number requiring about five pounds of phosphorus. In Austria and other parts of Germany, on account of the abundance and cheapness of timber and labor, this branch of industry is conducted on a still more extended scale, several manufactories making daily above six millions of matches.

PHOTOGRAPHY.—Of the various applications of chemistry to the arts, there is perhaps none more interesting than PHOTOGRAPHY—the art by which the images formed in the camera obscura are fixed upon various tablets, such as glass, paper, metallic plates, leather, *et cetera*; for when it is considered that by means of suitable lenses an image may be formed of any object, celestial or terrestrial, from which light proceeds, the applications of photography appear to be unlimited, and the art assumes an intellectual character, which raises it above those other arts of civilization that merely minister in some particular way to comfort or luxury.

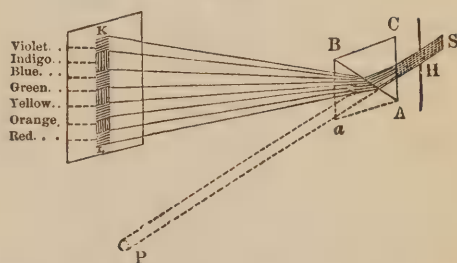
The word photography is derived from two Greek words signifying to *delineate by light*. It has been objected to this term, that the *luminous* rays are not those which effect the chemical changes that result in the production of an impression upon the sensitive tablet on which the image is received, but rather the violet rays of the spectrum; so that the word photography is a

misnomer. It was, however, hastily introduced, and having now become current in most modern languages, it is too late to alter it.

In point of fact, it is neither to the light nor to the heat of the solar rays that one is indebted for the beautiful results of photography, but to another mysterious power, a principle existing in combination with the light and heat of the sun, to which has been applied the appropriate name of *actinism*—a term derived from the Greek word for a *sunbeam*, and signifying merely the influence of the sun's rays, or *ray-power*, without involving the assumption of any theory on the subject.

To illustrate the composition and colored refraction of the sun's rays: suppose a beam of solar light is admitted into a darkened room through an aperture, H, in a window shutter, Fig. 401, and that it is made to pass through a prism of glass, A B C, with one of its angles downward, instead of being refracted altogether,

Fig. 401.



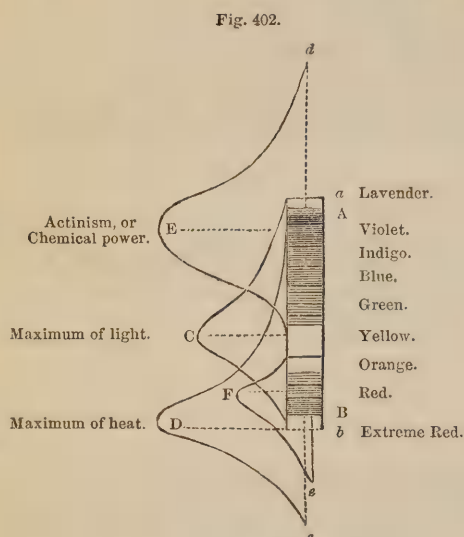
and appearing still as white light, which it does when the refracting surfaces are parallel—it is divided into several rays, and illuminates with different colors an oblong space of a white card, K L, placed to retain it. If one examines this oblong image with attention, it will be observed that it is distinguishable into seven colored bands, in the following order—violet, indigo, blue, green, yellow, orange, red. These are the seven *prismatic colors*; and the oblong image which they form is known, in scientific language, as the *solar* or *prismatic spectrum*.

The order of succession is invariable, and depends upon the unequal refrangibility of the different colored rays of which the composed white ray is made up. Thus the red ray deviates least from the direct path, S P; and the violet ray, most; and the intermediate rays have intermediate degrees of refrangibility—the orange is thrown further from the direct path than the red, and the indigo deviates less than the violet; and hence one speaks of the violet end as the most refrangible, and the red as the least refrangible end of the spectrum.

It is important to remark, however, that below the ordinary visible red, or least refrangible ray, another ray of a deeper red, distinguished as the *extreme red*, or *crimson ray*, may be detected by examining the prismatic spectrum through a deep blue glass; and by throwing the spectrum upon a piece of yellow paper, another ray appears at the violet extremity, named, by Sir JOHN HERSCHEL, the *lavender ray*.

The spectrum exhibits, therefore, when fully analyzed,

a wonderful variety of properties, of which the diagram, Fig. 402, will give a sufficient idea. In this diagram, the shaded portion represents the colors as they occur in the decomposed solar beam; the space included between A and B exhibits the Newtonian spectrum, and *a* and *b* are the rays which Sir JOHN HERSCHEL has added, thus increasing the number of the different perceptible colors from seven to nine; but all of which, as Sir DAVID BREWSTER has shown, are really reducible to three primary colors—red, yellow, and blue. The curved lines in the engraving represent the relative amount of *actinism*, *light*, and *heat*, in different parts of the spectrum. It will be observed that the actinism is



greatest at E, and ceases at *d* and *e* towards either extremity. At the point of greatest light, C, which is in the yellow ray, there is absolutely no actinic or photographic influence. At F, however, near the point of greatest heat, D, the actinic or chemical influence is sensibly felt; but this is ascribed by M. CLAUDET to the yellow rays being not merely passive or inert as regards actinic power, but having a positive destructive influence on any effects produced by the actinic rays.

Whatever be in this, it has been positively ascertained by experiment, that the *yellow*, which is the most luminous ray, has only a small heating power, while the greatest actinic or photographic power exists at that point of the spectrum where the light and heat are least sensible, and even, like the heat at the other extremity, extends a considerable distance beyond the spectrum entirely, producing effects on photographic paper where the rays of the sun are absolutely not visible.

This analysis of the refracted rays of a pencil of white light explains why a much longer exposure is required to insure a photographic image at the equator, than in Northern or Southern latitudes; the yellow rays being more abundant in the former region than in the latter, and actinism being wanting in proportion; in the latter it is *vice versa*.

HISTORICAL NOTICE.—The dawn of photography is intimately connected with researches on light. For a long time the question, whether light possessed any chemical properties, was discussed by a numerous body of scientific men. SCHEELE was the first to draw attention to the subject of the rays of the sun possessing properties able to effect chemical changes, more especially upon silver salts, and showed the comparative power of the different rays to darken them. In this department he was followed by SENEBIER, Count RUMFORD, and RITTER, who was the first to notice that solar beams, not possessing luminosity, but having a remarkable effect in inducing chemical metamorphoses, existed in sunlight. Between 1801, the period of RITTER'S researches, little was done bearing upon the origin of photography, till THOMAS, the youngest son of JOSIAH WEDGEWOOD, in 1802, published his method of producing sun pictures, by coating white paper or enamelled leather with a solution of nitrate of silver, and exposing the coated surface to the light of the sun under a painting on glass. Although he anticipated the advantages which would accrue from the art, he could not partake of them to the extent he deserved, owing to the means of fixing the impression being then unknown to him, notwithstanding the fact of Sir HUMPHREY DAVY being engaged with him in the inquiry. It appears that NIEPCE was the first who partially succeeded in fixing the image produced in the camera obscura; but this was not till 1827, long after the disclosures of WEDGEWOOD, and after many years' investigation. Previous to this period, DAGUERRE was likewise occupied with the subject, but was unsuccessful. In 1829 he entered into an agreement with NIEPCE to pursue their several researches on this subject for mutual advantage. At the period of the compact the latter published his method, which he called *heliography*. It consisted in coating a highly polished tablet of plated silver with a mixture of petroleum and essential oil of lavender, reduced to the consistency of thin varnish. After drying at a gentle heat, the prepared plate was exposed in the camera to the image thrown upon it, and after due time the latent impression was rendered visible by disengaging the unaffected parts. This was executed with a solvent composed of one part of oil of lavender, and ten of ordinary white petroleum or spirit of tar. On pouring this liquid over the plate, the impression began gradually to show itself; when sufficiently defined the plate was removed, the dissolving liquid allowed to drain off, and the operation terminated by careful washing. At this period they were anxiously seeking for a substitute for the varnish, and had recourse to alkaline sulphides and iodine for blackening the plates to form a ground for the picture; but the results were not as satisfactory even as the varnish coating, although the latter proved subsequently to be the most eligible in the hands of DAGUERRE. The heliographic method of NIEPCE was a very slow and uncertain process, requiring several hours' exposure in a strong light before a tolerably defined impression was made. DAGUERRE improved the process by using the resin of the essential oil of lavender dissolved in alcohol for the basis, and the vapor of petroleum, which

had not the effect of removing most of the varnish to the injury of the picture, as was the case in the other. From this period till that of NIEPCE's death the subject was actively prosecuted on both sides; but it would appear that the latter *savant* had lost faith in the efficacy of coating the plates with a metallic film, such as sulphide or iodide of silver; whilst DAGUERRE seemed as much impressed with these, or similar ones, being the true media for taking impressions. After the death of NIEPCE in 1833, the compact was renewed between DAGUERRE and the son, ISIDORE NIEPCE, and the research was as unflinching as before till 1839, when DAGUERRE was fortunate enough to discover the beautiful process which is now so well known under his name. It is almost needless to say, that upon the publication of the process, communicated to the Academy at Paris, the beauty of the gradations of light and shade, and the extreme delicacy and truthfulness of the pictures, took both the whole of the old and new world by surprise; and after the French Government had secured to DAGUERRE and NIEPCE a pension adequate to the importance of the discovery, and gave the process to the world, its practice became universal.

Whilst the French were diligently occupied in bringing the process of producing pictures on metallic plates to perfection, in England the subject was silently pursued by Mr. HENRY FOX TALBOT. His experiments were undertaken in 1834, with the view of rendering the image produced in the camera obscura permanent in the sun; these were prosecuted with varied success till 1839, when a paper was read by him to the Royal Society, on the thirty-first of January of that year, entitled—*Some Account of the Art of Photogenic Drawing; or, the Process by which Natural Objects may be made to delineate themselves without the aid of the Artist's Pencil*. This was the first account of this process—since called *talbotype*—methodized to the production of pictures. In February of the same year a fuller account of the preparation of the paper, and the method of fixing the picture, was communicated to the same body. TALBOT's pictures were produced on paper prepared for the purpose; and though less delicate in detail, in consequence of the inequality of the basis, than daguerreotypes, still they could be viewed with equal effect in any position, and were consequently free from the defect experienced in looking at the latter.

From this it will be evident that the British philosopher pursued his investigation independently of the French laborers in the same field; and arriving at results in a measure as satisfactory as those of DAGUERRE, he contributed, as HUNT remarks, equally with the latter most important services to *science*, in producing an instrument by which the mysterious phenomena of light could be satisfactorily investigated; and to *art*, by giving her votaries tablets upon which Nature impresses herself in all her delicacy and decision, in all her softness and grandeur, and in all her richness of tone and breadth of effect.

The fixing agent first used by TALBOT was a concentrated solution of chloride of sodium, which had the effect of dissolving the unaltered chloride of silver.

Iodide of potassium was employed for a similar purpose; but these do not give results as satisfactory as the hyposulphite of soda introduced by Sir J. HERSCHELL. Other improvements by the latter philosopher have also to be recorded, which, though not so important as the one just referred to, contribute, nevertheless, to the perfection of the art. This is particularly the case with his researches on the solar spectrum, the results of which have been already given, and by which he has laid the foundation of the principles of actinism, and brought it to its present comprehensive state.

HERSCHELL was the first to recommend the practice of saturating the saline washes used to prepare the paper with chloride of silver, and the employment of a double wash of nitrate of silver to be used in succession, alternated with drying the paper, with the view of doing away with the whitish spots so frequently seen in the pictures of TALBOT at the time; he also noticed—as likewise ROBERT HUNT—a method of fixing the impression formed in the camera with chloride of mercury, and, at the same time, rendering the paper to all appearance fit for the ordinary uses of writing and the like; whilst nothing was required to develop the picture but simply washing with hyposulphite of soda.

Another very efficient discovery of TALBOT's may be here recorded—namely, the property of gallic acid in rendering the prepared paper so sensible as to be capable of receiving impressions by instantaneous exposure, owing to the gallic acid of the ingredients continuing and developing the effect of the sun's rays. This agent was ultimately superseded by pyrogallie acid, introduced by ARCHER, the reducing or developing action of which is much greater than that of the gallic compound. Various methods for rendering paper sensitive to the reception of solar influence have been published, to dwell upon which would take up too much space. All, however, have their particular advantages, based upon the judicious application of the usual compounds, so as to produce a more even and more perfect coating with the silver salt.

Subsequent to the production of photographs on paper with considerable accuracy, glass was adopted for the basis of the picture; but as the sensitive media could not be made to adhere to this body alone, it was necessary to employ as an adjunct some adhesive matter. The first trials were with albumen—introduced by NIEPCE ST. VICTOR in 1848—and gelatin, laid in a thin stratum upon the clean surface of the glass. Iodide of potassium or alkaline chlorides were mixed with the adhesive composition; and after partial drying, the surfaces were exposed to solutions of nitrate of silver, when a sensitive coating formed on the film on which the picture was impressed. Generally, the pictures obtained on albumenized or gelatinized glass, owing to the even and close texture of the coating material, had many qualities superior to those produced upon paper, excepting where the practice of employing the latter waxed was followed. It was soon after the adoption of these materials by photographers, that ARCHER introduced pyrogallie acid, and soon after collodion, than which no other material is now more

extensively used. With the exception of modifications introduced from time to time to render the collodion film more sensitive, or to propagate the impression of the rays of light, and thus shorten the period of exposure, very little has been done within the last few years beyond rendering the art more general both in practice and application. Xyloidin, a compound prepared from starch with nitric acid, and tintured with iodine, was introduced a few years ago; but its use is not so extensive as that of collodion, notwithstanding its repute for being a more compact basis for the picture, and more capable of receiving the pictorial impression. The particulars of these methods will be detailed further on when describing the practice of photography. Besides the various progressive steps alluded to, there are a few others which tend to extend its usefulness, and deserve a short notice.

These are the methods for impressing colored pictures upon the prepared surface, and of engraving the photographic impression without the aid either of the artist's graver or pencil.

The latter, which might be called photogalvanography, is not recent, but almost as old as the first bituminous impressions of M. NIEPCE, whose finished pictures required but the application of the etching liquid to convert them into engravings. The system of procedure had been considerably improved by several others, more especially by NIEPCE the younger, LEREBOURS, and LEMERCIER, the latter applying it to lithographic printing. Dr. DORME of Paris endeavored to obtain engravings from daguerreotype plates by chemical agency, and partially succeeded. His method was to attack the plate with nitric acid before the gilding of the picture, when all the parts whereon the silver was reduced became more or less corroded according to the depth of shade. As nitric acid happened to be the agent used, it could not be always confined to the parts where its action should be manifested, and, therefore, the results were precarious. GROVE published a method for engraving the daguerrean image by voltaic agency in 1842; in this operation, the agent was chlorine liberated from hydrochloric acid, in which the picture, attached to the positive pole of the battery, was immersed. This method, though superior to its antecedents, was not all that was desired. A patent was granted in 1844 to FIZEAU and CLAUDET for engraving photographic impressions. Here hydrochloric acid, liberated from a mixture of chloride of sodium and nitrate of potassa, to which a little nitric acid had been added, was the etching medium, and ammonia and a hot concentrated solution of caustic potassa the auxiliaries to it in bringing the process to perfection—the former having the effect of removing the chloride of silver, and the latter protecting the surface coated with the mercury from the corroding action of the acid. When sufficiently deepened the plate was washed and dried, smeared with printers' ink, dried, cleaned, and the unetched parts gilded, after which the remaining parts could be deepened at will by first removing the ink. Another method discovered by H. F. TALBOT, and published by him in May, 1853, seemed to be most satisfactory. It consisted in coating a well-polished steel plate with a mixed gelatin

impregnated with a strong solution of bichromate of potassa; and, when dried, exposing this plate to the rays of light impinged from the illuminated subject in the camera; or, better, to the sun's rays, whilst a positive photographic picture had been laid upon it. As in the case of NIEPCE's bituminous method, so in this;—the influence of the light rendered the parts on which it fell insoluble, so that on subsequently washing in water the gelatin and bichromate solution were removed from the other parts, leaving a raised facsimile of the picture, the lights being represented by the bare metal, and the shades—corresponding to the lights in the original—by the altered gelatin. On pouring bichloride of platinum upon the washed surface, the plate became readily etched on the parts from which the gelatin was removed. When the action has been sufficiently continued, it is arrested by washing with a sponge, which removes the gelatin, and drying. The plate now exhibits a delicate etching of the picture on the steel plate, in which the raised surface corresponds to the light and half tones of the original design. PRETSCH of Vienna published a method for effecting the same purpose; it has much in common with TALBOT's, but instead of washing off the coating of gelatin, as directed by the latter, it is merely soaked in water, to swell the unaltered gelatin, and give the appearance of an engraved wood-block to the figure. An impression of the figure is then taken with a soft material in the way of a mould, and the latter is rendered a conductor of electricity, and copper is deposited upon it to any desired extent. In this way a true impression is taken of the photograph in copper, and may be multiplied at pleasure. Latterly, POITEVIN of Paris has used the same materials as TALBOT, and applied them to lithographic stone, and the results appear to be very satisfactory. Notwithstanding these several steps towards improvement, much still remains to be effected, both as to investigation and discovery, to give the art the utility which it is calculated to possess.

In color printing, or chromophotography, also, efforts have been made to impress the tints of the object upon the picture by chemical agency, but the results have not been as successful in this department as those just detailed of photogalvanography; still, sufficient indications have been given to show that the subject is feasible of attainment. In chromophotography, or heliochromy, as the process was called in France, BECQUEREL in 1854 and previously, showed that colors could be impressed on the picture at the instant of its formation, by employing the violet chloride of silver—a compound in which more or less of a basic chloride exists—for taking the picture. To give the subject more definition, he coated the silver plates by means of chlorine liberated from hydrochloric acid by voltaic agency, and in which solution the tablet was immersed, attached to the positive pole of the battery. As it was found that the shades were much altered by the thickness of the coating of the violet chloride on the plate, he introduced a voltameter of water in the circuit, to measure from the volume of hydrogen disengaged the quantity of chlorine set free, and by this means he was able to determine the quantity of gas that passed over a given extent of the plate. When a plate so prepared was

exposed in the camera to the solar light of the spectrum, all the chief colors were produced, beginning with the yellow and orange, and extending to the red and violet, thus leaving a colored picture. BECQUEREL observed that a temperature of 212° to 302° , applied to the plate before exposing it to the spectrum, or a heat of 97° kept up for two or three days, modified the strength of the colors, though giving good yellow and green impressions. As these hues could not be fixed so as to resist the effect of diffuse light, they were looked upon more as a scientific curiosity. NIEPCE St. VICTOR being led to infer a relationship between the color which many bodies communicate to flame, and that which light develops in a plate of silver coated as above, tried the effects of silver plates excited in chlorine water impregnated with various salts, such as chloride of strontium and the like, and placed the plate in the camera for the reception of the rays from colored bodies, when the image became impressed with the natural tints of the subject. Thus, an orange was obtained by the use of chloride of calcium, yellow by chloride of sodium or chlorine, red with chloride of strontium, green with boracic acid and chloride of nickel, and so on, employing for any particular shade a substance which similarly colors the alcoholic flame, or that of the blowpipe.

Mr. HILL of the United States had been engaged upon the same subject, and gave the public to infer that he had arrived at satisfactory results in obtaining colored photographs as early as 1850, by means of some chance composition of a nondescript nature; but though he has given details of the pictures he produced by this means, the Editor is unable to find any description of the method or substances which he employed. It is certain, however, that no sure means of impressing the hues of the natural bodies upon the daguerreotype or photograph have been yet arrived at; and notwithstanding the instances referred to, that the discovery of the process still remains a desideratum in the science and art of photography.

The art of photography is dependent partly on optics, and partly on chemistry. It is the business of the optician to provide a suitable camera in which the photographic tablet may be placed, and the image formed by the lens thrown upon it. It is the business of the chemist to prepare the sensitive tablet in a suitable manner to receive that image.

THE OPTICS OF PHOTOGRAPHY.—The simplest form of camera obscura is a dark box, having a small orifice in the centre of one end, and a focusing screen of ground glass at the other. On throwing a black cloth over the head and camera, and looking at the focusing screen, an inverted image is seen of the objects towards which the opening of the camera is presented. When the hole is large, this image is bright but indistinct; by reducing its size, the image becomes more distinct, but fainter. The brightness and size of the pictured objects depend upon the distance of the focusing screen from the hole; and the smaller that distance may be, the smaller are the objects and the brighter the picture. The shape of the aperture does not determine that of the picture or the outline of the objects, a triangular hole giving the

same image as a round one. The image formed in this simple camera, although more or less indistinct, is absolutely free from distortion, and the rules of plane perspective are strictly fulfilled.

To understand the principles on which the cameras are constructed, it must be remembered that every visible object of which an image can be formed by a lens, is supposed in optics to consist of an assemblage of luminous points, from each of which rays of light proceed in all directions, but without interfering with each other; and an assemblage of rays proceeding from any single point is called a *pencil*. A bright object, therefore, emits a pencil of light from each of the bright points composing it. Thus if A C—Fig. 403—be a piece of brass wire, the several points of it, A, B, C, emit each a pencil of light—not a single ray—and these pencils do not interfere with each other. To illustrate this further, let E F—Fig. 404—be the object, B C the camera, L the hole, and K D the focusing screen; then a pencil of light proceeding from E passes through the hole L, and the rays continue to diverge until they reach the focusing screen at e, at which point a spot of light is produced of the same shape as the hole at L, but somewhat larger than it, and of the same color as the point E of the object. Similarly the points F, G, H, I, *et cetera*, emit pencils which after passing through the hole illu-

Fig. 403.

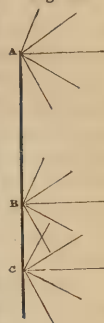
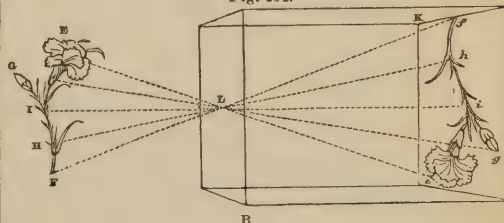


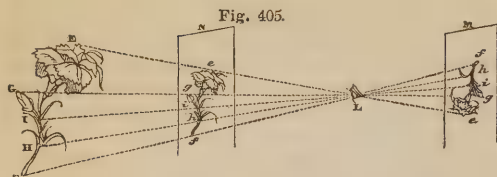
Fig. 404.



minate the spots at *f, g, h, i, et cetera*, and in this way an indistinct inverted image of the object is formed. The size and shape of the image do not depend upon the opening, because the luminous points of the object being infinite in number, and in close juxtaposition, the spots of light which compose the image, although individually of the same shape as the holes, glide one into the other, and form a continuous outline, in which all trace of the form of any particular spot is destroyed.

To show that the image upon the focusing screen is a correct perspective view of the object, the following illustration is submitted:—Suppose that L—Fig. 405—is the eye of a spectator, which is considered to be a mathematical point, and that straight lines, called *visual rays*, are drawn from L to the several points of the object E F; these straight lines constitute the edges of a system of pyramids, of which L is the common vertex, and if these are cut by any vertical plane at N between L and the object, the section is a plane perspective view. This is the fundamental definition of a plane perspective view. Now, let it be supposed that the visual rays are produced through L, so as to

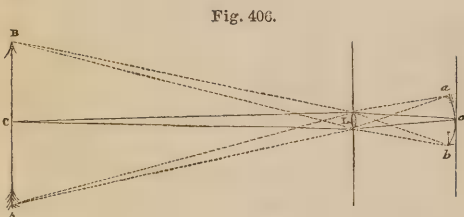
form another system of pyramids on the opposite side of it; it is evident that if this second system be cut by a plane at M parallel to that at N , and at an equal distance



from L , the inverted image thus formed would be an exactly equal and similar geometrical figure to the image at N , and the two figures would coincide if one were laid against the other. But the image at M , is that which would be formed by a camera having a hole at L , and a focusing screen at M ; so that this simple camera gives a correct perspective view of the object as seen from the aperture, and depicted upon a plane surface as far in front of the hole as the focusing screen behind it.

The great defect of the image produced in the simple camera is, its indistinctness, because the pencils have no foci or point of concurrence of the rays. In order to remedy this evil convex lenses, or convex combinations of lenses, are introduced and placed at L .

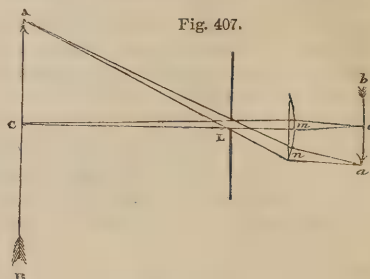
The simplest form of lenticular camera is that in which a very small convex lens is placed at L —Fig. 406. A direct pencil diverging from a point, c , of an object is then, after refraction through the lens, brought to a focus at e , where a distinct image is formed; but the



oblique pencils from points A , B , are brought approximately to foci at points a , b , upon a circular arc, of which L is the centre, and Lc the radius, and the rays after passing through the points, a , b , again diverge and produce round spots or discs of light upon the screen, instead of a sharp focus as at e ; the true image of the object being curved, as shown in the figure. A small single lens, therefore, gives so much curvature of the image as to render its margin very indistinct compared with the centre. It will be observed, however, that the image formed by a small single lens is free from distortion, because the axes of the pencils do not suffer deviation by passing through it.

In order to increase the radius of curvature of the image, the following plan has been adopted in the lenses used by photographers for taking *views*; in these the light enters through a small aperture, and the time of exposure is a matter of less consequence than obtaining a picture uniformly sharp to the edges. Instead of placing a small lens at L , a large one is fixed at some distance behind L , as in Fig. 407. A central pencil from c is refracted through the centre, m , of this lens,

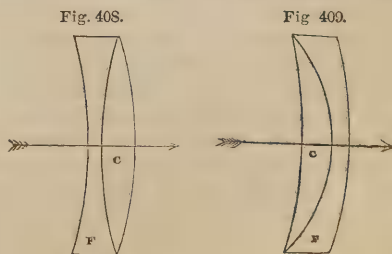
and an oblique one from A , after passing through the hole at L , is refracted near its circumference at n . This renders the image much flatter; because the distance, na , which is equal to the focal length, mc , of the lens, is measured from n and not from m , as in the case of a single lens placed at L . But this arrangement is open to the very serious objection, that the image is greatly distorted, in consequence of the axes of the oblique pencils being bent out of their course by refraction through the circumference of the lens, which acts as a prism in causing rays to deviate from its edges, and, therefore the marginal parts of the image are too small for the central; besides, all straight lines in the image which do not pass through the centre are curved inwards at their extre-



mities; so that in this form of view-lens, flatness of field is gained at the sacrifice of true perspective.

The form of this lens is meniscus, or concavo-convex, the concave side being turned towards the objects; and the radius of curvature of the image is equal to the focal length of the lens, plus the radius of its convex surface; it is, therefore, longer by the latter quantity than the radius of curvature of the image formed by a small single lens without a diaphragm in front.

All photographic lenses require to be achromatized, or so constructed as to refract the different colors equally, in such a way that the yellow and violet foci may coincide; because the yellow rays produce the *visible image*, while all the rays of the spectrum which lie between the green and the extreme lavender produce more or less chemical effect upon the sensitive photographic tablet. The common view-lens is an achromatic meniscus, and it may be achromatized in two different ways, one of which consists in placing a double

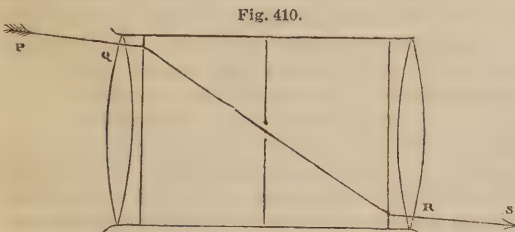


concave lens of flint-glass before and in contact with a double convex lens of crown-glass, as shown in Fig. 408; and the other, in placing a concavo-convex lens of crown-glass before and in contact with a concavo-convex lens of flint-glass, as shown in Fig. 409. The

effect of these combinations arises from the circumstance, that flint-glass and crown-glass possess very different powers of *dispersing* or of separating the rays of light.

In the preceding Figs., *c* denotes crown, *f* flint-glass. Both forms have equal radii of the front and back surfaces, equal focal lengths, equal curvature of the image, and an equal distortion; but the plan shown in Fig. 409 is the best, because there is rather less spherical aberration. Even this is very bad, and should be superseded by the view-lens, which has recently been invented by Professor PETZVAL, and which will be described presently.

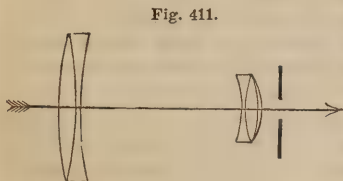
The best form of *view-lens* for giving pictures entirely free from distortion is a combination of two achromatic plano-convex lenses, with the convex sides outwards, and a small stop midway between them, as shown in Fig. 410. If a ray, *PQ*, be refracted



through this combination in such a way that its course between the lenses passes through the centre of the stop, it is evident, from the symmetry of the figure, that the emergent ray, *RS*, will be parallel to *PQ*; from which it follows that the axes of pencils refracted through this combination do not suffer deviation, and therefore there is no distortion in the image. The curvature of the image is, however, greater than with the single view-lens, and the central definition, when the diaphragm is removed, not quite so good as that of the *portrait-lens* to be described presently.

The best view-lens for combining tolerable freedom from distortion, with flatness of field and perfection of focus—that is to say, the most generally useful view-lens is that of Professor PETZVAL of Vienna, and commonly called the *orthoscopic lens*, from the fact that the straight lines of objects are not curved in the

image. Its construction is shown in Fig. 411. The front lens is achromatic and convexo-concave; and the back lens achromatic, and composed of two,



which only touch at the edges. The inner one—that is, the one next to the front lens—is of crown-glass and double concave, with the deepest concavity next to the meniscus; the outer one is a meniscus of flint-glass. The front lens of the combination is convex, and brings rays to a focus; the back lens is concave, and scatters them. In order to improve the definition, and bring objects at different distances into good focus, a stop is placed immediately behind the back

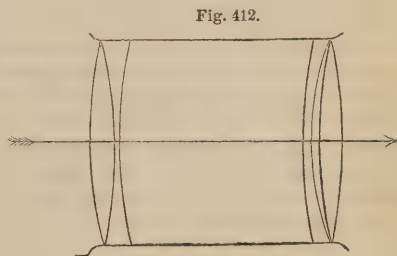
lens. The distance between the front and back lenses of the combination is about equal to half the diameter of the front lens, and the diameter of the back lens is about two-thirds that of the front one. In this combination the oblique pencils pass near the circumference of the front, and through the centre of the back lens; they are therefore lengthened, and the consequence is the production of a very flat field. A small amount of distortion is produced by this instrument, which causes straight lines not passing through the centre of the picture to be curved *outwards* at their extremities, and the objects at the margin of the field are rendered proportionally larger than those in the centre; but these defects exist to a much smaller extent than those of an opposite kind in the single view-lens.

There are, therefore, three different view-lenses used by photographers, namely—the single view-lens, with a stop in front, which gives a flat field, but great distortion; the symmetrical double combination, which gives an image entirely free from distortion, but having considerable curvature; and the orthoscopic combination of PETZVAL, which gives a tolerably flat field, and the image *nearly* free from distortion. The second lens is the best when a sufficiently small stop can be used to obtain good marginal definition. In other cases the orthoscopic lens is the best, and the single view-lens the worst.

The view-lens includes an angle of from 35° to 40°. It cannot be used for portraits in a glass room, because it would require too long an exposure.

The *portrait-lens* commonly used is that which was invented by Professor PETZVAL about seventeen years ago. In this combination everything is sacrificed to getting a large central pencil free from spherical and chromatic aberration. The curvature of the image is considerable, and the angular field of view rarely exceeds 20°. Its only merit is quickness of action, which is absolutely required in photographic portraiture. As soon, however, as more rapid processes are discovered, the portrait-lens, with its large aperture and many unavoidable defects, may be given up.

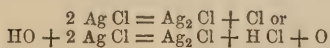
The construction of the portrait combination of PETZVAL is shown in Fig. 412. The front lens is



achromatic and convexo-concave, the lenses being in contact. The back lens is achromatic, and formed of two lenses separated by a small interval; the inner one is of flint-glass, and convexo-concave, the outer one of crown-glass, and double convex, with the flatter side outwards. The focal lengths of the two compound lenses are nearly equal, the front lens having the longer

focus, and both are convex lenses. The combined focal length of the instrument, measured from the back one, is from three to four times the diameter of the front lens. Sometimes, when the light is strong, or it is required to take objects out of doors, a stop is used. This should be inserted between the lenses, and the proper place for it must be determined by trial. If placed too near the front lens the image of a perpendicular straight line brought to the margin of the focusing screen is bent *inwards* at the extremities, and if placed too near to the back lens, *outwards*; there is an intermediate point where the image is perfectly straight, and that is the proper place for the stop. In mounting lenses care should be taken to exclude stray light, and to prevent reflections from the inside of the tube, and the outside edge of the lenses by blackening the interior.

THE CHEMISTRY OF PHOTOGRAPHY.—In this department of the art, the principle involved is the production of a saline surface which is capable of being modified by the actinic or chemical rays in light, the development of this action by chemical means, and finally its fixation, by removing all matter which is capable of further change by the agency that produces the picture. The substances which are pre-eminently employed in this art are the various salts of silver, more especially the chloride, iodide, and bromide of this metal. Besides these, there are other compounds which are capable of being acted upon in a similar manner, and consequently give, under proper treatment, impressions of objects; such, for instance, are compounds of gold, uranium, chromium, and other easily reducible substances. It is well known to every chemical student that a silver salt, such as the chloride, iodide, bromide, phosphate, and the like, when freshly precipitated and presented to the sun's rays, rapidly assumes a purplish hue, and finally turns black. So, also, in regard to compounds of gold, uranium, or chromium, an effect is observed when these are exposed in very thin layers, that shows a chemical action has taken place. In all these cases where diffuse light makes an impression, the effect is due either to a reduction of the salt to one of a more basic nature, or to the isolation of the metal from the salifiable body. For example, supposing a surface coated with a thin layer of chloride of silver be exposed to the light of the sun for a short time, the resulting darkening of the pure white of the salt is due to an abstraction of part of the chlorine from it; if its exposure be continued the change gradually progresses, till finally the compound will contain no chlorine, or at best but a very small portion. To illustrate this, if the chloride of silver be represented by Ag Cl , the effect of the chemical action of the actinism or chemical principle in light may be expressed by the formula—



that is, two equivalents of the silver salt will evolve one equivalent of their chlorine when water is absent, or one of oxygen when water is present. By continuing the reducing effect of the light, the chlorine ultimately is entirely separated, and only finely-divided metal remains. The latter change is, however, rarely

effected in the ordinary practice of the photographer. As with silver, so with gold and the other substances alluded to; they all lose a portion of their salifying element, and thus acquire a composition different from what they originally possessed, becoming by such metamorphoses more permanent under radiant influences.

In photographic practice, the action of the light is propagated by other chemical compounds, generally those which have a great affinity for oxygen, and by assimilating which they pass into a higher state of oxidation. Such are the various preparations of the protoxide of iron, protosalts of tin, and formic and other organic acids that are capable of assimilating oxygen from metallic salts. Hence the practice of *developing* the image incipiently formed by the light with a protosalt of iron, or any of the other compounds just alluded to. Besides these, another process of a chemical nature is required to give permanency to the impression produced by the combined agency—by the impinged rays and the reducing agent—and which has for its object the removal of the sensitive salt from the parts which form the lights in the positive and the shadows in the negative pictures, presently to be described in the practical details of the art. The agents used for this purpose are water, hyposulphite of soda, $\text{NaO S}_2 \text{O}_2$, ammonia, cyanide of potassium, and a few other compounds capable of dissolving the metallic combinations employed for the basis of the picture. After bringing these chemical processes to bear upon the production of a photographic picture, nothing further is necessary beyond the few simple operations of drying and mounting.

The chemical principles that govern the art will be more fully enlarged upon in the description of the practical details of the several processes, and which, for the sake of clearness, will be divided into the daguerreotype, the collodion, the albumino-collodion, the calotype, the photogenic and printing processes, to which will be added the application of photography to other branches of art, such as photolithographic, photoglyphic, and photogalvanographic operations.

PRACTICE OF PHOTOGRAPHY.—Before immediately entering upon a detail of working, it may be well to remark that in the images formed in the camera obscura the lights and shades are true to nature, but the position of objects is reversed, as regards right and left. In fixing these images by photography upon various tablets, the object is to produce impressions true to nature in the lights and shades, and non-reversed.

There are two ways of doing this. According to one method a *negative* photograph is first produced, from which, by a second photographic process, a *positive* photograph is obtained. The other method consists in obtaining a positive photograph by one operation.

By a *negative* is meant a transparent photograph in which the lights and shades are the opposite to those in nature, and the objects reversed as regards right and left. By a *positive* is meant a photograph in which the lights and shades are true to nature.

Two direct positive processes are commonly used; they are called the *daguerreotype* and the *positive collodion* processes. In the former the picture is

produced upon a silvered copper plate; in the latter upon glass, or some black even substance, such as glazed leather, oil-cloth, enamelled iron, *et cetera*.

THE DAGUERRETYPE PROCESS.—This process is now hardly ever practised in Great Britain, and but partially in America; nevertheless, a short description of it will not be uninteresting:—A silvered copper plate is first polished to the utmost; it is then rendered sensitive to light, by being exposed to the fumes of iodine and bromine, after which it is presented to the image in the camera; no visible picture is produced until the plate is submitted to the vapor of mercury, which adheres only to the parts that have been acted on by light, thus forming the lights of the picture, whilst the blackened polished metal forms the shadows. The subsequent operations consist, first, in removing the film of argentine, iodide, and bromide from the plate by immersing it in a solution of hyposulphite of soda, and next in fixing the picture permanently to the plate by means of a boiling solution of *sel d'or*—hyposulphite of gold and soda—which at the same time greatly improves the appearance of the picture. Such is a brief sketch of this very beautiful process. It now remains to describe the operations more in detail.

To Polish the Plate.—The plates are polished by dusting a little finely-powdered rotten-stone upon them, and rubbing them all over with a little cotton or fine flannel dipped in a solution of nitric acid in twenty parts of water. When all dirt is removed, they are dried by friction with fine dry cotton or flannel. Finally, the slight scratches produced in the first operation are effaced by rubbing the plates on pads of velvetreen nailed to a board, and upon which powdered charcoal of different degrees of fineness is laid. When perfectly clean and polished, the breath should condense upon it in an even sheet.

To Excite the Plate.—Two coating boxes are required for this operation, one to contain iodine, the other lime saturated with bromine. Those with glass pans are the best. The iodine is spread evenly over the bottom of one of these boxes, and the bromide of lime to the depth of an inch over the bottom of the other. The plate is then laid with its face downwards over the iodine, for a minute or two, until it assumes a deep yellow color; it is then removed, and laid over the bromine for a minute, or until it assumes a bluish steel color; and then again over the iodine for a few seconds, after which it is ready to be exposed in the camera. In exposing the plates to the exciting media, the time of exposure must necessarily be dependant on the temperature of the room, and consequently, there is nothing to direct the operator, except the tint of color on the polished surface mentioned above. The plate may be examined under a feeble light, until it is put over the iodine the second time; and should any accident occur in taking a picture, and the plate be exposed to light, there will be no necessity to clean and excite it again; for the mere exposure to iodine for two or three seconds will obliterate the impression, and render the plate in as good condition for receiving a fresh impression as it was before.

The Exposure in the Camera.—The exposure in the camera and development of the image should follow

the exciting of the plate as quickly as possible; nevertheless, if the sensitive plates be put into a closely-covered plate box, face to face, they preserve their sensitiveness for some hours unimpaired.

The time of exposure in the camera is a matter of critical importance, and it can only be ascertained to great nicety by experiment. The process is exceedingly sensitive and rapid, and with the full aperture of a portrait-lens, and a strong light out-of-doors, an instantaneous exposure is sufficient; but under glass, and with only a moderate diffused light, several seconds are required, and sometimes with a view-lens and small diaphragm several minutes; much of course depending upon the brightness of the object and the size of the diaphragm.

The over-exposed parts of a picture look blue, and are said to be *solarized*. The under-exposed parts appear black and devoid of detail. The photographer should avoid as much as possible too violent contrasts of light and shade in the model, and aim at half tone and modulation of shade; and in exposing a plate, the exposure should be timed with reference to the shadows, and the lights left to take care of themselves. There are differences of opinion with respect to the comparative sensitiveness of the daguerreotype and collodion processes, but the positive collodion process is generally believed to be the more sensitive of the two.

The Development of the Image.—On removing the plate from the camera, it is placed in a mercury box containing the vapor of mercury heated to about 140°. The most convenient mercury box is that used in America; it is made of iron, and shaped like an inverted pyramid, the mercury being at the bottom, and the plate laid horizontally over it. It is provided with a thermometer which indicates the temperature, and the mercury is heated by a spirit-lamp placed underneath. The surface of the mercury should be perfectly clean; and it will frequently require filtering either by squeezing through a wash-leather, or passing through a glass filter with a small aperture made for the purpose. The time of development depends upon the size of the box, the temperature, and the quantity of quicksilver used, and it may vary from two or three minutes to a quarter of an hour—about five minutes is a good average time. The development should not be stopped until all the details in the shadows are fully out. If continued too long, or if the mercury be too hot, the picture appears hazy, the shadows assuming a peculiar speckled appearance.

The Fixing and Gilding.—On removal from the mercury box, the picture may be exposed to daylight, as no further development can take place. In order to remove the iodine and bromine from the plate, it must be immersed in a solution of hyposulphite of soda in distilled water. The strength is immaterial; one part hyposulphite to six parts of water will do very well, but it is important always to filter the solution through blotting paper. It should be poured into a flat dish, and the plate immersed face upwards in such a way as that a wave of liquid flows quickly over it, and two waves not allowed to meet upon it in any part. The yellow film upon the plate is now quickly cleared off, and the polished silver with the grey image upon it

exposed to view. The plate must then be well washed with distilled water, drained, and laid accurately horizontal upon a levelling stand, ready for the operation of gilding. This is accomplished by pouring upon the plate through a funnel, having a tuft of cotton wool in its neck, as much of a solution of hyposulphite of gold and soda—*sel d'or*—as it will hold without any running over, and then heating this liquid to the boiling point by passing a spirit-lamp backwards and forwards under the plate. The *sel d'or* solution is made by dissolving half a grain of the compound hyposulphite in an ounce of distilled water. While boiling the solution upon the plate, bubbles form but must not be allowed to stick to it; this is prevented by tapping the foot of the levelling stand occasionally with the bottom of the spirit-lamp, and thus communicating a vibration to the plate. As soon as the liquid becomes hot, the lights of the picture darken; but after a few seconds they begin to get whiter, and the blacks blacker. In the course of a minute or two, the appearance of the picture is greatly improved, and the process is then arrested by pouring off the hot liquid, and washing the plate with cold distilled water poured over it from a bottle having a glass tube fitted into the cork; after which it only remains to dry the plate, and the picture is finished. This is done by taking the corner of it in a pair of pincers, holding it at an angle of about 45° to the floor, and passing the flame of a spirit-lamp underneath, beginning with the upper corner, chasing the line of wet from the upper to the lower corner, and removing the last drop with blotting paper.

The rationale of the daguerreotype may be inferred from what has been said under the chemistry of photography. A film of iodide and bromide of silver, sensitive to light, results from the exposures in the exciting boxes. This attenuated coating is reduced by the chemical rays of the light impinged upon it, to the state of a subsalt; and upon exposure to the mercurial vapor the metal deposits upon the part so attacked. All the unaffected argentine surface is deprived of the sensitive iodo-bromide of silver by the solution of alkaline hyposulphite—and the final treatment with gold solution has the effect of depositing the gold by electrolysis upon the parts of the plate acted upon by the light.

The daguerreotype process may be considered the most perfect of all the photographic processes at present known; for certainly it stands unequalled for microscopic perfection of detail, modulation of shade, and beauty of half-tone; nor is this superiority to be wondered at when it is considered that the chemicals are applied in the form of impalpable vapor, and that the tablet is a highly polished metal plate; while in other processes the chemicals are either contained in a coarse material like paper, or else in a gummy film, which is spread upon glass, leather, or enamel.

Daguerreotypes are permanent when the manipulation is properly performed, the plate thoroughly washed, and carefully sealed up in an air-tight case. In order to avoid the reversion of the image, a reflector must be used in front of the lens, an expedient which is not necessary in any other process.

THE COLLODION PROCESSES, POSITIVE AND NEGATIVE.—Collodion, so named from its adhesive nature, is a gelatinous substance made by dissolving pyroxylin—gun-cotton—in a mixture of ether and alcohol. It is extensively used in photography, as a vehicle for supporting the sensitive chemicals.

The reader will find a detailed account of the methods followed in the preparation of gun-cotton, or pyroxylin, *ante* Vol. II., page 329, and a brief description of the process for converting this material into collodion at page 334. It may be convenient, however, to repeat shortly in this place, the process of making plain collodion with a special view to its application for photographic purposes:—Mix together in a large and perfectly dry basin equal parts, by measure, of commercial oil of vitriol and nitric acid, specific gravity 1.42. The temperature of the mixed acids rises to about 150°; and it must be maintained at that temperature by placing the basin in hot water, if necessary. The operation must be conducted under a chimney in order that the fumes may escape. Then immerse in the mixture, in small quantities at a time, the best cotton wool, such as is manufactured for chemical purposes, pulled out into thin flat pieces. Put as much into the liquid as it will conveniently cover, and stir it about with two thick glass rods for the space of five minutes. Then pour the whole contents of the basin into an earthenware colander, so that the acids may drain off, and wash the cotton thoroughly by putting it for a minute under a tap; after which throw it into a pail of water and stir it about with the glass rods. Change the water, and continue this washing for some minutes, squeezing the gun-cotton between the hands occasionally; and, lastly, put it into warm water, to which a little soda has been added, in order to neutralize completely all trace of acidity; after which wash the gun-cotton again thoroughly in several changes of water, and let it soak in water for an hour or two; then remove it, squeeze it, and spread it out to dry spontaneously in a safe place, or hang it up to dry in a net suspended from the ceiling. When nearly dry pull it out into small pieces or tufts, and in this state let it get thoroughly dry. It should then be put away in a tin canister. It is an exceedingly inflammable and dangerous substance, and has been known to decompose by keeping, and evolve dense suffocating fumes. Great care should therefore be taken in the manufacture and preservation of gun-cotton.

The proper strength of the nitric acid should be strictly observed; for there are several kinds of gun-cotton, some of which are quite unsuitable for the purpose. For instance, if the strongest nitric acid is used, specific gravity 1.5, the gun-cotton is of the most explosive kind, and will not dissolve in ether and alcohol; if, on the other hand, the nitric acid be too weak, the gun-cotton is but imperfectly soluble, and a good deal of it becomes disintegrated, and is lost in the washing. But even supposing the gun-cotton to dissolve perfectly in the ether and alcohol, the collodion may still be faulty; for if the acids are too strong, the collodion film when spread upon a glass plate contracts greatly on drying, and if too weak, the film is opalescent, and partially opaque like tissue paper, instead of

being transparent and structureless. Then, again, the temperature of the acid mixture is a matter of importance; for if it be too low, the negatives are deficient in density; and if too high, the collodion becomes insensitive, and fails to give the half-tones of the picture—the blacks assuming excessive density, while the lights remain clear and devoid of detail. On the whole, the best proportions, strength, and temperature of the acid mixture appear to be those indicated in the former paragraph.

Having thus shown how to make photographic pyroxylin, it remains to describe the mode of dissolving it in a mixture of ether and alcohol, so as to produce *plain collodion*. This is done as follows:—Mix together absolute ether, specific gravity .725, one part by measure, and absolute alcohol, specific gravity .800, three parts by measure; and to every fluid ounce of this mixture add from six to eight grains of pyroxylin, according to the thickness of film required. Shake the mixture well for some minutes. The pyroxylin quickly dissolves. The bottle should then be put aside and remain undisturbed for several days, at the end of which time the clear liquid may be drawn off by means of a siphon from any sediment which may form, and it is then ready for use. The ether and alcohol employed may be either pure or methylated. *Absolute* methylic ether and alcohol appear to answer the purpose exceedingly well, and are much cheaper than pure spirits, since they pay no duty. They have also this advantage, that the iodized collodion does not become so quickly deteriorated as when pure spirits are used.

For making collodion, the following proportions by weight have also been severally recommended:—

Gun-cotton,	1	...	5	...	1
Ether,	120	...	110	...	196
Alcohol,	60	...	20	...	12

Whatever be the quantity of the fluids taken to dissolve the cotton originally, the solution, if too thick, can be easily diluted to the suitable degree. This is known by pouring a small portion of it on a plate of glass, on which it should flow freely, and leave at the same time a firm film of collodion, and so cohesive as not to break under a stream of water. Any fibres of the cotton that may remain undissolved may be separated by filtration. DELAMOTTE and others add a few drops of ammonia to the bulk of the collodion to prevent acidity.

To iodize the collodion many receipts are followed. ARCHER's method is to make a saturated solution of iodide of potassium in alcohol, and to add as much iodide of silver as the liquid will dissolve, even with repeated shakings, and, after the menstruum clarifies, to add a sufficient quantity to enable it to take up a coating of silver from the argentiferous bath. Generally the iodizing solution is made differently for positives and negatives. For negatives it is made by dissolving fourteen grains of iodide of potassium to the ounce of alcohol, specific gravity .825; for positives by dissolving ten grains of iodide of potassium and two grains of bromide of potassium to the ounce of alcohol, specific gravity .825. In order to iodize the collodion, one part by measure of the iodizing solution is added to three parts by measure of the

plain collodion. The mixture is shaken well together, and may be used at once.

Sometimes iodide of ammonium and fluoride of potassium are used for positive pictures, in the proportion of forty-two grains of the iodide and two of the potassium salt to six ounces of the collodion. The two salts are put into the sized bottle specified, and five or six drops of water added to moisten, but not to completely dissolve them, and the plain collodion afterwards added. On shaking the whole, and allowing it afterwards to rest, complete solution will take place. The following are other proportions which work well:—

Collodion,	6 ounces.
Iodide of ammonium,	53 grains.
Fluoride of potassium,	2 grains.
Water,	5 drops.
Collodion,	6 ounces.
Iodide of potassium,	12 grains.
Iodide of silver,	7 to 8 grains.

When methylated spirit is used, and the gun-cotton properly washed, the iodized collodion remains colorless; but when pure spirit is employed, it turns at once of a pale yellow color, which gradually deepens by keeping to an orange-yellow, and ultimately to a deep red; the collodion is then insensitive and useless.

The bottle containing plain collodion should never be shaken, and the iodizing solution should be filtered through blotting paper. The iodides of cadmium or ammonium are liable to objections, for the salts of cadmium impair the fluidity of the collodion and put the nitrate-bath out of order, while the salts of ammonium are exceedingly unstable. Collodion iodized with iodide of cadmium does not become discolored by keeping; but, although not visibly deteriorated, its good qualities are nevertheless impaired.

THE NEGATIVE COLLODION PROCESS.—The operations for taking negative collodion pictures consist in cleaning the glass plate, coating it with iodized collodion, rendering it sensitive by immersion in the nitrate of silver bath, exposing it in the camera, developing the latent image, removing the redundant chemicals, and washing, drying, and varnishing the picture.

Patent plate-glass should be employed for negatives; because plates of flatted crown or common window-glass, not being perfectly level, are liable to get broken in the operation of printing. The edges of the plates should be ground by rubbing them in a notch made in a piece of stone.

To Clean the Glass Plates.—Wash them well with water, and scrub them with a hard brush till they appear to be clean. Then rub them all over with a tuft of tow dipped in dilute nitric acid; wash them again thoroughly in several changes of water, or under a tap, wipe them dry with clean linen cloths, and finally polish them with a washleather or piece of cambric. When a plate is perfectly clean, the breath condenses upon it in an even sheet free from irregular markings.

To Apply the Collodion.—Hold the plate horizontally by one corner in the left hand, or put it upon a plateholder, blow off any dust that may have settled upon it, and pour in the centre of it a circular patch of collodion rather more than half as large as the plate. Then tilt the plate so as to allow the collodion to run

towards the thumb, but without actually touching it, and afterwards to the adjacent corners, and pour off the surplus from the corner diagonally opposite to that by which the plate is held, into the bottle. After which rock the plate backwards and forwards with the corner upon the neck of the bottle, so as to prevent the formation of lines in the collodion, and place it upon the dipper of a nitrate-bath, where it may remain from one to five minutes according to the temperature. It is now ready to be excited.

To Excite the Collodion Film.—This is done by immersing the plate, as soon as the film has set, in a bath of nitrate of silver, made by dissolving thirty grains of pure nitrate of silver to the ounce of distilled water. The bath should be an upright vessel, of glass or porcelain, and moulded in one piece. Gutta-percha is frequently employed; but although very good for the purpose, it is hardly so trustworthy as glass, and some operators have complained of gutta-percha baths communicating impurities to the nitrate-bath, and putting it out of order. The plate should be completely immersed without pausing, as that would occasion a line across it. It should remain in the bath during a minute, moved up and down two or three times to take the ether from its surface, and allow an even coating of the silver salt to be formed. After this it is permitted to remain during two or three minutes longer according to the temperature and the strength of the bath. Three minutes suffice when the bath is at 60° to 65°. The film will now exhibit an even coating of yellow iodide of silver. It should be drained for a few seconds over the bath, the back of it wiped with blotting paper, and then put into the dark slide.

It is important that the nitrate-bath be made with pure nitrate of silver, obtained by dissolving silver in pure nitric acid. When common commercial nitrate of silver is used, it is impossible to obtain good results with certainty and uniformity, and it generally becomes necessary to add acetate of silver to the bath in order to obtain sufficient density in the blacks. When the nitrate of silver is pure, and nearly all the free nitric acid got rid of by redissolving and recrystallizing it, the bath works well without any additions. It gradually acquires iodide of silver, nitrate of potassa, and organic impurities by use.

It may be remarked that by leaving the plate in the bath longer than is requisite, and when the collodion is tender, or has been introduced before it has sufficiently dried and acquired proper tenacity, it frequently cracks and drops in fragments into the bath. If the collodion be good and moderately old, the excited plate possessing an opal hue suffers no injury by remaining a little longer immersed; but when the bath is fresh, it should be taken out as soon as it becomes sufficiently excited, otherwise the iodide on the plate will be attacked. Some photographers obviate this inconvenience by adding about one grain of iodide of silver to the ounce measure of silver solution.

The Exposure in the Camera.—This is a point on which it is impossible to give exact directions; but the faults due to over and under-exposure may be clearly pointed out. In an under-exposed picture the details of the shadows cannot be brought out, and the

blacks acquire excessive opacity. In an over-exposed picture the details of the shadows appear before the blacks have had time to become sufficiently intense; and, since the development cannot then be sufficiently prolonged, the result is a flat feeble picture, deficient in contrasts.

The proper time of exposure depends on the aperture of the lens and its focal length, and it varies *directly* as the square of the focal length, and *inversely* as the square of the diameter of the aperture, when different lenses are employed. By the focal length is meant the distance of the *focus*, or point of convergence of the rays, from the centre of the lens; that is, the distance at which the image on the screen appears quite distinct.

To Develop the Latent Image.—Hold the plate in the left hand by one corner, or place it upon a leveling stand, and pour over it a sufficient quantity to cover it, of either of the following mixtures:—

	Hunt's.	Delamotte's.
Pyrogallic acid,	1 grain...	5 grains... 9 grains.
Water,	1 ounce..	10 ounces.. 3 ounces.
Glacial acetic acid, ..	1 scruple.	40 drops... 2 drachms.

In a minute or less the dark parts of the image appear, and are soon followed by the half tones and finer details in the shadows. Let the developer flow backwards and forwards over the plate until the picture is fully out, and sufficiently dense. If the collodion is good, and the nitrate bath in good order, the development need not be hurried, but may occupy several minutes. Under some circumstances it may be well to add a few drops of solution of nitrate of silver to the developer in a measure, and pour it again over the plate, in order to give the blacks greater intensity.

When the negative is fully out in all its details, wash it well with water.

Some persons use a developer composed of protosulphate of iron, thus:—

Distilled water,	1 ounce.
Protosulphate of iron,	5 grains or more.
Acetic acid,	5 minims or more.

A shorter exposure will then suffice, and the contrasts of white and black are less violent, and half tones prevail to a greater extent. The mode of treatment is the same as with pyrogallic acid. Nitrate of the protoxide of iron is sometimes substituted for the sulphate.

To Fix and Finish the Picture.—When the plate has been well washed after the development, by pouring water over it from a jug, the yellow iodide of silver should be dissolved out by means of either a saturated solution of hyposulphite of soda, or a solution of cyanide of potassium—strength about five grains to the ounce of water. This should be poured over the plate, and should be allowed to run backwards and forwards over it until the whole of the yellow iodide of silver in the plate has disappeared; after which it should be thoroughly well washed, by pouring water over it from a jug, and set up to drain and dry; or it may be dried before a fire. It is then ready to be varnished.

The best kind of varnish to apply to a cold plate is made by dissolving powdered dammara resin in benzol. This is poured over the picture in the same way as the collodion on the plate. It dries in a few minutes. But a better varnish, used with a heated plate, is made by dissolving shell-lac in alcohol. This is called spirit varnish. Before applying it, the plate should be heated before a fire to about 100°, and after applying it, to about 150°. When dry, this varnish is extremely hard and difficult to scratch, and it protects the picture effectually from injury in printing.

The negative is now finished. An unlimited number of prints may be taken from it, by the printing process.

THE POSITIVE COLLODION PROCESS.—A collodion negative is intended to be looked *through*; a collodion positive to be looked *at*. A negative must possess density when looked through, and the color of the surface deposit is of no consequence. A positive need not possess density when looked through, and the color of the surface deposit is of great consequence, for it should be white. Hence the difference between the processes. Now it is found that organic matter combined with the silver of the image gives density and a bad surface color; while the absence of organic matter gives a good surface color, but no density. It is evident, therefore, that in the positive process an inorganic developer, such as protosulphate of iron, must be used instead of pyrogallie acid, which is an organic substance; while the nitrate bath should be acidified with nitric, and not with acetic acid. Bearing these things in mind, the processes become nearly identical in manipulation; the only difference being, that in the development of positives, the operation is much quicker, since it is only a superficial indication of detail that is wanted, and not density.

A positive is true to nature, because wherever the light acts a white precipitate of metallic silver is formed; while the parts where light does not act remain clear glass, and these are converted into dense blacks by simply applying black varnish to the back of the glass.

The nitrate-bath for positives is composed of—

Distilled water,	1 ounce.
Nitrate of silver,	40 grains.
Nitric acid,	1 minim.

The developer is made thus:—Dissolve one ounce of powdered nitrate of baryta in sixteen ounces of boiling distilled water, and when cold, add two drachms of nitric acid, specific gravity 1.42. Next add one ounce and a half of powdered protosulphate of iron. Shake well until the iron salt is dissolved. The mixture becomes white and turbid, in consequence of the formation of sulphate of baryta. Let this settle to the bottom of the bottle, and then decant and filter the clear liquid, which is of a green color, and is a mixture of protonitrate and protosulphate of iron. Add two ounces of alcohol to make it flow better over the collodion film. It is now ready for use. It deteriorates by keeping, and acts much better when fresh.

One ounce of protosulphate of iron decomposes

about one ounce of nitrate of baryta, forming insoluble sulphate of baryta, and soluble protonitrate of iron. The remaining half ounce of undecomposed protosulphate of iron forms the energetic part of the developer.

The nitric acid should be added to the nitrate of baryta, and not after the addition of the iron salt, as some sesquioxidation of the iron might then occur, which would occasion a browning of the solution, and cause a precipitate.

Some operators use nitrate of potassa instead of nitrate of baryta, but this is not right, because the sulphate of potassa formed is soluble, and remains in the solution, while the sulphate of baryta, being insoluble, can be removed. The use of acetic acid instead of nitric acid, is also wrong, because it injures the color of the whites, being an organic substance.

The development of a positive only occupies a few seconds, and it must be stopped as soon as there is the faintest indication of the details in the shadows. The plate should then be well washed to remove all traces of iron, and the picture fixed with a liquid composed of:

	Parts.
Water,	60
Cyanide of potassium,	6
Nitrate of silver,	1

The picture should be fixed with cyanide of potassium, and not with hyposulphite of soda, for two reasons;—first, because the cyanide removes more perfectly any organic compound of silver which might injure the color of the picture; and, secondly, because the hyposulphite of soda injures the color by blackening the silver.

A black ground may be given to the picture, either by backing the plate with velvet, or by passing upon it black varnish. This is made by dissolving asphaltum in benzol, and adding a little india-rubber to prevent it from cracking, a fault to which it is very liable. Printers' ink makes a good varnish, which does not crack. To apply it, rub it upon the back of the glass, and also upon a piece of paper, and then press the blackened side of the paper against the blackened side of the glass, and put the picture at once into its case. Collodion positives should always be taken in a non-reversing slide.

Positive pictures may be obtained from negatives in a variety of ways. *FRY*, after developing the image with the prosalts of iron above-described, changed the negative to a positive by pouring upon it a mixture of pyrogallie acid and hyposulphate of soda which had undergone partial decomposition, and warming gently. By this treatment the darkened parts are rendered brilliantly white from the formation of metallic silver. *ARCHER* pours a mixture of one part of a saturated solution of protochloride of mercury— Hg Cl —acidulated with hydrochloric acid and six parts of water upon one corner of the plate, and allows it to flow over the fixed negative picture. At first the shades are deepened, but quickly the appearance alters, and a very delicate white picture results. This picture may be alternately changed from positive to negative, and *vice versa*, by the agency of ammonia and the mercurial compound above applied alternately.

THE DRY COLLODION PROCESS.—In the former processes the excited collodion film is exposed and developed in its wet state, immediately after its removal from the nitrate-bath; but by attending to the following directions, it may be used dry, and kept for many months in a sensitive state. On removal from the nitrate-bath wash the film thoroughly in distilled water, so as to remove as much as possible of the free nitrate of silver from it. Then pour over it a tepid solution of gelatin, made by dissolving about six grains of gelatin to the ounce of distilled water, and adding about one drachm of alcohol, specific gravity .820. Set up the plate upon one corner against a wall to drain and dry in the dark. The exposure in the camera must be about six times longer than with wet collodion.

To develop the picture, first immerse it for a few minutes in a dish of distilled water, then pour over it the usual pyrogallie acid developer, to which a drop or two of a thirty-grain solution of nitrate of silver are added. The image comes out, and is developed as quickly as an ordinary wet collodion plate. It is then washed and finished in the usual way.

It is important to observe in this process that the measure in which the developer is mixed should be chemically clean; it ought, therefore, to be cleansed with cyanide of potassium, and well washed after every picture. In the ordinary wet process it is not absolutely necessary to take this precaution, although it is well to do so. The nitrate of silver added to the developer should be fresh solution, and not taken from the nitrate-bath.

The process just described was invented and patented by Dr. HILL NORRIS of Birmingham. It is extensively employed, and gives universal satisfaction. A very similar process has been introduced lately by Mr. FOTHERGILL; it consists in substituting albumen for gelatin, all the other operations remaining the same. When the plates are not required to be kept for more than a few days, this process succeeds pretty well; but for long keeping Dr. NORRIS's mode is the best. In FOTHERGILL's process the albumen is applied to the plate after washing off the nitrate of silver, and the plate is then washed again so as to remove the albumen. The pores of the collodion are probably filled with a compound of albumen and silver, which has been improperly termed *albuminate of silver*.

THE COLLODIO-ALBUMEN PROCESS.—This is a dry negative process which differs in an important particular from Dr. HILL NORRIS's or Mr. FOTHERGILL's. After the excited collodionized plate has been washed with water, iodized albumen is poured over it, and it is either allowed to dry, or dried before a fire. It is then insensitive to light. It is excited by immersing it in a bath of acetate of silver; after which it is washed and dried. The development is effected by immersing the plate in a solution of gallic acid, to which a few drops of acetate of silver are added. The negative is then fixed and finished in the usual way.

The iodized albumen is composed of about equal parts of albumen and water, to every ounce of which about six grains of iodide of potassium are added. This is then beaten up to a froth, and allowed to settle in the usual way. The bath of acetate of silver

contains fifty grains of nitrate of silver and one drachm of acetic acid to the ounce of water.

This process is more complicated and troublesome than any other, and the negatives are of a bad color, having a strong tinge of yellowish-green.

PRESERVATIVE PROCESSES.—In certain processes, instead of allowing the excited collodion film to get dry, a sirup is poured over it, which is completely washed off before the development. Golden sirup, honey, and oxymel have been employed. The former is probably the best, from its not containing either grape sugar—which is a reducing agent and causes partial decomposition and stains, when the plate is kept too long—or an acid, which renders the plate extremely insensitive, and destroys the half-tones. In using golden sirup, the nitrate of silver is first washed off and then the sirup applied; after exposure the plate is well washed to remove the sirup, and then developed as in Dr. NORRIS's process.

The objections to the moist preservative processes are, that wet sticky plates are liable to contract dust, and cannot be closely packed one upon the other for a journey as dry plates can. This mode of operating is, however, useful when the plate is prepared in the morning and developed in the evening of the same day.

To describe fully all the difficulties which beset the tyro in the manipulation of the various collodion processes, and to point out the causes of failure and the means of remedying them, would occupy too much space to be attempted in this work. In fact, each separate process, to be thoroughly explained and discussed, would occupy a volume. There is, however, a strong analogy between them all, and a theory which appears to include them all. This the Editor will now proceed to discuss.

THEORY OF THE COLLODION PROCESSES.—The sensitive collodion film is composed of iodide of silver, free nitrate of silver, and collodion. The iodide of silver is formed by immersing the iodized collodion film in the bath of nitrate of silver, so that iodide of potassium, plus nitrate of oxide of silver, becomes iodide of silver, plus nitrate of oxide of potassium—that is, nitrate of potassa. Now the collodion in the above combination appears to have a retarding effect on the action of light, because when a mixture of iodide of silver and nitrate of silver alone is exposed to light, it darkens more rapidly than when collodion is present. The collodion must not, therefore, be considered as an accelerator, but as the vehicle for supporting the sensitive chemicals upon the glass, and forming with the reduced silver an opaque compound in the darker parts of negatives. In the development of the picture, the pyrogallie acid accelerates the reduction of the silver salts on those parts on which the rays of sunlight have fallen, producing finely-divided metallic silver, which constitutes the blacks of the negative. The acetic acid, added to the pyrogallie developer, prevents its spontaneous or too rapid decomposition when mixed with the nitrate of silver. When, in the development of a positive, protosulphate of iron is used instead of pyrogallie acid, the difference between it and the organic acid mentioned is attributable to the fact, that it does not reduce as much of the metal as

the latter; consequently the precipitate is thin and transparent, and looks white when viewed by reflected light.

When cyanide of potassium is used to fix the picture, that is, to remove the iodide of silver, it has but little action on the image, while it decomposes the iodide of silver, and forms a soluble double cyanide of silver and potassium, together with iodide of potassium. When hyposulphite of soda is used, the iodide of silver is decomposed, and the products are a soluble double hyposulphite of silver and soda, together with iodide of sodium.

It appears that the maximum degree of sensitiveness in the film, is when it contains a certain excess of free nitrate of silver; so that, in the dry processes, the sensitiveness is reduced to a minimum by washing off the free nitrate; and in developing dry plates it is necessary to add nitrate of silver to the developer, to insure depth of shade by the deposition of more silver on the affected parts. It is necessary to wash off the free nitrate of silver from the plate for this reason, that if allowed to remain and get dry in the film it becomes concentrated by evaporation, and a concentrated solution of nitrate of silver has the property of dissolving iodide of silver, and rendering the film transparent and insensitive, by forming a salt called idonitrate of silver.

THE ALBUMEN NEGATIVE PROCESS UPON GLASS.
—As indicated in the brief historical notice to this article, albumen has long been employed upon glass as the basis of photographic pictures, so likewise has gelatin, and the results which both these yield are very satisfactory. The principal operations concerned in taking the picture with prepared albumen are, with few exceptions, the same as those practiced in working with collodion. The following description will indicate any slight differences in the manufacture.

To Prepare the Albumen.—Collect in a basin the whites of a number of eggs, carefully separating the germ, and all portions of yolk. To each ounce of this albumen add one drachm of distilled water, in which are dissolved six grains of iodide of potassium; also to every five ounces of the mixture add one drop of ammonia. Beat the whole to a stiff froth with a bunch of quills, and allow the liquid to settle till the following day.

To Albumenize the Plate.—The glass plate must first be cleaned very thoroughly, dried, and polished with a cambric handkerchief just before use. Attach to the under side of it a gutta-percha plateholder, having a wooden handle a foot long. Then breathe on the plate, and, holding it horizontally in the left hand, pour upon the centre of it a sufficient quantity of the albumen from the basin to cover it, allowing the albumen to filter through an opening in the dry froth or crust. Make the albumen flow backwards and forwards over the plate three or four times, and then allow the excess to run off into a separate basin, from which it must be carefully filtered before being used a second time. In coating the plate, be careful to remove with the point of a fine camel-hair pencil any air-bubbles which may have formed upon it. Next, take the handle of the holder between both hands, and, with the plate in a vertical position, spin it round quickly for a minute

or so, in order to drive the albumen to the edges by centrifugal force. This done, remove the excess of albumen from the edges by means of a pipette, and dry the plate before a clear fire, keeping it rotating all the time by means of the handle, as before directed. When dry it is ready for the next operation. Albumenized plates may be put away in a platebox, and kept in a dry place for a considerable time without deterioration. Care must be taken in the operation of albumenizing the plate that no particles of dust adhere to it.

Many practitioners find it more convenient to apply a dilute solution of albumen at first, and then by means of a pipette, in which as much of the prepared albumen has been taken up as will suffice for one plate, applying it in horizontal lines almost bordering upon one another. A gentle horizontal oscillating motion afterwards serves to spread it in an even layer, leaving an excess in no part. There are many other methods recommended in treatises and journals, but they need not be dwelt upon here; for every operator, knowing that the desideratum is to get a smooth homogenous layer of the albumen on the plate, will contrive in his own peculiar way to do so effectually.

To Excite the Plate.—Place it on a dipper, and immerse it quickly and without hesitation in a vertical bath of acetate of silver, made thus:—Distilled water one ounce, nitrate of silver fifty grains, glacial acetic acid one drachm. Leave it in the bath for a couple of minutes, then wash it well in clean water, and lastly in distilled water, and set it up to dry. When dry put it away in the platebox until ready for use in the camera. It may be preserved in a sensitive state for several days. Some persons add a few drops of a solution of iodide of potassium to a new nitrate-bath, and filter it on the following day, in order to saturate it with iodide of silver. When this is done a new bath is not so liable to attack the iodide of silver in the film.

The Exposure.—Albumenized plates, from which the excess of free nitrate of silver has been removed by washing, are, whether used in a dry or wet state, extremely sensitive to light; but, when only slightly washed, exposed at once, and developed with a strong developer, a much shorter exposure is sufficient. This should be timed solely with reference to the shadows, the lights being left to take care of themselves. When the camera is properly constructed, so as to prevent stray light from falling on the plate, it is hardly possible to over-expose a dry, washed, albumenized plate.

To Develop the Image.—Immerse the plate in distilled water; then place it on a levelling-stand, and pour over it a saturated solution of gallic acid, to which a few drops of acetate of silver have been added. The development occupies about twenty minutes.

To Fix the Picture.—Wash the plate in rain water, and pour over it a nearly-saturated solution of hyposulphite of soda. This will quickly remove the yellow iodide of silver from the film. Then wash the plate well under a tap, and dry it before the fire.

The negative may be varnished with any good varnish, but this is not always done.

A great many modifications have been adopted with albumen to give greater sensitiveness and quickness of

effect. Serum of milk, honey, and a dense solution of sugar have been mixed with the albumen, in order to get a coating of silver possessing more body than can be obtained by the albumen alone. HUNT introduced the use of fluoride of potassium mixed with iodide; and this method, in the hands of M. BLANQUART EVERARD, is said to be so sensitive as to give pictures on instantaneous exposure.

THE CALOTYPE OR PAPER PROCESSES.—These processes are founded on the same principle as the collodion and albumen methods, the only difference being that the vehicle for supporting the chemicals is paper instead of a collodionized or albumenized plate. They may be divided into two classes according to the mode of operation pursued, and the chief difference between them consists in the mode of rendering the paper sensitive, that is, in the order in which the ingredients are introduced, the mode of development being nearly the same in all, and merely involving a difference in the strength of the developer and the mode of applying it.

Considerable attention must be paid to the quality of the paper, for every kind is far from being applicable. That most suitable is a white paper as pure as possible from mineral matters, having a close fibre, sized either with starch or gum, and well pressed, to render the surface fine and even and homogeneous throughout. Unsized paper does not give satisfaction when silver salts are the sensitive agents, as it absorbs too much of the materials, and the picture is developed rather in the body of the material than upon its surface. These requirements are happily understood to a great degree, and manufacturers devote attention to the production of a paper possessing many of the qualities which the photographer requires.

The calotype processes may be classed under two heads. In the first the paper is coated with insensitive iodide of silver, and then excited by a weak solution of acidified gallonitrate of silver; in the second class, the paper is first coated with an alkaline iodide, and then excited by immersion in a *strong* bath of nitrate of silver, the excess of free nitrate being subsequently removed by washing. Of these, one will be selected for minute description, which appears to be, of all the calotype processes, the simplest in manipulation and most scientific in principle. In the processes of Class I. the paper is iodized with iodide of silver; in those of Class II. with a soluble alkaline iodide. The first kind of iodized paper may, for convenience, be called *argento-iodized* paper, the second kind simply *iodized* paper.

Chloride of Silver Paper.—For a variety of purposes, more especially for copying from negative pictures, papers on which a surface of chloride of silver has been produced is extensively used. The manipulations by which the above is effected consist in first saturating wholly or in part with chloride of sodium solutions, and subsequently with those of nitrate of silver; chloride of silver is formed by a well-known process of double decomposition, thus—



The strength of the solutions employed are various, dependant always upon the amount of sensitiveness required. In practice the quantity of materials per

ounce of distilled or rain water indicated below are the most general:—

	Grains. I.	Grains. II.	Grains. III.
Chloride of sodium,.....	30	25	20
Nitrate of silver,.....	120	100	60

These solutions are applied in even strata to the paper, preference being given by some persons to the alkaline salt, by others to the silver compound; and it would appear that the latter practice is more commendable, as it insures a surface better coated with the silver than if it were applied after the soda salt. The manner of coating these papers being the same as when preparing them with iodine compounds for taking impressions in the camera, and which is to be detailed, will not be dwelt upon. It may be remarked, however, that when they are to be used, the sensitive side should be recently washed with a dilute solution of nitrate of silver, as it adds considerably to the effect of the light upon them.

Iodide of Silver Paper.—It may be premised here that, however varied the methods of manipulation of different photographers may be, if they be not calculated, firstly, to secure a uniform coating of iodide of silver over every part of the surface of the paper; and, secondly, an even distribution of a small quantity of nitrate of silver, or, where great sensitiveness is required, of this salt mixed with a reducing agent—gallic acid—and an entire absence of alkaline salts before the paper is placed in the camera, they should not, as the science and practice of photography is at present understood, be adopted. Without these conditions being supplied good pictures cannot be obtained by this method.

CALOTYPE PROCESSES—CLASS I.—There are *two* methods which come under this head. In the first, argento-iodized paper is prepared by what is called the *double wash*; in the second, by the *single wash*. In all other respects the two methods are identical.

To Argento-iodize the Paper by the Double Wash.—Float the face of the paper on a bath containing twenty grains of nitrate of silver to the ounce of distilled water. Let it remain a minute or two in the bath, then hang it up to dry. Next immerse it in a solution containing twenty-five grains of iodide of potassium to the ounce of distilled water. Let it remain a minute or two in this solution, the exact time depending on the kind of paper employed, and requiring to be ascertained by experiment. If too short a time is allowed, the whole of the nitrate of silver is not decomposed, and the paper darkens in the light; if, on the contrary, too long a time is allowed, the iodide of potassium in the bath dissolves the iodide of silver in the paper. The time of immersion in the iodide-bath is therefore rather critical. On removing the paper from the bath, let it drain, and then immerse it in a pan of water, in which it must be allowed to soak, the water being changed several times, until the *whole* of the free iodide of potassium is removed. This soaking operation is rather troublesome, and the texture of the paper is decidedly injured by it. Should any excess of iodide of potassium remain in any part of the paper, it would decompose the weak exciting solution and produce insensitive iodide of silver, and consequently a white patch in the negative. When the paper has been sufficiently washed, hang it

up to dry. It is of a yellow primrose color. When dry, it may be kept for use in a portfolio. It is not sensitive to light.

To Argento-iodize the Paper by the Single Wash.—Lay the paper on a board with a piece of blotting paper under it, and brush over it a solution called *double iodide*; that is, a solution of iodide of silver in iodide of potassium. The best kind of brush is a large round one of camel's hair, bound with string or silver wire. Apply the solution copiously both longitudinally and transversely, inclining the board, and keeping a flowing edge. Hang up the paper to dry in a room having a pure atmosphere, free from sulphurous or other acid vapors. When very nearly or even quite dry, immerse the paper in a pan of water as before, to remove completely the excess of iodide of potassium which it contains. Two or more papers should not be soaked in the same pan, but each paper ought to have a separate one. When sufficiently washed—an operation which requires several hours—dry, and keep it for use.

The solution called *double iodide* is made by dissolving twenty grains of nitrate of silver in one ounce of distilled water, and adding crystals of iodide of potassium, a few at a time, until the yellow turbidity at first produced in the solution is quite cleared up. The quantity required is nearly half an ounce. The menstruum should be filtered before use.

Argento-iodized paper will retain its good qualities for some weeks. Some persons even affirm that it may be kept for an indefinite period in a dry place. It is said, on good authority, to be much improved by exposing it for an hour or two to strong sunshine. When this is done, it should not be excited immediately after insulation, but kept for some days previously in the dark, since it has been found that paper absorbs light in sufficient quantity to react on a sensitive surface placed in contact with it in the dark.

In comparing the two foregoing methods of iodizing the paper, it will be seen that the first is the most economical, but at the same time the least certain. A considerable quantity of iodide of potassium is wasted in the second mode of iodizing, and the washing operation is rather more tedious.

The paper having been iodized by either of these methods, may be proceeded with as follows:—

To Excite the Paper.—Make a saturated solution of gallic acid in cold distilled water, which call solution A; and another, by dissolving fifty grains of nitrate of silver in one ounce of distilled water, and adding one drachm of glacial acetic acid, which call solution B. Immediately before use, mix, in a chemically clean measure, one ounce of distilled water, fifteen drops of solution B, and about as many drops of solution A, the number of the latter depending on the temperature and kind of paper employed.

Lay the paper on a board with a piece of blotting paper beneath, and apply this mixture copiously to it with a clean Buckle's brush. Hold up the paper to drain for a minute, then abstract the surface moisture with clean blotting paper, and place it in the dark slide.

The Exposure.—The average time of exposure, with

a good light, a lens of fifteen inches focus, and a half-inch stop, is seven minutes.

To Develop the Picture.—Lay it on a board, and brush over it with a clean Buckle's brush, a mixture composed of three parts of solution A, and two parts of solution B. The picture, the darker parts of which are at first faintly visible, soon comes out of a fiery red tint. At this stage of the development it is necessary to check it, in order to obtain dense blacks instead of feeble reds in the darker parts of the negative. To accomplish this, brush over the picture, and complete the development with a solution of gallic acid alone.

Under this treatment the reds soon darken and intensify, and become eventually opaque blacks. The active development should occupy about twenty minutes. It is an excellent plan, after having brushed on the gallic acid, to lay the paper face downwards on a horizontal glass slab, on which a quantity of gallic acid solution has been previously spread.

To Fix the Picture.—When the details are fully out, and the blacks of the proper intensity, wash the negative with water, and then immerse it in a solution containing one part of hyposulphite of soda to four of water. Let it remain until the whole of the yellow iodide of silver dissolves; then wash and soak in water for several hours, changing the water several times, in order to remove the whole of the hyposulphite from the paper, and hang it up to dry.

The negative is now finished, and may be waxed at any convenient time in order to render it more transparent. This is done by melting some white wax in a vessel placed in a shallow pan of boiling water, applying it with a clean hogs'-hair paint-brush to the picture, which should be placed between sheets of blotting paper, and a moderately-hot iron passed over the whole until no shining patches of wax are seen.

There are one or two important points to be observed in this process. If the iodized paper is excited with a weak solution of aceto-nitrate of silver containing no admixture of gallic acid, it is quite as sensitive, or even more sensitive than before, but the negative is devoid of density, and the dark portions are grey, feeble, and metallic, like the dark parts of a collodion positive on glass when viewed by transmitted light. This shows that it is necessary to employ a substance—gallic acid—that will continue, as it were, the chemical effect of the radiant agent, or the proper tones cannot be produced. If, on the other hand, too much gallic acid is added to this solution, the reducing effect will be so great that the paper is liable to become brown all over, particularly in hot weather. The process has, therefore, its drawbacks and uncertainties, particularly in that season of the year when photographic tourists are most in want of a good process. A good test of the proper state of the sensitive paper is to take a strip into the light. If it darkens instantly to a cold grey tint, incapable of being intensified by the further action of light, the negatives will probably be grey and feeble; but if it assumes a redder tint, which becomes still darker by continuing the exposure, there is sufficient matter present to give a good intense picture.

CALOTYPE PROCESSES—CLASS II.—In these processes the operations consist in first impregnating the

paper with an alkaline iodide; next, rendering it sensitive by immersion in a strong bath of aceto-nitrate of silver; and developing with gallionitrate of silver rather weaker than that used in the foregoing process.

To Iodize the Paper.—Immerse a number of sheets, one at a time, in a solution of iodide of potassium containing twenty grains of the salt to the ounce of distilled water. Let them remain together in the bath for at least a couple of hours, then hang up to dry, after which they may be kept in a portfolio for use.

To Excite the Paper.—Immerse it in a bath of acetonitrate of silver, containing thirty-five grains of nitrate of silver, and two scruples of glacial acetic acid to the ounce of water. First, float the face of the paper for a few seconds on the bath, then immerse it entirely for nearly three minutes, and then remove it into a dish of distilled water. Rinse well, then press it between blotting paper and put it into the slide, with its face to the front shutter.

The Exposure.—This is about the same as in the former process.

The Development.—The paper will scarcely exhibit any trace of an image. Immerse it in a solution of gallic acid, to which a few drops of aceto-nitrate have been added. The picture should not exhibit itself of a grey tint but red, which should darken in the course of the development to an intense black in the deepest parts. The dish should be chemically clean, and the developer should remain colorless throughout; the whites of the picture will not then be discolored, and the development will proceed much more quickly.

If the picture comes out grey and metallic, exhibiting all the detail, and having but little intensity, it indicates a want of a reducing agent in the sensitive film. To remedy this, add a little citrate of soda to the iodizing solution. This will entirely alter the character of the picture, increasing the density of the black, and also the necessary time of exposure. Sugar, honey, gelatin, and substances of this kind added in large quantity to the iodizing solution produce little or no effect. Serum of milk contains some organic salts—lactates—which are decomposed and form corresponding salts of silver.

As a rule, it may be considered that organic salts, which at once decompose nitrate of silver and form an insoluble organic compound with oxide of silver, act most powerfully in producing blacks; for instance, as gallic acid, which when added to nitrate of silver, forms a mixture which is immediately decomposed by light, metallic silver being produced. It is a convenient plan, when travelling, to develop without a dish, by turning up the edges of the picture and making it into a tray, into which the developer may be poured and spread with a glass rod.

To Fix the Picture.—Proceed as described in the former process.

Having described the simplest form of the second class of processes, it remains to indicate the various modifications which it has assumed. The first and most important of these consists in waxing the paper before iodizing it. This modification has received the name of the *Waxed-paper Process*.

Wax being nearly inert as regards its power of com-

bining with silver and forming an organic compound of that metal, its presence does not modify the character of the negative in any appreciable way as regards density; nor does it appear that any other good is derived from the introduction of wax in the first stage of the process, than stiffening the paper, and rendering it less liable to be torn in the various operations. The wax and fatty impurities contained in all the commercial samples cause it to repel water, so that there is some difficulty in getting a sheet of waxed paper to imbibe the solutions. This may be overcome by dissolving a few shreds of gelatin in the iodizing solution, and by adding a little alcohol to the gallic acid. In all other respects the waxed-paper process is the same as that previously described.

The other processes of Class II. are merely modifications of the waxed-paper process in its simplest and best form, as described above. They consist in adding various organic substances, such as rice-water, gelatin, honey, and the like, and also bromides, cyanides, fluorides, *et cetera*, to the iodizing solution. Most of these organic substances are nearly, if not absolutely inert, and many of the salts added are of very questionable utility. It would appear, however, that the bromide of potassium may be employed to replace the iodide of this base with a good effect, especially in taking landscape views, since it gives a better result as to light and shade. A word or two may be said on the subject of substituting iodide of cadmium for iodide of potassium in the paper processes. It is a tolerably good salt to employ when pure, and the negative is free from the white spots which sometimes occur when a crystal of iodide of potassium remains undecomposed. But the nitrate of cadmium introduced into the nitrate-bath has an acid reaction which resembles, in a slight degree, the reaction of the nitric acid. This renders the paper less sensitive, increases the difficulties of bringing out the details of the shadows, and diminishes the density of the blacks.

Before concluding an article which embraces a description of the most important modes at present known, of obtaining negatives on paper, it may be well to discuss the points in which these processes are inferior to the analogous ones on glass.

The principal fault of a calotype negative consists in the fact, that a sheet of paper, waxed in the ordinary way, is not evenly transparent when held against the light, but exhibits a granular appearance, and sometimes the marks of the wire frame used in its manufacture. Before a paper negative can be expected to rival one on glass, this radical defect must be overcome. Now, it will be found that if a sheet of paper is dipped for a minute or two in linseed oil and dried, it will exhibit precisely the same defects as one that is waxed; but if left in the oil for a week, so as to imbibe it thoroughly, it will appear as evenly transparent as could possibly be desired. It is obvious, therefore, that the radical fault of a calotype negative consists in the paper not thoroughly imbibing the wax, which would evidently be a work, not of minutes but of hours, or even days. Fortunately, however, the inconvenience may be repaired by a very simple process. If one half of a sheet of paper be immersed in a mixture con-

taining equal parts of hydrochloric acid and water, thoroughly rinsed in several changes of water, and dried, it will be found, in waxing the whole sheet, that the half which has been treated in the manner described imbibes the wax much more readily than the other half, and presents a beautifully even appearance.

A finished negative on plain paper may be treated with hydrochloric acid with perfect safety, since it does not attack the image, unless very strong.

Another frequent defect of paper negatives is a want of half tone, too great intensity in the blacks, and too little detail in the shadows. In such cases the fault may generally be corrected by lessening the quantity of the organic reducing agent, by diminishing the acidity of the nitrate-bath, and increasing the time of exposure.

Lastly, the paper processes are very insensitive when compared with wet collodion. This may proceed from the great quantity of acid used in the acetone-nitrate-bath in paper work, as compared with the neutral, or, at least, but slightly acid one, in collodion work.

The best paper to employ in these processes is HOLLINGWORTH'S *thin* photographic paper; WHATMAN'S is also recommended.

THE PRINTING PROCESSES.—There are several methods of printing positives from a negative. Some of these consist in producing prints upon paper, others in producing prints upon glass, which are intended to be viewed as transparencies. The negative processes are always employed for the latter, and the negative is either copied by superposition upon a dry albumenized or collodionized plate, or by means of a lens upon a wet one. In the former case, an exposure of a second or two to diffused light is sufficient. In the latter, a portrait lens is employed, with a stop between the lenses, and the time of exposure depends on the size of the stop. The negative should be so placed as that the light from the northern sky is transmitted through it. Stereoscopic transparent prints are very beautiful when properly executed.

There are many ways of printing upon paper. They may be classified as *carbon printing*, *uranium printing*, *ink printing*, and *silver printing*. These various processes differ in principle, and must be treated separately.

Carbon Printing.—This process is the most economical, simple, and permanent of any. As first practised and published by Mr. POUNCY of Dorchester, it consists in blackening a sheet of paper all over with a mixture of vegetal carbon, gum arabic, and bichromate of potassa, drying it, and exposing it to light under a negative. Where the light acts the bichromate is reduced, and the black mixture rendered insoluble. The paper is then immersed for some hours in water, which entirely removes the unaltered carbon mixture from the paper, leaving the lights tolerably pure. The print is then finished.

Simple as this process may appear, it was found to succeed only in the hands of the inventor, who disposed of it for a sum of money, reserving to himself the sale and secret of a peculiar paper which he professed to be essential to its success. Even in Mr. POUNCY'S prints the lights were by no means quite pure, and the blacks were disfigured by a yellowish or greenish tinge; while many experienced photographers who had sub-

scribed to raise the amount demanded for the publication of the secret, complained that, after following most carefully the inventor's published directions and using his own paper, their efforts had resulted only in repeated failures. While this article is going through the press, however, the Editor learns that the difficulties and uncertainty attending the process have been overcome by an amateur photographer, Mr. W. BLAIR of Perth, who observed that the greater part of the black compound lay on the surface of the paper, without penetrating it, thereby preventing the light which passed through the negative from reaching the paper; and what did reach the paper acted with greater or less effect at different points, according to the varying thickness of the carbon coating, which it is impossible to spread with the brush with absolute regularity. On thinking over this matter it occurred to him, that to get a good picture with anything like certainty and ease, the process must in some way be reversed, and that the carbon must be *lighted* or *sunned* from the other side, that is, on the side *next the paper*; and that the only way to do this was to use thin paper, and turn the back or white side of it to the negative. Having found by experiment, also, that something must be laid on the paper besides the very soluble gum, to prevent the carbon from being removed in the final washing, and conceiving that albumen possessed the desired property, he tried the *reversed* method with MARION'S albumenized thin paper, and found it to succeed perfectly, yielding, with full sunshine and an exposure of one or two hours, prints which are pronounced by a high photographic authority to be remarkable for the vigor of the blacks and the purity of the whites. The blacks, says Mr. SUTTON, precisely resemble those of an engraving, being entirely devoid of gloss, free from the greenish yellow tinge observable in Mr. POUNCY'S prints, and reminding one of black cloth. If the process, on further trial, shall continue to deserve these commendations, it will be creditable to Mr. BLAIR, that, unlike many photographers, he has given his secret to the world gratuitously: for carbon printing, on account of the absolute permanence which it ensures—a quality which has long been the great desideratum in photography—must ultimately, if carried to high perfection, supersede all other processes.

Uranium Printing.—In this process a sheet of paper is immersed in a saturated solution of nitrate of uranium, and dried in the dark. It is then exposed under a negative to sunshine for a few minutes. Where the light acts, the uranic salt is reduced, and a faint positive picture obtained. This is intensified to a deep purple tint by immersing the paper in a solution of chloride of gold; strength, half a grain to the ounce of distilled water. After which it is well washed in water, dried, and the print is finished.

Ink Printing.—By means of this process, positive prints may be obtained in common writing ink. A sheet of paper is immersed in a nearly saturated solution of bichromate of potassa, and dried. It is then exposed under a negative to sunshine for a few minutes. Where the light acts the bichromate is reduced, and a brown positive upon a yellow ground obtained. This is well

washed in many changes of water, and the yellow bichromate thereby removed. The print is now fixed, and is of a pale brown tint upon a white ground. It is intensified by being immersed for a few minutes in a solution of protosulphate of iron, five grains to the ounce; then washed in several changes of water; and, lastly, immersed in a moderately strong solution of tannic acid. The ferruginous salt, which adheres only to the image, is thereby converted into tannate of iron, or common writing ink.

The Silver Printing Processes.—There are two different methods of printing with the salts of silver—one called sun printing, in which the print is produced in its full intensity by exposing a sensitive paper to light under a negative; the other, called development printing, in which a faint image, obtained by the direct action of light, is intensified by a process of development.

In sun printing, the paper may be either plain or albumenized; but as the methods of toning the print are different in the two cases, they must be described separately.

Sun Printing upon Plain Paper.—Dissolve, with the aid of heat, four grains of gelatin and four grains of common salt to the ounce of filtered rain water. When cold strain it through a fine muslin into a shallow dish larger than the sheet of paper to be printed upon. Use the best Saxe paper, and float the face of it for a couple of minutes upon the above solution. Hang it up by one corner to dry. When dry lay it upon a board, and brush over it a solution of ammonio-nitrate of silver, made thus:—Dissolve fifty grains of nitrate of silver to the ounce of distilled water, and add liquor ammoniæ to the solution, drop by drop, until the brown turbidity, which is at first formed, is entirely redissolved, and the liquid rendered again clear and colorless. This turbidity is due to oxide of silver which is at first thrown down, and then redissolved by the addition of more ammonia. The best kind of brush to employ is what is called a Buckle's brush, made by pushing a tuft of cotton wool into the open end of a glass tube. The paper should be brushed, first longitudinally, then transversely, and after being left to imbibe for two or three minutes, it should be brushed again, then hung up to dry. As soon as it is dry—for it would turn brown by keeping—it should be exposed to light under the negative until it is rather deeply printed, then taken from the pressure frame, well washed in rain water, then in water to which a few drops of ammonia are added, afterwards in water again. The picture is now a deep slate color, and still sensitive to light.

The next process is to tone it, that is, to substitute gold or oxide of gold, for the silver, which forms the shadows of the picture. This is done by immersing the print for two or three minutes in the following solution:—

Distilled water,	2 ounces.
Hyposulphite of gold and soda,	1 grain.
Pure hydrochloric acid,	5 minims.

In this bath the tint of the shadows changes to a deep purple, and the lights sometimes become slightly yellower. While in the toning-bath the changes of color may be watched by feeble diffused daylight. The

print must then be washed in several changes of water, until all traces of acidity are removed, and fixed by immersion in a solution of one part of hyposulphite of soda to twenty parts of water. In this it should remain about twenty minutes, and the solution should then be thrown away, and the print well washed and soaked in water, many times changed during some hours, after which it is dried. The print is then finished.

Sun Printing upon Albumenized Paper.—A mixture of equal parts of albumen and water, to every fluid ounce of which six grains of salt are added, must be beaten up to a froth, and allowed to settle. Filter the clear liquid through two layers of damped muslin into a shallow dish, and float the sheet of paper—CANSON'S or MARION'S—upon it for a minute, then hang it up to dry. When exsiccated excite it by floating it upon a solution of nitrate of silver, containing forty grains to the ounce of distilled water. Hang it up to dry. The paper should be exposed under the negative until the print is darker than it is intended to be ultimately. On removal from the pressure frame put the print into the following solution:—One part hyposulphite of soda to six parts of water, to every ounce of which half a grain of chloride of gold is added. Leave it in the solution until the red tint which it at first assumes has deepened considerably. Then remove it, wash it in several changes of water, and let it soak for several hours; desiccate it, and it is finished.

Printing by Development.—HOLLINGWORTH'S thin paper is to be preferred to any other. Immerse it in a solution containing six grains of salt and one part of iodide of potassium to the ounce of rain water. When dry, brush over it, precisely as in the ammonio-nitrate process, the following solution of nitrate of silver:—

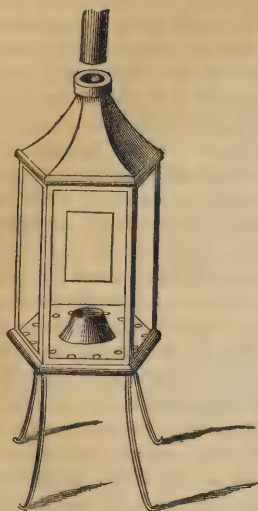
Distilled water,	1 ounce.
Nitrate of silver,	30 grains.
Lemon juice,	6 drops.

Expose in the pressure frame until a faint image is produced; this will require a few seconds only. Then turn up the edges of the paper so as to form the print into a tray; place it upon a perfectly horizontal sheet of glass, and pour into it a small quantity of a saturated solution of gallic acid, which spread quickly over all parts of the print with a bent glass rod. The image immediately begins to intensify. At first it comes out of a fiery red tint, which ultimately passes to a black. As soon as it is sufficiently developed, wash it in two or three changes of water, and fix it by the same treatment as that described in the ammonio-nitrate process; but gold toning is unnecessary. Prints produced by this, or by the ammonio-nitrate process with gold toning, are permanent. Those printed by the albumenized paper process frequently fade.

Before closing this part of the subject, it may be mentioned that the light of the sun is not directly essential to the production of pictures, the light of the moon and stars being sufficient to give an impression of those bodies—a fact highly interesting to astronomers. Considerable condensation of the light is required, and also a lengthened exposure. With the exception of the mechanical adaptations for throwing the light on the sensitive plate, and retaining the image on the same

part during the necessary time, the operations are the same as in ordinary photographic practice. A

Fig. 413.



method has recently been invented by Mr. JOHN MOULE of London for taking positive photographs by means of artificial light, and which is reported to be quite satisfactory. The author has given the method the title Photogenic, and the apparatus suited for the purpose he calls the *Photogen*. The latter is a kind of lamp, hexagonal in form, and supported upon a stand of suitable height. The base, frame, dome, and chimney are of galvanized iron, and the sides of glass. In the bottom, as shown in the sketch—Fig. 413—are a number of holes to admit air, and a pan is fixed in the centre, wherein the combustibles for yielding the artificial light are consumed. The composition which the inventor uses is—

Pure saltpetre—nitrate of potassa,.....	112 parts.
Flowers of sulphur,	42 "
Black antimony—sulphide,.....	12 "

It is said that the light emitted by the combustion of this matter is highly charged with the actinic rays that effect the decomposition of the photographic agents, and that the portraits which are taken by it leave nothing to be desired. A square of blue glass introduced between the light and the sitter protects the latter from the glare, at the same time that it does not weaken the effect in the camera. All the other operations are the same as when taking portraits in the sunlight. It is needless to say that the invention, when it becomes more known, will be a great acquisition to photographers and amateurs generally, as it will place them beyond dependence upon the changes of the weather in times and seasons.

PHOTO-LITHOGRAPHY.—This is a process of obtaining a lithograph upon stone by means of photography, from which copies may be printed in printers' ink in the usual way. The best method appears to be that which was recently patented in England by Messrs. CUTTING and BRADFORD of Boston, U.S.

They spread a composition of water, one quart; gum arabic, four ounces; sugar, one hundred and sixty grains, and bichromate of potassa, one hundred and sixty grains upon the stone, which must be preserved in the dark until required, and when the coating is dried it may be exposed in the camera a suitable length of time, or it may be covered by the print or picture to be reproduced and exposed to the light. After it is thus *lighted* it is washed with a solution of soap, which removes the coating from

every part, except where the light has operated in rendering the gum and chromium compound insoluble in the menstruum.

It would appear, by the terms of the specification, that an insoluble soap is supposed to be deposited, or produced, on the surface of the stone, but the explanation given by the patentees is very dubious.

The most delicate grades and tints of light and shade may thus be produced upon the stone, true to nature as the photographic picture itself. The stone having been thoroughly washed with clean water and dried, now receives a coating of ink from the roller, which, uniting with the soap already deposited thereon, serves to give additional body to the picture, and shortly after the stone is ready for the printer; the portions which have been protected by the undissolved or *lighted* gum when wet resisting the ink.

Previous to the commencement of the above-described process the stone is to be prepared, and this preparation will vary according to the nature of the picture or subject to be produced. If it be a manuscript, a lithograph, line engraving, or any plan or line drawing without gradations of light or shadow, running the one into the other, a polished surface may be employed. This will not answer, however, so well for portraits, landscapes, and a great variety of other pictures in which the variations of shade blend the one into the other: in such cases it becomes necessary to give the stone a roughened surface, or, in the language of the workman, the stone is *grained*. Into such a surface the chromated solution of gum sinks deeper, and is then removed more or less according as it has been fixed by the light, and thus the required variations of intensity and the gradations of light and shadow are produced. Where a polished stone is employed, the chromated gum lies upon the surface, and it is found that the variations of light and shadow cannot be produced with that nicety necessary to make a perfect graduated picture such as a portrait that shall be easily printed.

The claim of the patentee is simply confined to the use of gum-arabic mixed with sugar, and of soap for removing the unchanged coating, and depositing an insoluble saponaceous film on the stone, that enables the latter to combine with the ink. All the other ingredients may be modified as to quantity at pleasure.

PHOTOGLYPHIC ENGRAVING.—The process thus designated was patented by Mr. FOX TALBOT in April, 1858; it consists in etching, by purely chemical means, a positive photograph printed upon a copper plate.

Plates of steel, copper, or zinc, such as are commonly used by engravers, are employed. Before using a plate its surface should be well cleaned. It should then be rubbed with a linen cloth dipped in a mixture of caustic soda and whiting, in order to remove any remaining trace of greasiness. The plate is then to be rubbed dry with another linen cloth. This process is then to be repeated, after which the plate is in general sufficiently clean.

The sensitive coating for receiving the image, is prepared by adding to about a quarter of an ounce of gelatin, dissolved in eight or ten ounces of water, by the aid of heat, one ounce, by measure, of a saturated solution of bichromate of potassa in water, and straining

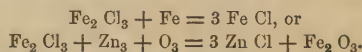
the mixture through a linen cloth. The best sort of gelatin for the purpose is that used by cooks and confectioners, and commonly sold under this name. In default of this, isinglass may be used, but it does not answer so well. Some specimens of isinglass have an acidity which slightly corrodes and injures the metal plates. If this accident occurs, ammonia should be added to the mixture, which will be found to correct it. This mixture of gelatin and bichromate of potassa keeps good for several months, owing to the antiseptic and preserving power of the bichromate. It remains liquid and ready for use at any time during the summer months, but in cold weather it becomes a jelly, and has to be warmed before employing it. It should be kept in a cupboard or dark place. The proportions given above are convenient, but they may be considerably varied without injuring the result. The engraving process should be carried on in a partially darkened room, and is performed as follows:—

A little of the prepared gelatin is poured on the plate to be engraved, which is then held vertically, and the superfluous liquid allowed to drain off at one of the corners. It is then held in a horizontal position over a spirit lamp, which soon dries the gelatin, and the latter is left as a thin film of a pale yellow color, covering the metallic surface, and generally bordered with several narrow bands of prismatic colors. These tints are of use to the operator, by enabling him to judge of the thinness of the film. When it is very thin, the prismatic colors are seen over the whole surface of the plate. Such plates often make excellent engravings; nevertheless, it is perhaps safer to use gelatin films which are a little thicker. Experience alone can guide the operator to the best result. The object to be engraved is then laid on the metal plate, and screwed down upon it in a photographic copying frame. Such objects may be either material substances, as lace, the leaves of plants, *et cetera*, or they may be engravings, writings, photographs, or the like.

The plate bearing the object upon it is then to be placed in the sunshine, for a space of time varying from one to several minutes, according to circumstances; or else it may be placed in common daylight, but of course for a longer time. As in other photographic processes, the judgment of the operator is here called into play, and his experience guides him as to the proper time of exposure. When the frame is withdrawn from the light, and the object removed from the plate, a faint image is seen upon it, the yellow color of the gelatin having turned brown wherever the light has acted. The process, thus far, is similar to one which was patented by TALBOT in 1852. The novelty of the invention consists in the improved method by which the photographic image, obtained in the manner above described, is engraved upon the metal plate. The first improvement dispenses with the operation of washing the plate bearing the copied image in water, or a weak alcoholic solution, in order to dissolve the gelatin from the parts on which the light had not fallen, as recommended in TALBOT's patent of 1852. Instead of this, he immediately spreads over the surface of the plate bearing the picture, carefully and very evenly, a

little finely-powdered gum copal—in default of which common resin may be employed. It is much easier to spread this resinous powder evenly upon the surface of the gelatin, than it is to do so upon the naked surface of a metal plate. The chief error the operator has to guard against, is that of putting on too much of the powder; the best results are obtained by using a very thin layer of it, provided it is uniformly distributed. If too much of the powder is laid on it impedes the action of the etching liquid. When the plate has been thus very thinly powdered with copal, it is held horizontally over a spirit-lamp, in order to melt the gum. This requires a considerable heat. It might be supposed that this heating of the plate after the formation of a delicate photographic image upon it, would disturb and injure the image, but it has no such effect. The melting of the copal is known by its change of color. The plate should then be withdrawn from the lamp and suffered to cool. This process he calls the laying an aquatint ground upon the gelatin, and which he considers a new process. In the common mode of laying an aquatint ground, the resinous particles are laid upon the naked surface of the metal before the engraving is commenced. The gelatin being thus covered with a layer of copal, disseminated uniformly and in minute particles, the etching liquid—sesquichloride of iron—is to be poured on. It is prepared by dissolving sesquioxide of iron, with the aid of heat, in hydrochloric acid. After straining the solution to remove impurities, it is evaporated till it is considerably reduced in volume, and is then poured off into bottles of a convenient capacity. As it cools, it solidifies into a brown semi-crystalline mass. The bottles are then well corked up and kept for use.

This substance, when laid upon a metallic surface of iron, copper, or zinc, attacks these bodies by virtue of its excess of acid, being itself reduced to the state of a protosalt of iron, or if the action be continued with exposure to air, to sesquioxide, thus:—



Hence its use in the present invention.

A bottle—number one—is filled with a saturated solution of sesquichloride of iron in water. A bottle—number two—with a mixture consisting of five or six parts of the saturated solution, and one part of water; and a bottle—number three—with a weaker liquid, consisting of equal parts of water and of the saturated solution. Before employing these solutions to etch the photolyphic plate, TALBOT directs that it is necessary to make trial tests of their power, by applying a portion of number two bottle to metallic surfaces prepared as directed, observing, that when the etching goes on too rapidly, a quantity of the saturated liquid in number one bottle should be added to it. On the contrary, if the etching does not commence for a few minutes, or proceeds only slowly, it is a sign that the liquid is too dense, and requires dilution either with water or the contents of the third bottle; either of which ought, however, to be added very sparingly, as a small proportion of either gives great activity to the etching liquid. After the strength and power of the solution have been

determined by three or four such trials, it may be poured on the prepared plate, and spread evenly with a camel-hair brush. The liquid penetrates the gelatin wherever the light has not acted on it, but it refuses to penetrate those parts upon which the light has sufficiently acted. In this way the etching proceeds till all the details of the picture have become visible, and present a satisfactory appearance to the eye, which generally occurs in two or three minutes, the operator stirring the liquid all the time with a camel-hair brush, and thus slightly rubbing the surface of the gelatin, which has a good effect. When it seems likely that the etching will improve no further, it must be stopped. This is done by wiping off the liquid with cotton wool, and then rapidly pouring a stream of cold water over the plate, which carries off all the remainder of it. The plate is then wiped with a clean linen cloth, and rubbed with soft whiting and water to remove the gelatin. The etching is then found to be completed.

Another etching process, very slightly differing from the former, is also recommended. When the plate is ready for etching, pour upon it a small quantity of the liquid number one—saturated solution. This should be allowed to rest upon the plate one or two minutes. It has no very apparent effect, but it acts usefully in hardening the gelatin. It is then poured off from the plate, and a sufficient quantity of solution, number two, is poured on. This effects the etching in the manner before described, and if this appears to be quite satisfactory, nothing further is required to be done. But it often happens that certain faint portions of the engraving, such as distant mountains or buildings in a landscape, refuse to appear, and as the engraving would be imperfect without them, the operator is in that case to take some of the weak liquid, number three, in a small saucer, and without pouring off the liquid, number two, which is etching the picture, to touch with a camel-hair brush, dipped in liquid, number three, those points of the picture where he wishes for an increased effect. This simple process often causes the wished-for details to appear, and that sometimes with great rapidity, so that caution is required in the operator in using this weak solution, especially lest the etching liquid should penetrate to the parts which ought to remain white. But in skilful hands its employment cannot fail to be advantageous, for it brings out soft and faint shadings, which improve the engraving, and which would otherwise probably be lost. Experience is requisite in this as in most other delicate operations connected with photography. The claims of this invention are the etching of the plate without disturbing the coating of gelatin and bichromate of potassa, by washing; the laying of an aquatint of resin or copal upon the surface of the gelatin, after the production of the image, and the application of heat to melt it, and the use and employment of sesquichloride of iron as an etching liquid instead of nitric acid, for the production of photoglyphic engravings.

PHOTOGALVANOGRAPHY.—This process, to which allusion has been made in the historical notice, page 692, consists in obtaining from a photograph, and by means of electro-plating, a metal plate in raised and

sunk parts, from which impressions can be printed in printers' ink.

The positive print—generally on paper—is laid face upwards, on a sheet of glass coated with gelatin, containing bichromate of potassa, and dried; it is then exposed to light in a pressure frame for a few hours. The time of exposure, of course, depends on the intensity of the light. Sunshine is preferred, but is not necessary. The picture on the gelatin is developed in raised and sunk parts by immersion in water. Where the light has *not* acted, the gelatin swells and forms a ridge, or a series of minute granulations, but where it *has* acted, the gelatin is hardened and does not swell. The picture thus formed is very curious, and resembles a positive by reflected light, the shadows and dark parts being rough, and the lights smooth and polished.

A mould of the picture is then taken in gutta-percha, about half an inch thick. This mould is an intaglio picture, precisely resembling the finished copperplate.

A copperplate is made from the gutta-percha mould, by electrolysis. This part of the process is very slow, occupying perhaps a week or two. The copperplate thus obtained is called the matrix. It precisely resembles the original gelatin picture.

The plate from which the proof is to be printed is obtained by the electrotype process from the matrix. This is a slower process than the last, because the copper is much thicker. It occupies about three or four weeks.

The entire operation, therefore, occupies about six weeks. From the final plate, four or five hundred good impressions may be struck in the ordinary way. A considerable number of plates may be obtained from the matrix; also of matrices from the gutta-percha mould, and of gutta-percha moulds from the gelatin picture. Here, then, are the means of almost indefinite multiplication. The most elaborate subjects may be engraved by this process in as short a time as the simplest; the amount of detail in a photograph or photogalvanograph making no difference—for light, chemistry, and electricity do the work. The time at present required for any subject is a few weeks; the time frequently spent on engravings is two or three years.

THE STEREOSCOPE.—Before closing this article on photography, it may be well to dwell for a short time upon an instrument which creates, as it were, the pictured objects anew, and gives to them all the fulness and solidity which they exhibit in nature. Such is the *stereoscope*; and it may be stated with truth that it has more than doubled the pleasure and gratification derived from the beautiful productions of the photographic art. As a full exposition of the very simple optical principles on which the stereoscope is constructed would occupy more space than can be devoted to it, the Editor will give only the leading facts connected with it, together with brief directions for the taking of portraits or pictures to be seen in this instrument. Every one knows that by its agency two dissimilar pictures, of the same object or group of objects, placed on the same plane at a proper distance, are resolved into one; and that this exhibits all the attributes of the original, such as length, breadth, thickness, and relative distance.

The stereoscope—so named from two Greek words expressing *to see solid*—has given rise to much unpleasant discussion, with reference to the honor of its invention. There can be no doubt that Professor WHEATSTONE constructed the first reflecting stereoscope, and his memoir describing the instrument appears in the *Philosophical Transactions* for 1838, having been read before the Royal Society of London in June of that year. No claimant appears prior to this, and therefore there can be no doubt that to WHEATSTONE belongs the honor of having invented the stereoscope, or an instrument calculated to exhibit two slightly different pictures of the same object in such a manner as to produce the appearance of a single object, or group of objects, invested with the attribute of *solidity*. Sir DAVID BREWSTER, however, in the latest edition of his *Optics*, not only claims for himself the merit, to which he is justly entitled, of having invented the first really useful form of the *lenticular* stereoscope in 1844, but even prefers the claim of Mr. ELLIOT, an Edinburgh mathematician, to that of Professor WHEATSTONE, as the original inventor of the instrument. In the *Cosmos* for June, 1856, the latter distinguished philosopher indignantly confutes this statement, and cites Mr. ELLIOT's own admission, that in claiming priority of invention he labored under a mistake as to dates; having thought that a republication of WHEATSTONE's memoir which appeared in the *Philosophical Magazine* for April, 1852, was the first and original account of an instrument which had been recently invented. It appears, however, that Mr. ELLIOT is really entitled to the merit of having constructed a kind of lenticular stereoscope so early as in 1839; and the only question which remains unsettled is the claim of Professor WHEATSTONE to the prior invention of this form of the instrument also—a claim which he rests on certain expressions in a letter received from Sir DAVID BREWSTER himself. But the reader who desires fuller information on this subject is referred to the eighth volume of the *Cosmos*, and without entering further into the question of these conflicting claims, it may be stated as a fact beyond doubt that to Sir DAVID BREWSTER belongs the honour of having, in 1844, invented a lenticular stereoscope which, in convenience and portability, far excelled any other form of the instrument previously known, and first brought it into general use—an instrument which soon became very popular, and still contributes to the pleasure and gratification of thousands. Messrs. KNIGHT of London have, within the last few years, patented a new form of stereoscope, similar to BREWSTER's however, excepting the eye-tubes, which are dispensed with; their place being supplied either by a plano-concave and plano-convex lens of the same focal length, fixed to one another by their plane sides, or by prismatic ones.

The construction of the stereoscope is founded upon the faculty of binocular vision, or that property by which only one object is seen, notwithstanding that the form of it is depicted on the retina of each eye. On looking at any object it is evident that more of it is seen with the right eye on the right side than with the left, and equally the left eye observes more on the left side

than the right. Hence the picture presented to the right eye is slightly different from the view which the left takes of the same object; but by looking with both eyes all the parts noticed in the two monocular views are visible, and the pictures presented to both appear to each in the same spot, or overlap each other, so that only one object is seen, but a view of it slightly different from that which would be taken by one eye. It is partly owing to this circumstance, and partly in consequence of the greater or less convergence of the rays from the different points of an object in proportion as they are nearer or more distant, that the idea of solidity is realized; and this explains the cause of the difference observed between a picture of a bust or statue and the original, or of a landscape painting, and that which it represents.

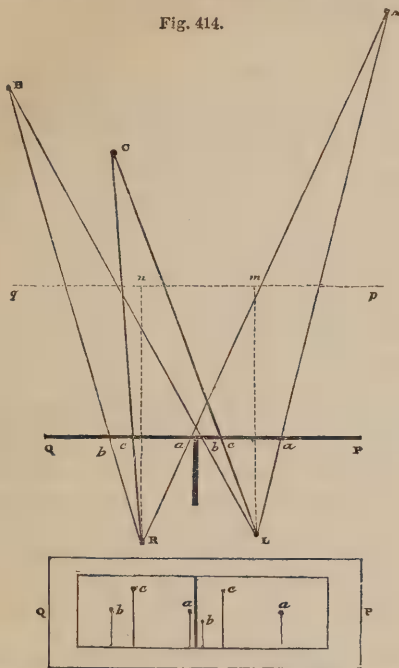
On these simple facts the stereoscope was founded, it being considered that by representing two pictures of the same object exactly corresponding to those which would be formed on the retina of each eye, the head remaining stationary, a means of converging them into one, so that they might have the appearance exhibited by them in nature, could be devised. The difficulty of producing two such pictures had been a drawback to the project; and it was not till photography had obviated this inconvenience, by producing pictures of the object corresponding to those which the right and left eye respectively take of it from a given point, that its value was fully appreciated. On looking at the stereoscopic pictures singly with both eyes, no appreciable estimate of solidity or distance can be formed. If, however, the observer could contrive so to converge the optical axes as to throw the two pictures into one, then, indeed, all the solidity possessed by the originals would appear. It is needless to say, however, that very few are capable of doing this; and, when effected, it is with much pain to the eyes. But this, which is so difficult with the unaided eye, is what the stereoscope accomplishes—that is to say, it brings the corresponding points in each picture together, and, by their coincidence, gives the appearance of solidity and distance to them, just as in natural vision the binocular pictures are resolved into one view, leaving the impression of one or a series of objects, as the case may be, having length, depth, and breadth.

To simplify this a little more, if two stereoscopic pictures of the same object be mounted, so that the distance from their centres shall be equal to that between the pupils of the human eyes, and placed at one end of a box eighteen inches long, divided by a partition, and having two holes in the other end to correspond with the eyes of the observer; on illuminating the pictures only one will be discerned in consequence of the rays from each being refracted, first from the pupil of each eye at a slight angle to the retina, and thence in a straight line till the two lines meet or converge, at which point not two, but one picture will be seen, but this one will exhibit all the details of solidity and relative distance. Such was the instrument contrived by ELLIOT; but the distance from the eyes at which it was necessary to place the pictures to bring them to coincide, is reduced by the use of reflectors or lenses, as in the instruments of WHEATSTONE, BREWSTER, and others.

Mr. SUTTON gives the following explanation of the principle of the stereoscope:—

Let L, R —Fig. 414—be the eyes of a spectator; A, B, C , lamp-posts of different heights, having lights, or luminous points, A, B, C , at the top. Draw the visual rays,

Fig. 414.



LA, LC, LB, RA, RC, RB . Cut them by a vertical plane, PQ , parallel to the line which joins L and R . Then the points a, c, b, a, c, b , where the visual rays pass through this plane will be the images of A, B, C , as seen from the stations L and R , PQ being supposed to be the plane of a perspective picture. If the plane, PQ , be placed as shown in the figure, so that the perspective view as seen from L may be completely exterior to that seen from R , the pictures will be as represented on a card beneath L and R in the lower part of the figure.

Now, if the perpendicular distance between L and the plane PQ be such that the points a, b, c can be distinctly seen by an eye at L ; that is to say, if this perpendicular distance be not too short for distinct vision, and if the card, PQ , be placed before the eyes, as in the figure, the right picture being cut off from the left eye and the left picture from the right eye by a partition, as shown, then instead of seeing two pictures, abc, abc , only one image will be seen, and that one image will appear to be the lights, A, B, C , in their natural position, and at their true distance. For when the left eye is directed to a along the line La , the right eye is directed to a along the line Ra , and the optic axes La, Ra , would meet at A , so that the spectator, instead of seeing two images, a, a , upon a plane, PQ , sees one image, A , at the true distance and in the true position of the light, A . Similarly with respect to the other images, b, c, b, c , which combine and produce single images apparently at B and C .

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It is evident that the perpendicular distance of PQ from L or R , which call F , will depend upon the size of the angle, ALB or ARB ; for the smaller that angle is, the farther the plane, PQ , may be placed from L and R , and therefore the more easy it will become for the images a, b, c , to be seen distinctly by persons of ordinary vision. Most persons can see a thing distinctly at a distance of eight inches. If then $F = 8$, the angle ALB may be about 16° .

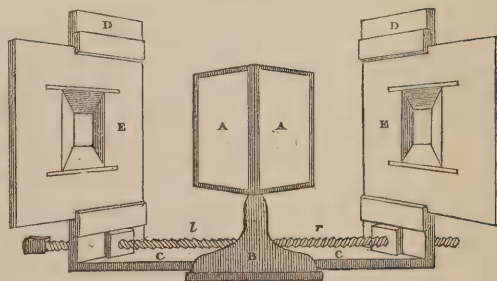
Now suppose that at each of the stations, L, R , a photographic camera is placed, the lens of which is eight inches focus, and adjusting these cameras with their axes strictly parallel, take the pictures of A, B, C , including an angle of 16° . Then when these pictures are properly mounted they will be identical with the perspective views of A, B, C , upon the plane PQ ; and if placed in a box having a partition in the middle and holes to look through at P and Q at a distance of eight inches from the pictures, the spectator on looking through the holes will perceive a single image of the points, A, B, C , at their true distance, and in their true relative positions.

A box so constructed may be called a *simple stereoscope*, because it does not involve the use either of lenses or reflectors, and the pictures properly taken and viewed in it have the inexpressible charm of truthfulness.

Of what use then, it may be asked, are lenses and reflectors? In the first place, the simple stereoscope, when adapted to persons of ordinary sight, does not include an angular field of more than 16° ; which is in general too small. A photographic picture should include at least an angular field of from 25° to 30° . This can only be effected by bringing the pictures as near to the eyes as five inches, at which distance most persons find a difficulty in seeing them distinctly; but this difficulty is overcome by placing a *whole* lens of five inches focus in each of the holes L, R , and viewing the pictures—which must be taken with a lens of five inches focus—through them.

Reflecting Stereoscope.—Fig. 415 represents the stereoscope of WHEATSTONE. It consists of two plane mirrors, AA , so adjusted as to form an angle of 90° with each other. They are fixed by their common edge against an upright, B , in such a way as to reflect the images placed in the side-frames, EE , fixed on the

Fig. 415.



upright boards, DD . The latter are attached to the sliding-boards, CC , movable from either end by the wooden screw, L , formed with a right and left hand thread for that purpose.

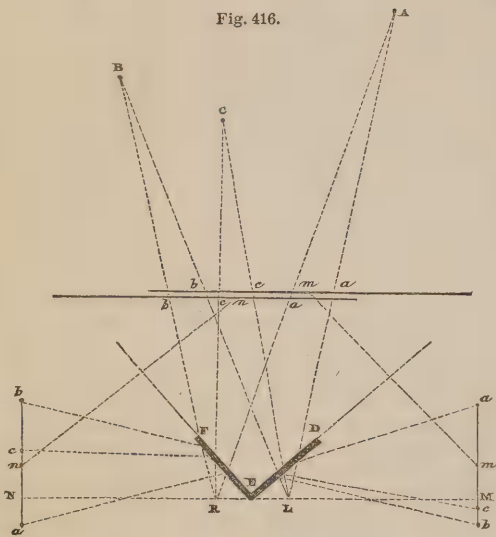
To see the pictures by this instrument, the observer

4 X

must stand before the mirrors, having the right and left eye respectively before the right and left hand mirror; then, on moving the frames EE , by the screw rl , backwards or forwards, the reflected images will be made to coincide at the optic axes and produce a single image of the same apparent magnitude as that observed. When properly executed pictures—such as are taken in a binocular camera, and which are seen with the same inclination of the optic axes—are introduced, the instrument may be simplified by omitting the screw and movable boards, the side ones being fixed in their proper places.

Mr. SUTTON, discussing the subject of the reflecting stereoscope, says:—Referring again to Fig. 414: if the visual rays are cut by a plane, $p q$, instead of $P Q$, the

Fig. 416.



pictures will be larger than before, and instead of being entirely exterior one to another, will overlap, and be, as it were, mixed together. But if the pictures be taken in cameras placed at L and R , with lenses of focal lengths Lm or Rn , having their axes parallel, and then by means of reflectors the images of the pictures so taken be thrown into their proper positions on the plane, $p q$, and these images viewed by eyes at L and R , a truthful solid image will be produced, as in the former case; because the left eye will not then see the picture from the right station, nor the right eye that from the left station. The principle of this arrangement is exhibited in Fig. 416, where DE , EF are the reflectors placed at right angles to each other, and ab , ba the pictures at right angles to the dotted line, or base, MN , passing through the point E , the distance of the reflectors from that angular point being equal to Lm or Rn , and therefore to the focal length of the lens with which the pictures are taken. The distance of the middle points, m, n , of the pictures from the dotted base, is half the distance LR . The pictures are taken in a nonreversing slide, so that their images on the plane $p q$, as seen in the reflectors, are not reversed; this is an important point to attend to. The image of the left hand picture is amb ; that of the right hand

picture bna , the lines, $p b$, $q a$, being separated for the sake of distinctness, but in point of fact the images lie on the same plane. The left eye cannot of course see the image of the right picture, and *vice versa*, so that the images overlapping produce no confusion. The image of each picture and the picture itself are symmetrically situated with respect to the reflector by which it is viewed.

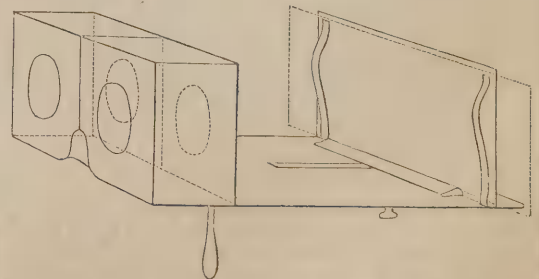
All this being understood, the mode in which the instrument acts will now be intelligible. A pencil from b in the left picture, after reflection at the left mirror, DE , enters the left eye as if it had come from the point b on the line $p b$; the point b , is therefore seen by the left eye in the direction Lb . Similarly, a pencil from b in the right picture, after reflection at the right mirror, FE , enters the right eye as if it had come from the point b on the line $q b$; the point b is therefore seen by the right eye in the direction Rb . These two lines, Rb , Lb , are the instantaneous directions of the optic axes, and being produced they meet at B , which is the true position of the object, B . Similarly with respect to the other objects, A, C . Therefore by means of the reflecting stereoscope a true representation is afforded in natural relief and actual distance of the objects in the picture.

The reflecting stereoscope is not open to any single practical or theoretical objection. As an optical instrument it is *absolutely perfect*, being subject to no defects of distortion or aberration. For any scientific purpose, therefore, the reflecting stereoscope should always be preferred to the other. The reflectors may be made of polished speculum metal if objection be raised to glass mirrors, and the pictures may be taken simultaneously in a camera with double lenses two and a half inches from centre to centre.

The Lenticular Stereoscope.—The best construction of this instrument for exhibiting paper positives is shown in Fig. 417, which scarcely needs explanation.

The *whole* lenses fixed in the front of the box are placed two and a half inches from centre to centre, and should not be less than one inch in diameter. They should be five inches focus, and achromatized meniscus lenses with the hollow side outwards; in fact the same lenses as those used for taking the pictures, which may

Fig. 417.

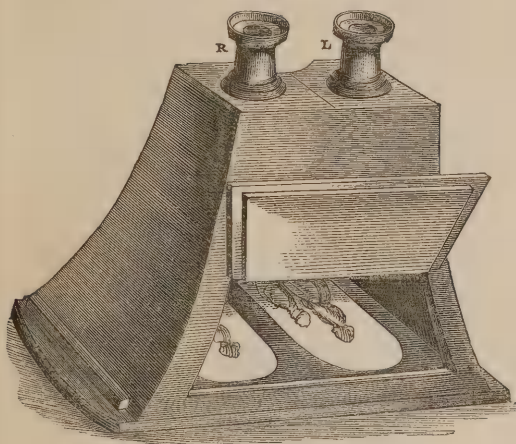


be unscrewed from the camera, and screwed to the stereoscope. The back of the solid box should have holes in it as represented by the dotted lines, and also a partition in the middle. The orifices should be two and a half inches from centre to centre, and their dia-

meter determined by trial—generally about one inch. The inside of the front box should be properly blackened. The picture may be either square or circular, mounted two and a half inches from centre to centre, and about two and one-fourth inches in diameter. By the centre of each picture is meant the point where the axis of the lens cuts it.

Brewster's Stereoscope.—The stereoscope, modified by Sir DAVID BREWSTER, is shown in its most popular form in Fig. 418. It is a box having an aperture at the bottom, but most generally at the front, as seen in the drawing; an aperture at the side allows the slide bearing the pictures to be introduced. In the two brass tubes, R, L, half or quarter lenses are fixed, so that their curved circumferences will be inwards, or nearest one another, for the purpose of aiding the eyes in bringing the pictures, or representation of them, to coincide at the point of convergence of the visual axes. The tubes are made to slide up and down to suit the focal lengths of different eyes. By adjusting the lenses, the observer, on looking through both, sees only one picture midway between the two, and exhibiting the object or objects in bold life-like relief. It is

Fig. 418.

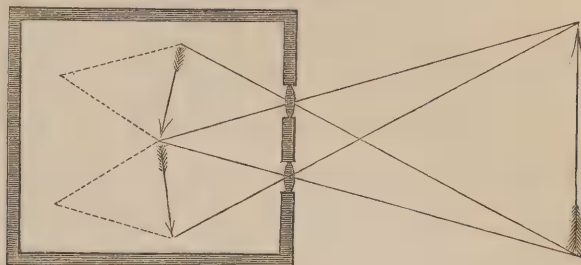


necessary to have the central points of the pictures within two and a half inches of one another, as also the tubes, in order to correspond with the position of the eyes.

Stereoscopic Pictures.—To obtain two pictures in their proper position for the stereoscope by means of one camera, it is evident that the instrument must have two apertures, and that these must correspond to the position of the eyes. The stereoscopic camera is constructed on this principle, with two lenses in front, of the same focal length, two and a half inches apart, focussing glass, and other requisites, as in the ordinary instrument. BREWSTER, however, contends that exact pictures of natural objects cannot be taken by the cameras in general use, in consequence of the lenses being too large, and causing a distortion in all the lines and portions of the object which do not fall in

the centre of the picture. He further states that it is almost impossible to take true stereoscopic portraits with a single-lensed camera, owing to the difficulty of measuring the proper angle at which the two should be taken, and of the sitter maintaining the same expression. Instead of employing two lenses, he bisects one,

Fig. 419.



and employs the half in each aperture, with the view of obtaining better results; for, as he says, it is impossible to grind or polish two lenses, whether single or achromatic, of exactly the same focal length, even when the same glass is used for both the sections. To overcome this difficulty, the single lens must be bisected and ground to a circular form, and afterwards placed in the camera with their diameters of bisection parallel to one another as in Fig. 419.

When portraits or views are to be taken in the monocular camera for the stereoscope, WHEATSTONE makes the position of the camera dependent, not upon the distance of the object from it, but upon the distance at which the pictures are observed in the stereoscope. Thus, when they are to be viewed at a distance of eight inches, he directs that the two pictures should be taken at an angle of 18° ; that is, if the object be the centre of the circle of which its distance from the camera forms the radius, the pictures must be taken from points on this circle 18° apart. BREWSTER, on the other hand deduces the angle at which the portraits or views should be taken from the distance of the subject, and the angle which the distance between the eyes subtends at that distance. This angle he finds by the formula—

$$\text{Tang. } \frac{1}{2} \Delta = \frac{\frac{1}{2} d}{D} = \frac{1.25}{D}$$

d being the distance between the eyes; D the distance of the sitter, and Δ the angle which that between the eyes—two and a half inches—subtends. By this he finds the angle formed by the two directions of the camera, when the distance of the object from it is that specified, to be as follows:—

Feet.	Degrees.
1.....	11.54
2.....	5.58
3.....	3.59
4.....	2.59
5.....	2.23
6.....	1.59
7.....	1.42
8.....	1.30
9.....	1.20
10.....	1.12

When the distance of the subject from the camera is

one hundred feet, the latter should be placed at points in the circle of which this is radius four feet distant from one another; for one hundred and fifty, six feet, and so on.

To pursue the subject of the stereoscope through all its details, as exhibited in the tubular reflecting, the single and double reflecting stereoscopes, the opera-glass, reading stereoscopes, *et cetera*, is incompatible with the limits of this work; the student who may desire further acquaintance with the subject is referred to BREWSTER on the Stereoscope, or any of the works on optical science which are to be found in libraries. The following remarks will not be out of place:—

In printing stereoscopic pictures from a negative, taken in a double-lens camera by contact in the pressure frame, it must be borne in mind that the print requires to be cut in half and the pictures transposed, in order to bring the picture that was taken from the left station before the left eye in the stereoscope, and *vice versa*. If this be not attended to, a pseudoscopic effect is produced.

In printing stereoscopic transparencies by means of a lens, the following plan may be adopted:—A copying camera, rather more than double the length of the stereoscopic camera, is provided, and the lenses of the stereoscope are fixed in the middle of it. There must also be a partition dividing the camera in half lengthwise. In this way the left lens copies the left picture, at the same time that the right does the opposite. The negative must be placed with its back next to the lenses at one end of the box, and the sensitive positive plate in a common slide at the other end. The camera is then directed towards the sky, and the wet collodion process employed. An exposure of a few seconds is sufficient. The positive need not be divided and the pictures transposed; for, when placed in the stereoscope with its plane side next to the lenses, and a ground glass laid against the film, the pictures are in their right position to be viewed. By putting the lenses midway between the negative and positive, the positive becomes of the same size as the negative. The best lenses to employ are portrait ones, with a small stop between the back and front lenses in each.

In the stereoscopes and stereoscopic pictures commonly sold there are the following five serious defects:

1. The pictures are frequently taken in converging cameras, and then mounted upon the same flat surface.

2. The pictures are generally mounted so wide apart, that the most distant objects in each are wider apart than the distance between the centres of the eyes.

3. An attempt is made to obviate the evil produced by the above practice, by using *semi*-lenses in the stereoscope, which displace the images. This of necessity produces distortion, because straight lines are always represented by curves, when the outside part of a lens is used to view objects through, instead of the centre.

4. The displacement of the images is in general so great as to cause the optic axes to converge to points situated within two or three feet from the nose, instead of the true distance of the objects. The effect of this

is to make the solid picture look like a small model of the object, which the spectator could, if he chose, lay his hand upon, or touch with a yard measure.

5. The focal length of the lenses of the stereoscope is in general six inches, while that of the lenses in the camera is only four inches. This makes objects appear much smaller than they do in nature.

To sum up: The common stereoscope and pictures make objects look very near, very small, and distorted. The lenticular stereoscope, represented in Fig. 417, makes them look of their *true* size, at their *true* distance, and without perceptible *distortion*.

In the preceding it has been announced that the object of the stereoscope is to exhibit things precisely as one sees them in natural vision; that is, with eyes two and a half inches apart. But if it be thought desirable for any purpose to represent things as one should see them, were the eyes wider apart than two and a half inches, then the distance between the stations may be exceeded.

Mr. SUTTON of Jersey kindly supplied the Editor with some valuable matter for this monograph.

PLATINUM.—*Platine*, French; *Platin*, German.—Whoever attentively regards the progress of any science, and sympathizes with those whose labors are ardently directed to its development, must, considering the difficulties that have to be overcome, necessarily feel interested in every discovery which tends to give greater certainty to their researches, and enable them to deduce laws for its extension and simplification. On this ground the subject of the present article cannot fail to recommend itself to every chemical student, since to it in a great degree may be attributed the precision observed in the results of every well-conducted analytical research. Although numerous subjects had been investigated before the discovery of platinum, and well-based conclusions drawn from them, still the methods by which these investigations were conducted were most circuitous; and, in the absence of a metal like platinum, the stoichiometrical equivalents of bodies were frequently mere approximations that required to be rectified by more appropriate apparatus and modes of analysis. In the multifarious operations of fusion, solution, evaporation, and weighing, connected with the labors of the chemist, no other substance can bear comparison with platinum. The corrosive agents used, and the unconquerable power of affinity, affected more or less all the utensils which the operator could command previous to the discovery of this metal, so that when the most devoted care was bestowed upon any research the results did not indicate the truth, and could not be depended upon even when they were rectified by an approximate estimation of the amount of the error. It is not so now; for, unlike gold, silver, or porcelain, platinum stands the test of intense heat, and so enables the operator to determine the effects of temperature and chemical action on the most refractory bodies; resists the effects of the strongest acids singly; and from the facility it offers of being forged into every convenient shape—such as basins, crucibles, weights, and the like—it facilitates working in the laboratory to a surprising extent. But it is not to the student or chemical philosopher alone that platinum is

of advantage—the manufacturer likewise is benefited by it; thus, in the distillation of sulphuric acid it can hardly be replaced by any other material, and in the preparation of drugs and extracts nothing safer than platinum can be employed.

This metal is not very abundant, though distributed in small quantities over extensive districts, and in numerous and diverse localities. The first account of it with which Europeans are acquainted is that of ANTONIO D'ULLOA, who observed it in the auriferous sands of South America. This notice was published in 1736; but the *savans* of this country and of the continent could form no idea of its nature till 1741, when Mr. WOODS, an assayer of Jamaica, sent a portion of the ore to Europe. Among the metallurgists of South America, however, it was long known, and bore the name *platina*, a diminutive of the Spanish name *plata* for silver. This term must have been applied on account of its occurrence in bright polished grains, appearing in color and brilliancy like silver. At that period, however, nothing being known of its properties further than that it possessed great weight, it was regarded as having no value, and, therefore, any quantity which might have been collected was thrown aside as useless—in fact, it was put beyond the reach of the miner, by casting it into the deep rivers, lest they might use it to sophisticate the gold they collected. On this account a large quantity of platinum ore has doubtless been put out of the reach of present or future use for a considerable time to come. WOOD gave the first scientific account of it in a paper published in the *Philosophical Transactions* in 1750; and in 1752 its proportion in the platinum sand was determined by SCHEFFER. LEWIS wrote upon it in 1754; MARGGRAF in 1757; and since then researches upon it have been published by BERGMANN, VON SICKINGEN, MUSSIN-POUSCHKIN, FOURCROY, and VAUQUELIN, WOLLASTON, DESCOTILS, TENNANT, BERZELIUS, EDWARD DAVY, DÖBNER, and CLAUS; from which investigations resulted the discovery of palladium, rhodium, iridium, osmium, and ruthenium in the ore, and all alloyed with platinum.

LOCAL SOURCES.—The principal districts which afford platinum are those of Brazil, Peru in South America, and Antioquia in the North, also the slopes of the Ural Mountains. In Borneo, and in almost all the gold-washing districts throughout the world, traces of the metal have been detected. Along the coast of the South Sea, and on the Western slopes of the Cordilleras of the Andes, between the second and sixth degree of north latitude, platinum occurs; but the most productive washings are those of Condoto in the province of Novita, of Santa Rita or Viroviro, of Santa Lucia, of the ravine of Iro, and Apoto, between Novita and Taddo. The deposit of gold and platinum is found in alluvial ground at a depth of twenty feet; both metals are separated sometimes by picking out the grains of platinum ore, and, when this method cannot be conveniently adopted, by amalgamating the gold, by which process the platinum is left.

In the provinces of Matto Grosso and Mineas Geraes in Brazil, platinum is found in the alluvial deposits which

produce gold. The ore of these localities differs from that of Peru, being met with in grains of a globular form, and which exhibit a surface made up of small spheroidal protuberances strongly adhering together, the interstices being clean and even brilliant. None of the magnetic iron ore or small zircons observed in the Peruvian product are observable in it. It is, however, mixed with small radiated or fibrous grains of palladium.

The veins of manganese in the weathered syenite near Santa Rosa de Osos, in the Columbian province of Antioquia, afford platinum; and it has been obtained from the valley of the river Jacky in Saint Domingo. Like the platinum sands of Peru, the product of this district appears in brilliant rounded grains, as if polished by friction. It yields chromium, copper, osmium, iridium, ruthenium, palladium, and probably titanium. The total quantity derived from South America does not exceed eight hundred and fifty pounds annually, a product which is much inferior to the washings in the districts of the Ural Mountains where the metal is found. In 1819 a whitish kind of gold was detected in the mine of Neiwin Körner; but its nature was not ascertained till 1822, when platinum was detected in it. Platinum washings were established in 1824, and since that period considerable quantities are annually produced by them; they are situated on the Western slopes of the chain of mountains, and the ore is met in alluvial deposits partly, and in other localities injected into the greenstone and serpentine rocks. The chief workings are at Nischne-Tagilsk, Goroblagodat—Kuschwa—Nischne-Turinsk, where the metal occurs almost without gold; Bogoslawsk in important quantities; also at Slattoust, Werch-Isetsk, Newiansk, and Bilimbajewsk. In most of these washings the platinum ore constitutes from one-four-thousandth to one-fourteen-hundredth of the sand, and contains on an average about seventy per cent. of platinum. That from Goroblagodat yields eighty-eight per cent. Another ore, osmide of iridium, is also met with in small quantity in these districts, yielding on an average two per cent. of platinum.

Platinum is also found in greater or less quantities in other countries; for instance, in the Ratoo Mountains in Borneo, and in the gold sands found on the North of Ava, black magnetic particles are collected which yield twenty per cent. of the metal. The gold sands of the Rhine afford a small per centage of platinum; so also does the palladium from Wilhelm Works on the Hartz. It has been detected in the departments De la Charente and Deux Sevres in France, in Guadalcanal in Spain, and in Ohlápian in Hungary. According to PETTENKOFFER, all silver, unless subjected to a particular process of purification, contains traces of this metal; he found it in the gold reclaimed from the furnace slags of Munich. GUEYRNARD latterly detected it in the grey copper from the Department des Hautes Alps, and in the bournonite from Saint Arey on the Mure. RITTERSON observed it in the gold sands of California, and MALLET in the auriferous gleanings from the Wicklow Mountains.

Platinum, though invariably found in the metallic state, has never been discovered pure and unalloyed.

The annexed table exhibits a few analyses of the product from different localities:—

COMPOSITION OF CRUDE PLATINUM ORES.

	Berzelius.				Svanberg.		
	a.	b.	c.	d.	e.	f.	g.
Platinum,	78.94	73.58	86.50	84.30	86.16	81.34	55.44
Palladium,	0.28	0.30	1.10	1.06	0.35	1.66	0.49
Rhodium,	0.86	1.15	1.15	3.46	2.16	3.13	6.86
Iridium,	4.97	2.35	—	1.46	1.09	2.58	27.79
Osmium,	—	—	—	1.03	0.97	0.19	trace
Iron,	11.04	12.98	8.32	5.31	8.03	7.52	4.14
Copper,	0.70	5.20	0.45	0.74	0.40	trace	8.30
Manganese,	—	—	—	—	0.10	0.31	—
Osmium-iridium,	1.96	2.30	1.40	—	1.91	1.56	—
Grains of sand,	—		—	0.60	—	—	—
Lime,	—	—	—	0.12	—	—	—
Loss,	1.25	2.14	1.08	1.92	—	—	—
	100.00	100.00	100.00	100.00	101.17	101.29	103.02

The sample *a* in the foregoing table was a dark-grey ore from Nischne-Tagilsk in the Ural, which was non-magnetic; the sample *b*, from the same locality, but magnetic; *c* was from the washings at Goroblagodat in the same region, and perfectly non-magnetic; *d* was obtained from Barbacoas, and consisted of very large grains; *e* was from Choco, an ore freed from ferruginous particles as much as possible with the magnet; *f* from the river Pinto. This variety was classified into several subvarieties; thus, *a*, rounded grains, having considerable lustre and a color inclining to leaden-grey, of specific gravity equal 17.88; *b*, angular grains, of a light grey color and little lustre, of specific gravity 17.08; *c*, rough grains, somewhat yellowish, but having black points, specific gravity 14.24; and *d*, black shining grains, specific gravity 7.99. Of these, the *a* variety was analysed, and the numbers stand under *f* in the table. The results under *g* are of the osmium-iridium from South America.

Generally the ore of platinum is met with, as already stated, in small grains; but considerable masses of the metal have occasionally been discovered. The largest lump that has been found in America is retained in Madrid; it weighs eleven thousand six hundred and forty grains, or two pounds troy, and appears in size nearly equal to a turkey's egg. This specimen was found in 1814 in the gold mine of Condoto. A lesser lump was brought from Choco by HUMBOLDT, and presented to the cabinet of Berlin; it weighs one thousand and eighty-eight grains, or little more than two and a half ounces. Much larger masses of the metal have been found in the Russian territory already mentioned. A nugget of platinum, found at Nischne-Tagilsk, and still retained in the St. Petersburg collection, weighs ten pounds fifty-four zolotnik—9.2364 Prussian pounds weight—but its specific gravity is only 16.0. Another lump of nearly double the size of the former, was discovered in 1830 in the same works; it weighs twenty pounds thirty-four zolotnik Russian—equal to 19.684 pounds avoirdupois; and later, another mass weighing 22.744 pounds was found. In the royal mineral collection of Berlin is a piece of platinum ore which was presented to the cabinet by Count DEMIDOFF.

SCHUBART states that from 1822 to 1835 no less

than thirty-one thousand and seventy-two Prussian pounds of platinum were obtained from the Ural Mountains; in 1836 one hundred and eighteen puds two pounds, and in 1848 one hundred and fourteen puds, equal to three thousand nine hundred and eighty-seven and a half Prussian pounds were obtained.

PREPARATION OF PLATINUM.—When obtained directly from the ore the difficulty of preparing the metal pure increases according to the number of other components associated with it; if the platinum be alloyed only with gold, all that is necessary is to treat it at once with nitro-hydrochloric acid till the whole is dissolved, to remove the excess of acid by evaporation, and then produce the ammonio-chloride of platinum by the addition of chloride of ammonium. The terchloride of gold may be washed out of the yellowish-red crystalline salt by water. If other metals be united with the platinum, as in the samples of which the analyses have been given above, then the sand is alternately treated with strong nitric and hydrochloric acids, till all the copper, iron, lead, and silver, manganese, *et cetera*, are removed; the washed residue is then acted upon with *aqua regia* till the whole of the metals dissolve. A moderately dilute solution of sal-ammoniac is now added to the clear filtered liquid, which should, however, be as free of acid as possible, and the precipitated double salt of ammonia and platinum collected, washed well with cold water, dried, and reduced to the metallic state. The latter operation is effected by gently heating the mass at first, and indeed till the whole of the ammoniacal salt is expelled, and subsequently bringing it to a strong red heat. The residue now will be pure metallic platinum in a very finely-divided condition, or, as it is ordinarily termed, *platinum mohr*—*platinum black*. The rhodium, palladium, osmium, and iridium, provided a little nitric acid be added previous to precipitation, remain in the mother-liquid, and can be recovered subsequently.

The product thus obtained may be again dissolved in *aqua regia*, and reprecipitated as before, when any palladium which might have been thrown down before will be removed in the liquor and washings of the ammonio-platinum salt. The metal obtained by heating to redness the last-mentioned compound, or by

electrical precipitation, by means of a plate of zinc, from an acid solution of the bichloride of platinum, is—after washing and drying, and subsequently heating to redness—in the form of a black slightly adhesive mass, which may be reduced to a powder of the same appearance, capable by pressure and friction of being made to assume the metallic lustre.

PROPERTIES.—In its purity platinum has a white color, nearly approaching to that of silver. Its density is, with the exception of iridium, the greatest of any known body. Several results nearly coinciding have been arrived at regarding its weight, among which are the following:—CLARKE found the specific gravity of hammered platinum to be 20·875; BORDA, 20·98; SICKENGEN, 21·061; WOLLASTON, 21·25; BERZELIUS, 21·45; KLAPROTH, 21·74; and CLOUD, at 62·6°, 23·543. When compressed by welding, and drawn out into thick wire, it indicated 21·4, and after being still further extended, 21·5. It is infusible at the highest temperature of a wind furnace, though capable of being welded like iron at a white heat; the temperature of the oxyhydrogen blowpipe, however, as also that of the flame of a powerful voltaic current, readily melts and even boils it, dispersing a portion into vapor, which appears to burn and form an oxide of the metal. DUMAS observed that it becomes harsh and brittle when heated powerfully in contact with charcoal, owing to its combination with a little carbon, or silica, or phosphorus. Platinum is very malleable, and, therefore, can be beaten out into very thin plates, and drawn into wires one-two-thousandth of an inch in diameter; and with proper means, such as inclosing it within a silver wire, into wire only one-thirty-thousandth of an inch. The least admixture of iridium deprives it of this quality to a greater or less extent. Air and moisture have no effect upon the metal even in the heat; unlike gold and silver, sulphur and mercury do not injure it even when intensely heated. Nitrate of potassa, however, and potassa and lithia, at a high temperature, oxidise it; but it remains uninjured by the strongest simple acids. The combination of hydrochloric and any other of the mineral acids dissolves it readily; so likewise chlorine water, or a mixture of a chloride or nitrate, and of nitric or hydrochloric acid, and in every instance a bichloride— Pt Cl_2 —of the metal results. With phosphorus, arsenic, antimony, bismuth, cadmium, tin, and lead, platinum forms alloys at moderately high temperatures; and if the heat be increased it combines even with silver and copper, in which state it is sometimes readily dissolved by nitric acid, although this has no action upon it in its purity. Platinum is not such a good conductor of heat and electricity as other metals of less density. DESPRETZ has given the following numbers indicative of the comparative conducting power of the metals, assuming that of gold to be equal to one thousand:—

Gold,	1000
Platinum,	981
Silver,	973
Copper,	898
Iron,	374
Zinc,	363
Tin,	304
Lead,	180

WOLLASTON has shown, however, that the above results are untenable, since, according to a simple experiment devised by him, if rods of the several metals of equal length and weight be covered with wax, and equally heated at one end, the wax on the copper rod will have melted at the distance of 3·5 inches, on the silver at 2·5 inches, and on the platinum and palladium only at the distance of an inch. Its expansion is less than any of the other metallic bodies, being only 0·0009918 between 32° and 212°, or one thousand one hundred and eighth of its bulk. Its specific heat, according to DULONG and PETIT, is 0·03414.

Such are the principal properties of forged platinum, or of the metal made into utensils, wire, or thin leaves; but in its other states, such as platinum black and spongy platinum, it exhibits other properties, which are highly interesting and characteristic of this metal.

Spongy platinum is obtained, as already intimated, by heating the ammonio-chloride of platinum to redness; and provided the salt be pure, no other substance will contaminate it. The substance appears of a dull grey color, soft and porous; when ignited strongly it adheres together, and by subjecting it to pressure with hard bodies, it is made into the form of laminæ, having the metallic lustre. The interest attached to this body arises from the fact that without any apparent change it induces the combination of gases with one another, or the oxidation of bodies, to a remarkable extent. DÖBEREINER was the first to bring this remarkable fact before the consideration of the scientific world, by showing that a stream of hydrogen and of oxygen gases directed upon it are inflamed merely by its contact, and that hydrogen alone is capable of making it red hot. DULONG and THENARD showed that this metal, in the more compact form of fine wire and foil, is capable of inducing the union of oxygen and hydrogen in a limited degree, and FARADAY has shown what precautions are necessary to be observed to insure success in the trial—namely, cleanliness of the metal effected by fusing potassa on its surface, and after washing in water, rinsing it in hot oil of vitriol, and again with water. In this state platinum foil will act upon a mixture of the two gases in the proportion of one volume of oxygen and two of hydrogen, so as to speedily become red hot. Contact with the skin, a cloth, or mere exposure for a few days divests it in a great degree of this property; so likewise do sulphide of hydrogen, carbonic oxide, and olefiant gases. The explanation given of this remarkable effect is, that it results from the concurring influence of two forces, namely, the self-repulsive energy of similar gaseous particles, and the adhesive attraction exerted between them and the platinum. Each gas, repulsive to itself, and not repelled by the platinum, comes into the most intimate contact with that metal, and both gases are so condensed upon its surface that they are brought within the limits of their mutual attraction, and so combine.

Spongy platinum has, besides the power of causing the ignition of oxygen and hydrogen gases, that of condensing vapors upon its surface and in its pores to a

surprising extent. Thus, when exposed to the air, ordinary freshly-prepared spongy platinum absorbs oxygen gas to the extent of many times its volume, but little or no nitrogen. In this state it induces the combustion or oxidation of several gases of a combustible nature, and also of liquids. Thus it is that hydrogen is burned and oxidised into water, and alcohol into acetic acid. There are several forms of finely-divided platinum, which exhibit greater power of condensation of gases, and so of effecting chemical changes with greater force than spongy platinum. Such is the product resulting from the combustion of bibulous paper which had been saturated with a solution of bichloride of platinum and dried, and that produced by voltaic action in an acid solution of bichloride of platinum by a bar of zinc; but the most remarkable for this effect is the platinum black of LIEBIG. It is prepared by boiling bichloride of platinum solution with an excess of potassa or carbonate of soda, by which the heavy metal is reduced to the state of a proto-compound, and on now pouring alcohol gradually into the solution, a precipitate of a black color falls, which is the compound in question. It is in a finely-divided, and probably in a more amorphous state than any of the other compounds. When this body is well washed and dried, it takes up as much as two hundred and fifty times its volume of oxygen, and if absolute alcohol be dropped upon it in this state ignition immediately takes place. The combustible gases are quickly inflamed by it, and spirits of wine energetically acetified. As with the others, exposure for some time to moist air, ammoniacal vapors, or sulphide of hydrogen gases, destroys in part or wholly its power of effecting these changes; but washing with an acid and water, or heating it to redness, restores its usual properties again. LIEBIG's platinum black, however, when treated with dry ammoniacal gas is rendered red hot, and considerable quantities of the vapors are absorbed.

Platinum is capable, under certain conditions, of uniting with most of the non-metallic elements, and forming combinations that enter into new formations of the binary saline class; and with the metallic bodies in the form of alloys, but which are of little importance. The chemical symbol of platinum is Pt., and its combining weight 99.

METALLURGY OF PLATINUM.—The complex nature of the crude ore of platinum has attracted considerable notice, and has led chemists to publish several methods for its preparation, as well as for the estimation of the associated bodies.

Whatever method is chosen, the crude ore is submitted to a purifying process before the business of extracting the platinum commences. For instance, the gold which may be mixed with the particles of platinum or alloyed with it, is separated usually by adding mercury, and removing the residual matter from the amalgam. Particles of titanate of iron may be abstracted from it by the magnet, or if the ore itself should be partly attracted, the sortment will afford different qualities of ore. At St. Petersburg, where the platinum of all the ore found in the Ural is extracted, the following process is pursued:—Into each of thirty open platinum basins capable of holding eight pounds,

that are ranged on a sand-bath covered by a glazed dome with movable panes, and the whole surmounted by a ventilator which carries off the liberated acid vapors, a certain quantity of the material is introduced, and a mixture composed of three parts of hydrochloric acid 42° Twaddell, and one of nitric at 73° Twaddell, poured upon it. The whole is then heated during eight to ten hours, or till the evolution of red fumes ceases; and after allowing the undissolved matter to subside, the liquid is decanted into a large cylindrical vessel, the residue is washed with water, and the washings added to the first liquor. The undissolved matter is treated with further quantities of acid till the whole becomes soluble, and the liquors commingled in the common receptacle already mentioned. Aqua regia to the amount of from ten to fifteen times the weight of ore operated upon is required, according as the granules of the ore are smaller or larger in bulk. Moderately dilute aqua ammonia is now added to the acid liquor in the glass vessel, when a precipitate occurs, and on its subsidence the supernatant liquor is decanted into other vessels and evaporated to about one-twelfth in glass retorts, embedded in a sand-bath; on allowing this liquor to cool the double chloride of ammonium and iridium crystallizes out in the form of a dark purple powder, which is separated, and the mother-liquor evaporated to dryness in porcelain vessels, the residue calcined and treated anew like fresh ore. The precipitate obtained in the first instance is dried, calcined, and heated to redness for obtaining the metal in a spongy state. In order to agglomerate this sponge, it is pounded in a bronze mortar, the powder passed through a fine sieve, and the product introduced into the mould in which the ingot is to be formed. Here it is compressed with a rammer which is forced in by a coining press, and when reduced to the proper size, it is removed from the mould and baked for thirty-six hours in a porcelain kiln, after which it may be forged with ease, provided the iridium had been separated from it. The ingot of platinum contracts to the extent of one-sixth or one-fifth of its volume during the roasting in the oven. The cost of preparing platinum is estimated to be about twenty-five to twenty-seven shillings per pound in Russia.

WOLLASTON's method, of which the preceding is a modification, is the most perfect, and that best calculated to yield a pure metal. VAUQUELIN struck upon the same, but in its details that of the former is the most complete. For the preparation of the pure metal, the platiniferous grains are treated with aqua regia and chloride of ammonium, as in the preceding case; only, to prevent the solution of the iridium it is necessary to dilute the acids, so that it will remain in the residue. It is well to reduce the strength of the hydrochloric acid with an equal quantity of water, and also that the aqua-fortis and muriatic acid be quite pure. WOLLASTON has indicated that a quantity of hydrochloric acid, equivalent to one hundred and fifty of dry acid, and as much nitric acid as will contain forty parts, is sufficient for the solution of a hundred parts of the platiniferous matter; but as it is best to have an excess of the ore, one hundred and twenty parts of the latter should be employed. The action of the compound acid should

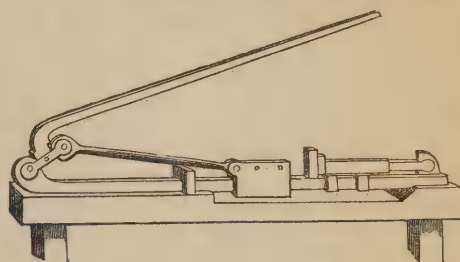
take place slowly, and a very gradually increasing temperature be applied till the operation be completed, which happens in about four days. After this the contents of the vessel are allowed to repose, in order that the iridium suspended in small particles in the liquid may deposit; this done the clear solution is to be drawn off, and after the separation of any subsided matter, forty-one parts of chloride of ammonium are added, when the yellow crystalline chloroplatinate of ammonia falls. This precipitate weighs one hundred and sixty-five parts, and contains sixty-six parts of platinum. Palladium, iridium, rhodium, ruthenium, osmium, gold, silver, iron, and any other foreign matters, are all or in part contained in the mother liquor from the last precipitate, together with eleven parts of platinum. To obtain it the whole of the metals are precipitated by means of a clean plate of zinc or of iron, the metallic deposit well washed, redissolved in aqua regia as before, and the platinum thrown down with chloride of ammonium, after having added one part of strong hydrochloric acid to every thirty-two parts of the liquor, with the view of holding the palladium and lead from falling down with the yellow platinum salt. By a later method, WOLLASTON neutralizes the acid solution with carbonate of soda, and precipitates the palladium from the liquid with the cyanide of mercury, in the form of whitish flakes. When this is removed by filtration, the platinum may be removed from the mother-liquor by the addition of forty-one parts of chloride of ammonium.

The precipitate from the first liquor, as well as that from the re-solution of the residuary matter in aqua regia, must be as well washed with cold water as possible, quite free from the chloro-iridate of ammonia; it is then to be dried carefully by pressure between folds of bibulous paper or other absorbent matter. After the whole of the moisture is dispersed, the substance is introduced into a black-lead crucible, and subjected to a temperature merely sufficient to expel the ammoniacal salt and the radical of the platinum compound. Should the heat be raised too high, it would cause the agglutination of the metal, so as to render its subsequent compression into ingots difficult, at the same time that it would decrease its welding power. The loose platinum powder is next rubbed between the palms of the hand very gently, sifted through a linen cloth, and the coarse particles that remain behind reduced in a wooden dish with a pestle of the same material, with as little force as possible. This portion is then sifted like the rest, and the fine powder, which ought not to exhibit any metallic lustre, or the finer parts, may be separated by elutriation and decantation. Having sufficiently reduced the mass, it is mixed with water to a pastelike consistency, and introduced into a brass mould or cylinder 6.75 inches high, 1.12 inch wide at the top, and 1.23 at the bottom, which is inclosed by a steel stopper that enters it to the distance of a quarter of an inch, having the inner face smeared with grease. The whole is now wrapped round with bibulous paper, and placed in a vessel of water so as to fill it with the liquid, when the metal sinks and fills every portion of it equally, and cavities in the ingot are avoided.

A piece of bibulous paper is now laid on the top of

the platinum, and then woollen cloths, and the excess of moisture removed by pressing the contents of the cylinder by a wooden pestle forced by the hand. The cloths and paper are removed at this stage, and a disc of copper substituted, the paste having sufficient consistency to allow the mould to be placed horizontally in a press, to be condensed preparatory to its forging. The kind of apparatus which WOLLASTON invented is represented in Fig. 420. After the pressure is sufficiently exerted, the cylinder is opened, and the ingot, shaped in the form of the cylinder, taken out without

Fig. 420.



danger of breaking in the hands, and heated nearly to redness in a charcoal fire, in order to drive off moisture, burn the grease, and give it greater compactness. It is now laid endwise on a support of clay, which is strewn over with quartz sand, and introduced upon the bars of a wind furnace, but so that it will be two inches and a half above them. A brisk coke fire is to be supplied, and while exposed to the intense heat of the fire the cylinder is covered with a crucible of very refractory clay, but in such a way as not to touch the metal. Twenty minutes' ignition is given, but the intensity of the temperature is moderated during the last few minutes. The defect of blistering so frequently observed in platinum arises from improper treatment of the metal at this stage, and to remedy it the highest possible heat of a wind furnace should be applied. Whilst still red hot the ingot is taken from the furnace, placed upon the anvil endwise, and struck with a hammer repeatedly. Should it bend under this treatment, it must not be straightened by striking it in a horizontal position, but the blows must be directed on the edges as to rectify the bend, and so still preserve it straight. After the ingot is sufficiently condensed by this means, it is in a position to bear forging and working into any desired shape, like any other metal. To separate the ferruginous scales with which it may become coated during its exposure in the furnace, the ingot must be coated with a mixture of equal parts of borax and cream of tartar, in a moist state; placed upon a platinum support; a refractory crucible inverted upon it, without touching; and then introduced into the furnace, and there brought to a full red heat. It is next withdrawn, and immersed in a bath of dilute sulphuric acid, which has the effect of dissolving the incrustated flux and any adhering iron. The ingot may now be hammered out into foil or drawn into wire as required. WOLLASTON found the specific gravity of the metallic powder

compressed in the mould to be 10·0, after strong ignition 17·0 to 17·7, after hammering 21·25, when drawn into thick wire 21·4, and into fine wire 21·5.

The manner of manufacturing crucibles and such vessels designed for chemical purposes, is to introduce the powder platinum into a steel mortar of the intended shape of the crucible, and then the stamp is forced in by means of a press or by repeated blows of a hammer. On removing the steel base of the mortar, the cylinder of platinum may be forced out by carefully pressing the stamp further inwards. The cylinder is then carefully ignited in a platinum crucible, at first in an ordinary assay or air furnace, and afterwards in a blast one to the highest degree, after which it may be beaten on the anvil.

The following directions for mending platinum vessels in use in the laboratory may not be uninteresting. An injured platinum vessel may be mended in the following manner:—The cracked or perforated vessel is thoroughly cleansed, either by fusing potassa in it, and then treating it with an acid, or by scraping the part and afterwards filing down the asperity of the surface; a clean piece of foil of a thickness suited to the vessel is then laid on the defective part, and the whole heated to bright redness in a smith's forge, after which the article is removed to the anvil as quickly as possible, and while yet red hot, struck quickly with a hammer to weld the piece to the body of the vessel. After the adhesion of the two, the part may be beaten out after successive heatings, to give it a smooth surface. To renovate a crack on the edge of a crucible, a narrow bent strip of platinum foil is suspended over it, and pressed as near as possible to the side of the vessel; the whole being then heated in the flame of a blowpipe lamp to whiteness, and while in this state struck on the pointed end of the anvil lightly, but quickly, with the hammer. The part may be smoothened by repeating the heating, and striking it whilst hot on the anvil. When the injury is in the form of a perforation, a platinum wire is selected of the size of the hole and struck flat at its end; this is then passed through the vessel, cut off close at the other side, and the end flattened by a few strokes of the hammer. The vessel is now heated in the fire till it becomes nearly white hot, and struck in the manner directed above, when a secure welding takes place. Should the hole be large, a piece of platinum plate of the suitable size is taken and secured to the edge of the vessel by a number of platinum rivets; it is then transferred to the fire, and when sufficiently heated beaten on the anvil with the flat smooth hammer. In either of these cases the new joint is indiscernible when properly effected.

Platinum crucibles and vessels are liable to injury from the following agents:—Nitrohydrochloric acid, chlorine water, a mixture of hydrochloric acid with chromic acid or its salts, or with a peroxide, such as manganese, attack the metal and readily dissolve it. Lead, bismuth, zinc, or any other metal heated in a platinum vessel to its melting point, or nearly to that degree, alloys itself with the platinum, and either produces a hole at once or an alloy, which is acted upon by acids. The most destructive of this class are those of arsenic and antimony; and hence, not only must the

operator carefully avoid heating these to redness in a platinum vessel, but likewise their oxides and the salts which they form with other bases. This is more especially the case, if charcoal or any carbonaceous matter be present that would cause a reduction of the arsenical or stibic compound. Many other oxides of an easily reducible nature injure crucibles when carbonaceous matters are not carefully excluded. This also applies to phosphoric acid and its salts, since in contact with carbon at a high heat reduction takes place, and a brittle and easily fusible phosphide of platinum results. Alkaline sulphides or cyanides should not be fused in platinum vessels, as these agents dissolve considerable quantities of the metal. Silicium at a high heat unites with platinum, rendering it brittle and disposed to crack; hence vessels of this metal ought never to be heated exposed in an open fire; they should be protected by an outer earthen crucible, contact of the two being prevented by calcined magnesia. Potassa, soda, lithia, and their nitrates, when fused in a platinum vessel, oxidise part of the metal, which is dissolved in the form of an alkaline platinate. This is more particularly the case with lithia. Sulphur does not affect it unless arsenic or some other deleterious body be present, neither has pure phosphoric acid any action upon it.

The purity of platinum vessels is tested by treating them with the simple acids—hydrochloric and nitric—in succession, and examining the acid liquor to ascertain the nature of the dissolved matter, should any exist. It frequently happens that platinum vessels in frequent use in the laboratory get tarnished, in which case they may be again rendered bright and clean by smearing over their surface a paste made with equal parts of pounded borax and cream of tartar—bitartrate of potassa—and fusing it in the heat. On immersing the vessel subsequently in a bath of pure dilute sulphuric acid, all extraneous matters are dissolved, and it presents a clean bright surface.

Platinum is rarely applied to the purposes of the jeweller, silver being preferred; indeed, its chief use, except in Russia, where it is coined, is for chemical apparatus and philosophical instrument making, in the construction of electrical batteries, dentistry, *et cetera*. It is chiefly absorbed in the construction of stills for sulphuric acid rectifiers, pans, stills, and digesters employed in the manufacture of drugs and many of the purer chemical preparations. Like silver and gold, this metal, when it is past use in the various forms in which it is manufactured, is carefully collected and returned to the platinum founders, to be again worked up into the same or other articles. It is usual to allow half price for returned platinum; but this standard is evidently too low when compared with the price of the manufactured goods. The amount of platinum manufactured and traded with annually averages from five thousand eight hundred to six thousand three hundred pounds troy, of which North and South America yield about seven hundred to eight hundred and fifty pounds, and Russia five thousand one hundred to five thousand four hundred and fifty. What is obtained from other sources is small, and does not enter into the foregoing statistics.

ALLOYS.—Platinum forms alloys with several metals, the most interesting to the artisan being those which it yields with zinc, iron, lead, copper, and silver *with zinc*. When one and a half to two parts of zinc are mixed with one part of spongy platinum and heated, vivid combustion of the mass is observed to take place, even before it has attained a red heat. The compound mass has a bluish-white appearance, acquires considerable hardness, and is easily melted, the zinc becoming an oxide if air be admitted. With a quarter of its weight of zinc, platinum is rendered brittle; and zinc, with about a twentieth of its weight of platinum with iron. A powerful heat is required to effect the combination of iron and platinum, which, however, constitute a very hard alloy, scarcely acted upon by the file, and somewhat malleable. FARADAY and STODART have made several experiments upon the alloys formed from steel and platinum. Those averaging from four to nine parts of steel to one of platinum, are characterized by their close texture, which enables them to take a high polish, and by their not tarnishing in the air. An alloy of sixty-seven parts of steel and one of platinum, they found to be well adapted for the manufacture of cutting or edged tools. One part of platinum and a hundred of steel is a metal less hard than silver steel, but tougher. With one of platinum and two hundred of steel, a metal was formed which BRÉANT recommends for the manufacture of razors.

With Lead.—Alloys of lead and platinum have few peculiar or striking characteristics, except that they melt readily, possess a color approaching to purple, and break or split under the hammer.

With Copper.—A sustained white heat is required to induce combination of copper and platinum. In equal quantities they melt, and form a golden-colored alloy very malleable; with one-sixth to one-twenty-fifth of platinum, the color of the alloy is between pale red and rose red; the metal works well under the hammer, and takes a good polish, but it is a little duller in its aspect than pure copper. An alloy of copper and platinum has been introduced for mounting telescopic and other lenses. COOPER prepared an alloy of seven parts of platinum, sixteen of copper, and one of zinc, which is similar to sixteen carat-gold, is very extensible, and remains unaffected by strong nitric and sulphuric acids.

With Silver.—Silver, when combined with platinum, becomes darker in color, less malleable and harder than it is *per se*, and in proportion as the admixture of platinum is increased, its melting point becomes higher. Equal weights of silver and platinum give a hard dull-hued alloy, very brittle under the hammer; when the proportion of silver is more than five per cent. and cupelled with lead, no brightening occurs. Sulphuric acid dissolves part of the silver from the alloys rich in this metal, but nitric acid does not effect the analysis of both metals, as the solution contains both silver and platinum.

With Gold.—Platinum unites with gold, but when the proportions are equal it requires the strongest heat of a wind-furnace to effect the fusion; and when the combination of the two metals in the ratio of three of gold to seven parts of platinum is essayed, the tem-

perature of the oxyhydrogen blast is necessary. The alloys in every instance are characterized by having a lighter color than gold, a great density, and when the gold averages a sixth to a fifth of the weight, considerable elasticity.

COMBINATIONS OF PLATINUM.—This metal is capable of uniting with most of the non-metallic elements; with several of them it readily combines, whilst with others the conditions requisite to effect the combination are varied. In a practical point of view, however, these are uninteresting, as no particular application of them has been made, with, perhaps, the exception of the bichloride, which is in continued request in the laboratory, and in some cases in the potter's art, for producing bright steel greys. Some of the compounds thus produced, more especially the chloride, enter into the formation of other well-marked bodies of a compound saline nature, wherein the platinum compound remains intact, and occupying as it were the part of a radical in the new salt.

It would be useless to describe these combinations here, the more so as they serve but little the purposes of the manufacturer. The bichloride of platinum, which is the most useful of the class referred to, may be prepared as stated when speaking of the preparation of platinum, namely, by treating the metal with aqua regia containing an excess of hydrochloric acid, and evaporating till all the free acid is removed. The salt has a dark red crystalline appearance, is deliquescent, and gives with water and alcohol—in which menstrua it is soluble in all proportions—dark red solutions. Its symbol is $Pt Cl_2$, and its atomic or equivalent weight one hundred and seventy.

POTASSIUM.—*Potassium*, French; *Kalium*, German and Latin.—The discovery of this interesting metal was made as lately as the commencement of the present century. The compound nature of the alkaline base—potassa—had long been suspected, though never previously proved to a certainty. Nor were philosophers agreed as to its supposed constitution; for while LAVOISIER suspected it to be a true metallic oxide, the more generally received opinion was, that nitrogen was an ingredient in its composition. The proof of its compound nature, until then merely hypothetical, was reserved for that distinguished philosopher, Sir HUMPHREY DAVY, who in 1807 succeeded by means of a powerful voltaic battery in separating potassium, with the metals of the other alkalies and of the alkaline earths, from their combinations. This, unlike the great majority of discoveries at that period, was not the result of accident, but of true scientific reasoning, and was confidently expected to follow the application of that agent, the extraordinary powers of which had been until this period so little understood and investigated, but which has since been so beneficially applied to the wants of mankind. Lord BROUGHAM, referring to the discovery of this and the other alkaline metals, remarks, that he could well remember that in discussing the subject, they used to look forward with perfect confidence to the analysis of those bodies which had hitherto proved the most stubborn, and expected soon to find the fixed alkalies, and even the alkaline earths, shown to be oxides, as by some very imperfect experiments they

had at one time been supposed to be proved. The discovery was not long delayed. In October, 1807, DAVY, after in vain endeavoring to decompose the alkalis when mixed with water—for then he could only decompose that fluid—exposed them in the dry state, but made liquid by fusion; and to his great delight he found, as he had expected, that the process of decomposition proceeded, the oxygen appearing at the positive wire, while globules of a metallic substance were found at the negative one. The glory of having made the greatest discovery of the age was plainly DAVY'S. His praise would have been the same if, instead of at once discovering the alkalis to be oxides, and the metals forming the bases to be lighter than water, while one of them burned unheated in the open air, he had only shown these salts to be oxides of well-known metals; but as his investigation had been crowned with the discovery of strange substances—metallic, and yet like no other metals—the admiration excited was still greater.

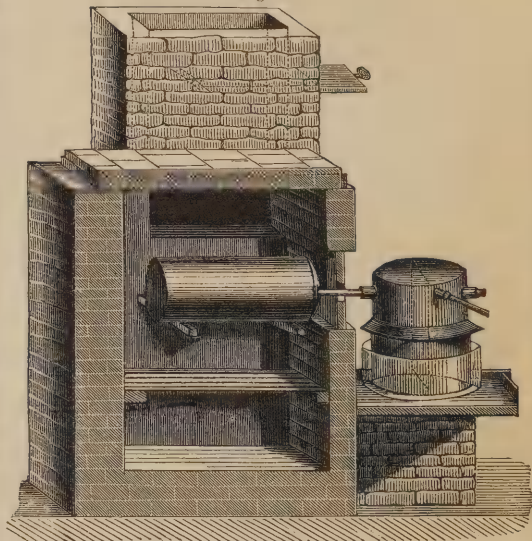
The investigation of DAVY was afterwards prosecuted by GAY-LUSSAC and THÉNARD, who, however, for some time still regarded the metal to be a compound of the alkali with hydrogen. BERZELIUS, on the contrary, repeating DAVY'S experiments, satisfied himself of the correctness of the theory of the latter chemist.

SOURCES.—In consequence of its intense affinity for oxygen, potassium is never met with in nature uncombined. It occurs principally as carbonate of the oxide or potassa in the ashes of land plants, and also as chloride in those of marine plants. In the mineral kingdom, it is found as sulphate, as well *per se*, as in combination with earths and water, and especially in alum and aluminosilicate. In polyhallite it is associated with the sulphates of lime and magnesia. As nitrate of potassa, or saltpetre, it is found in large quantities on the surface of the earth; as chloride, it exists sparingly in rock-salt, in sea-water, and in many salt springs, and other mineral waters. It is also an ingredient in several rocks, especially in felspar, leucite, apophyllite, and potassa tourmalin, in all of which it exists as silicate of potassa. Being always contained in plants, its salts are of course a most important ingredient in soils.

PREPARATION.—The expensive and troublesome method of DAVY, for the production of this metal, has long been abandoned, or at least is exhibited only as an interesting example of the power of electricity in producing chemical decomposition. The following process invented by GAY-LUSSAC and THÉNARD, and subsequently modified by BRUNNER, WÖHLER, and MITSCHERLICH, is that most frequently adopted. The salt made use of is the carbonate of potassa, and by careful manipulation, large quantities of metal may be obtained. The reducing agent employed is charcoal in a state of the most minute division. These ingredients are most readily procured in a proper admixture by the calcination of *argol*, or crude bitartrate of potassa. MITSCHERLICH directs six pounds of tartar to be ignited in a covered iron pot, till gases cease to be evolved. The product, termed *black flux*, is, while still hot, to be pulverized and mixed with ten ounces of coarsely-powdered charcoal. This addition is intended, by making the mass more porous, to allow of the more

easy escape of the gases subsequently developed. The whole is then transferred as quickly as possible to a wrought-iron quicksilver bottle, to the mouth of which an iron tube, not exceeding five inches in length, is screwed, to serve as a connection to a copper receiver, partly filled with rectified naphtha, and so constructed with partitions as to exclude the air. Another tube is inserted in this receiver, directly opposite to the tube in the bottle, so as, if necessary, by means of a strong steel rod, to cleanse the connecting tube, which occasionally becomes clogged by the products of decomposition. This tube serves also as an escape aperture for the gases. The whole arrangement is fixed in a wind furnace, as shown in Fig 421. This furnace should have a wide grate,

Fig. 421.



and a chimney ten feet high. The receiver is kept cool by means of ice applied to the outside. A strong and uniform heat, produced by the combustion of dry wood, is then applied to the bottle, and when the mass is sufficiently heated, the decomposition of the alkali by the charcoal begins, indicated by the appearance of a pink flame at the mouth of the tube. The potassium now distils over, accompanied by carbonic oxide and some solid products, and, dropping into the naphtha in the receiver, is effectually protected from the action of the air.

Instead of the iron bottle used in the above process, a gun barrel is sometimes employed, and is bent upwards at the thick end at a very obtuse angle, and downwards at the other end for about four inches, the middle part being laid horizontally in the furnace. This is the form of apparatus originally employed by GAY-LUSSAC and THÉNARD. The ingredients used by these chemists were hydrate of potassa, and metallic iron in the form of wire, filings, or borings. The latter were placed in the middle of the tube, and the potassa salt contained in the anterior bent portion of the tube was gradually fused and allowed to flow down; and coming in contact with the iron at a white heat was decomposed, yielding potassium and hydrogen

gas, which latter escaped by the lower end of the barrel, and the potassium was collected as previously described. To preserve the iron bottle or gun barrel used in these processes from wasting away rapidly by the action of the intense heat, it has been recommended to coat them externally with luting. GAY-LUSSAC and THÉNARD used for this purpose a mixture of one part of clay, five of fine sand, and a small quantity of horse dung; this luting is slowly dried, and the cracks filled up with fresh material. MANTELL incloses the gun barrel in a tube of baked clay, of such a width as to allow of the expansion of the barrel. SCHADLER and WERNER surround the bottle with a wire net, and on this the former applies a luting composed of two parts of pounded Hessian crucibles, one part of pipe-clay, and some cow hair; the latter two or three coatings of thin paste consisting of coarse quartz sand and a little clay. ANTHON covers the bottle with a mixture of loam and sand, and GALE with a mixture of equal parts of sand, clay, and soap-stone.

Instead of the mixture of charred tartar and charcoal, recommended by MITSCHERLICH, one of carbonate of potassa and charcoal in proper proportions may be used. KUKLA evaporates to dryness a mixture of three parts of pearlash dissolved in water, with the addition of one part of flour, carbonizes the residue, mixes it when cold with sufficient water to moisten it slightly, and transfers it to the bottle. It is always desirable to employ an excess of charcoal, as the rapid choking of the tube, as well as the fusion and projection of the contents of the bottle, is thus prevented. If a complete stoppage is actually formed in the tube, the greatest care must be exercised in reopening it; and if the attempt be successful, which is not always the case, masses of burning potassium may be forcibly projected by the sudden expansion of the compressed gas in the bottle, and occasion serious injury to the operator. The latter should therefore expose himself as little as possible, and his hands should be carefully protected by leathern gloves. The metal adhering to the borer should also be quickly scraped off into naphtha or rock oil, and should it take fire, extinguished by covering with a plate.

The theory of the production of potassium from the carbonate of potassa, by heating in contact with charcoal, is not clearly understood. In its simplest form, the decomposition may be represented thus— $K_2O, CO_2 + C_2 = K + 3CO$. Unfortunately, however, the greatest portion of the potassium at the moment of separation enters into combination with the carbonic oxide, forming a grey powder termed croconaceous matter, and from which, by digestion in water, *croconate* and *rhodizonate* of potassa may be separated. The grey powder is possessed of most powerfully explosive properties, and if the greatest care be not exercised in removing it from the tube and other parts of the apparatus—such as carefully excluding it from the atmosphere until quite cool, and soaking well in naphtha previous to attempting its removal—the most dangerous accidents may occur. The loss in potassium, owing to the formation of these compounds, is very great—amounting even under the most favourable circumstances to at least one half of the metal contained

in the mixture. PLEICHL obtained from six pounds of tartar, carbonized and mixed with six ounces of charcoal, nine and a quarter ounces of potassium, equal to 9.2 per cent. This is nearly one half of the total amount present, and may be considered a good yield. In most cases the product is much less.

PURIFICATION.—Potassium, as obtained in the processes above described, is found in the receiver in the form of globules mixed with carbonaceous matter. From this the visible globules are picked out with a pair of forceps, and by distilling the black residue a further quantity may be separated. The metal thus collected is, to separate remaining impurities, tied up in a linen bag and heated to about 150°, and then pressed out with a pair of wooden tongs. A far more effectual method of purification is, however, by distillation from a small iron retort, with which a short wide tube is connected, as represented in Fig.

Fig. 422.



422. This bottle is, after being filled with the crude metal, slowly raised to a strong red heat in a small air furnace. The potassium after some time begins

to pass over, and is received into naphtha. The process requires to be conducted with great caution, otherwise a dangerous explosion may ensue. Under any circumstances there is a considerable loss of metal from oxidation and other causes.

PROPERTIES.—Potassium is of a bluish, or silver-white color, and is possessed of a high degree of metallic lustre. Its consistence is very variable according to the temperature; below 32° it is brittle, and its fracture has a crystalline texture. At 60° it is malleable, and easily cut with a knife. At about 130° it enters into perfect fusion, and in appearance resembles mercury; and at a bright red heat it boils and rises in green vapor. Its specific gravity at 60° is 0.865; it is, therefore, lighter than water. When exposed to the air, potassium is instantly tarnished by the formation of a film of oxide; indeed so powerful is its affinity for oxygen, that when thrown on the surface of water, it instantly takes fire, forming potassa and liberating hydrogen gas. Potassium must always, therefore, be kept in naphtha, rock oil, or some liquid free from oxygen. The brilliant lustre of this metal is most beautifully shown by heating it in melted tallow, or by pressing a small portion between two plates of glass. The symbol for potassium is K, and its equivalent 39. Owing to its intense affinity for oxygen and the other metalloids, potassium is a most powerful instrument of research; thus, it decomposes all oxides, in most cases with complete reduction; and, with the aid of heat, all carbonates, phosphates, sulphites, sulphates, nitrates, and many other salts, withdrawing the oxygen not only from the acid, but also from the base. By its means many metals, previously unknown in the separate state, have been withdrawn from their combinations, and may now be prepared in any quantities to supply the demand for them in the arts and manufactures. Potassium has also been employed in surgery, as a substitute for the

actual cautery; in some cases with most beneficial results.

OXIDES OF POTASSIUM.—By combining with oxygen, this metal forms three compounds—suboxide, K_2O ; protoxide, KO ; and peroxide, KO_2 . The first named is produced when potassium is heated with a limited supply of air in a close vessel, or when it is heated with the higher oxides. The protoxide is obtained when an equivalent of potassium is allowed to act upon one of water, in a vessel from which the air is carefully excluded.

The decomposition is as follows:—



It is also procured by exposing the peroxide to a strong heat. The latter—the highest oxide—is produced when the metal is burned with free access of air or oxygen gas, by burning the suboxide and the protoxide, and also by the continued ignition of the nitrate of potassa. None of these oxides, *per se*, are of use in the arts or manufactures, and therefore will not require further mention. The protoxide, however, in combination with water, is a most important salt, and demands a more detailed notice.

HYDRATE OF POTASSA—Caustic Potassa.—This salt is most conveniently prepared by decomposing carbonate of potassa by hydrate of lime. One part of the carbonate is heated with twelve parts of water till the solution boils; slaked lime—prepared by mixing three parts of warm water with a little less than one of burned lime, and keeping it in a covered pan till the latter is reduced to a soft powder—is gradually added with constant agitation. The vessel is then covered, and its contents boiled for a quarter of an hour. The caustic solution is now tested by decanting a small portion and pouring it into hydrochloric acid; if there be no effervescence, the potassa is completely decomposed; in the contrary case, longer boiling, perhaps with the addition of more lime, is requisite. When a portion of the liquid no longer disengages carbonic acid on the addition of a stronger one, the whole is allowed to remain at rest for some time, in order that the carbonate and the excess of hydrate of lime may subside. The clear liquor is then siphoned off, concentrated by evaporation in covered iron pots, and, should it become turbid, set aside for some time and then again decanted. Lastly, the solution is rapidly boiled down in a polished iron or silver vessel till it acquires the consistence of oil, and on cooling concretes into hard masses. Carbonate of potassa is also decomposed by lime at ordinary temperatures; but in this case the decomposition is effected less rapidly, and the carbonate of lime formed being much less dense than when ebullition is used, its separation is much more difficult. As thus prepared, this hydrate frequently contains considerable quantities of alumina, silica, and phosphoric acid.

For use in the laboratory, hydrate of potassa, prepared as above, is treated with rectified spirit of wine in a stoppered bottle. The solution is allowed to deposit, decanted and evaporated in a silver dish, until fumes cease to be evolved, adding from time to time during the evaporation some water to prevent blacken-

ing of the mass. Except a minute trace of alumina, this hydrate, if carefully manufactured, is free from other impurities.

To obtain it perfectly free from alumina, SCHUBERT directs hydrate of potassa to be prepared by decomposing the sulphate of that base by means of hydrate of baryta. A solution of this latter salt is added to one of pure sulphate of potassa in exactly sufficient quantity to effect decomposition. The decanted solution is then evaporated as previously described.

A still better method for the production of this salt in a state of chemical purity is the following, recommended by WÖHLER. Put one part of nitrate of potassa, and two or three parts of sheet copper cuttings, in an iron or copper crucible in alternate layers; cover the latter, and expose it for half an hour to a moderate red heat. Allow the mass to cool, treat it with water, let the solution deposit in a tall cylinder, and afterwards remove it by means of a siphon. By evaporation the perfectly pure hydrate may then be obtained.

According to FUCHS, hydrate of potassa may be economically obtained from certain varieties of felspar and from mica. For this purpose the minerals are calcined with lime, then left for some time in contact with water, and the solution is afterwards filtered and evaporated. From his statement it appears that nineteen per cent. of potassa may be obtained from felspar, and fifteen per cent. from mica.

Hydrate of potassa is a white opaque mass, which, when broken, exhibits a crystalline fracture. Its specific gravity is 1.7. It fuses at a low-red heat, and at a white heat volatilizes unaltered. Its taste is acrid and corrosive. It has a strongly alkaline reaction, a rapid solvent action on animal matters, and is the most powerful base known. Its formula is KO, HO ; it is very deliquescent, very soluble in water, and crystallizable. The following table, deduced from DALTON's experiments, shows the quantity of anhydrous potassa contained in solutions of various densities:—

Specific gravity.	Potassa per cent.	Boiling point. Degrees.
1.68	51.2	329
1.60	46.7	290
1.52	42.9	276
1.47	39.6	265
1.44	36.8	255
1.42	34.4	246
1.39	32.4	240
1.36	29.4	234
1.33	26.3	229
1.28	23.4	224
1.23	19.5	220
1.19	16.2	218
1.15	13.0	215
1.11	9.5	214
1.06	4.7	213

The latter is about the strength of the solution of potassa of the London Pharmacopoeia.

The impurities most frequently met with in solution of and solid hydrate of potassa are carbonate of lime, oxide of iron, silica, alumina, carbonate and sulphate of potassa, and chloride of potassium. Carbonic acid is indicated by effervescence on the addition of an acid. Carbonate of lime and oxide of iron remain insoluble when the salt is treated with water. Silicic acid and

alumina are precipitated when an acid is gradually added to saturation, and the latter is redissolved by a slight excess of acid. The presence of a sulphate is shown by the addition of nitrate of baryta to a solution previously acidulated with nitric acid, and of chloride of potassium, by adding nitrate of silver to a portion of the same solution.

Hydrate of potassa is a most valuable agent to the chemist, and especially in the estimation of the carbon of organic bodies. It is also used to displace metallic oxides from their combinations, as a solvent for oxides of zinc and alumina, also for the decomposition of silicious minerals by fusion, for drying certain gases, and a variety of other purposes. In surgery, it is used in the solid state, cast into sticks, as a most powerful caustic. In medicine, its solution is also frequently employed, especially as an antacid.

Physiological Effects.—In the solid state its local action is remarkably energetic, rapidly destroying the tissue with which it comes in contact. When dissolved it is also powerfully corrosive, and consequently an energetic poison in large doses. It excites no constitutional action, except what depends on the local injury it occasions. In medicinal doses it possesses antacid and antilithic properties, and is administered in some bitter infusion.

CARBONATE OF POTASSA—*Potashes, Pearlash, Salt of Tartar.*—This salt is most readily obtained in a state of purity by heating the crystallized bicarbonate to a temperature exactly sufficient to expel its water and half of its carbonic acid, which is effected below a red heat. The residue dissolved in water and filtered yields the pure salt by evaporation. The solution in water and filtration is for the purpose of separating a small quantity of silica usually contained in the bicarbonate, and which is rendered insoluble by heating. If, however, the salt is heated too strongly, a silicate of potassa is formed, which dissolves with the carbonate; while, on the other hand, if not sufficiently heated, the residue still contains soluble silica. The pure salt may also be obtained by heating the bitartrate of potassa, or a mixture of nitrate and bitartrate to redness, lixiviating the residue, and evaporating to dryness; also, by passing carbonic acid into solution of potassa till saturated, evaporating to dryness, and exposing the mass to a dull red heat.

Properties.—Carbonate of potassa— KO, CO_2 —is very soluble in water, and the solution, when concentrated to about 1·2 and suffered to cool, deposits crystals containing two equivalents of water, and therefore having the formula $\text{KO}, \text{CO}_2, 2 \text{HO}$. As usually met with, it forms a white solid anhydrous mass, deliquescent, and at a red heat fusible without alteration. Its solution has a powerfully alkaline reaction and taste, but is only slightly caustic. It rapidly abstracts water from the atmosphere, and yields a dense solution originally termed *oil of tartar per deliquium*. The specific gravity of the pure anhydrous salt is 2·24. It is insoluble in absolute alcohol. Boiling water, on the contrary, dissolves more than its own weight of this salt. A cold saturated solution contains about forty-eight per cent., and its density is about 1·5. The subjoined table by TUNNERMANN shows the quantity of anhy-

drous salt contained in solutions of the densities enumerated:—

Specific gravity.	Per cent.	Specific gravity.	Per cent.
1·4812	40·504	1·2282	19·580
1·4750	40·139	1·2150	18·601
1·4626	39·160	1·2020	17·622
1·4504	38·181	1·1892	16·643
1·4384	37·202	1·1766	15·664
1·4265	36·223	1·1642	14·685
1·4147	35·244	1·1520	13·706
1·4030	34·265	1·1400	12·727
1·3915	33·286	1·1282	11·748
1·3803	32·307	1·1166	10·769
1·3692	31·328	1·1052	9·790
1·3585	30·349	1·0940	8·811
1·3480	29·360	1·0829	7·832
1·3378	28·391	1·0719	6·853
1·3277	27·412	1·0611	5·874
1·3177	26·432	1·0505	4·895
1·3078	25·454	1·0401	3·916
1·2980	24·475	1·0299	2·934
1·2836	23·496	1·0108	1·958
1·2694	22·517	1·0098	0·979
1·2554	21·538	1·0048	0·489
1·2417	20·539		

The carbonate of potassa of commerce—usually termed *potashes* or *pearlash*—is an article of great importance in the arts and manufactures; and it is, therefore, necessary to dwell at some length on its production, the methods for procuring it on the large scale, and its purification for manufacturing purposes. As previously mentioned, potassa is an essential ingredient in plants, and it is from this source that the carbonate is obtained for commercial purposes; for though some other salts of this base are frequently met with in nature and in large quantities, still potashes are never procured on the large scale by a chemical decomposition of these salts. The great natural depositary of potassa is the felspar of granite and other unstratified rocks, where it exists in combination with silica, and quite insoluble in water. Its extraction directly from this source, though it has been attempted on the large scale, is attended by difficulties so great as probably never to allow its successful prosecution. As the rocks disintegrate into soils, however, the alkali acquires solubility; and, being taken up by plants, it accumulates in their substance in a condition highly favorable to its subsequent applications. The precise condition in which potassa is contained in the vegetal kingdom, is to a great extent involved in mystery; and the same may be said, also, as to the part it plays in the organism of plants. A considerable portion, however, undoubtedly exists in combination with vegetal acids—as tartaric, citric, malic, and oxalic—and in smaller quantities in some plants as carbonate. Besides potassa, however, all vegetables contain other inorganic constituents in variable proportion—as, for instance, chlorides of potassium and sodium, sulphates of potassa and soda, carbonates and phosphates of lime and magnesia, silicate of alumina, some metallic oxides, as those of manganese, iron, and copper, and also nitric acid, iodine, and bromine, in combination with oxides and metals. The alkalies, potassa and soda, appear to be capable of replacing each other in the constitution of plants, as it is found that in those growing on the shores of the ocean, where the latter base is of course more abundant, it usually predominates; while in plants produced on an inland soil, potassa is always prepon-

derant; indeed, according to CHAPTAL and FONTENELLE, the same plants which, when cultivated at a short distance from the sea, yield soda salts, when reared at a distance of ten leagues produce salts of potassa. Other researches which have been made upon this subject leave no doubt that plants, in the absence of a particular ingredient in a soil, can take up some other, which, as regards chemical action, is endowed with similar properties, and that bases replace each other and act conjointly with reference to the functions of plants. This property of plants to secrete other principles than those generally supposed to be essential to their growth, and which appear to be their natural sustenance, is very remarkable; it is, nevertheless, of frequent occurrence—indeed, the ashes of two specimens of the same species of plants are seldom perfectly alike in composition, and are often considerably at variance. Thus, SAUSSURE found in the ash of a fir the following ingredients:—

	Per centage
Carbonate of potassa,	3.6
“ lime,	46.34
“ magnesia,	6.77

In the ash of the same tree, but grown in another locality, he found of—

	Per centage.
Carbonate of potassa,	7.36
“ lime,	51.19
“ magnesia,	0.00

In both cases the proportion of oxygen in the base of the salts is precisely the same—namely, 9.0. It appears, therefore, that the action of a base is dependent upon the amount of oxygen it contains, and is, indeed, measured by that quantity; the bases of such ashes—independent of that portion which is in combination with mineral acids—must together contain one and the same quantity of oxygen. This view is confirmed by the experiments of WILL and FRESSENIUS, who obtained from the ashes of tobacco very variable results as to the proportion of the different ingredients; but as regards the oxygen of the base, the total amount in one case was 24.27, and in the other 24.57. The nature of the ash also, as proved by SAUSSURE, varies in the same specimen with the part of the plant from which it is obtained, and, even in the same part is not uniform throughout the different periods of development and changes of season.

The first operation in the production of potassa is the combustion of the wood, when, after the volatilization of the destructible matters—as carbon, hydrogen, *et cetera*—all the mineral constituents abstracted from the soil naturally remain in a fixed state. This residue may contain all, or only a portion of, the constituents previously mentioned as the mineral food of plants. The bases—potassa and soda—are found for the most part as carbonates, formed during incineration from the decomposition of the vegetal acids with which they were combined. In general, the herbaceous plants yield much more ash than shrubs, and these again more than trees. In the latter the bark and leaves afford the largest quantity, next the branches and twigs, while in the trunk only a very small quantity is contained. The subjoined table shows the centesimal

amount of ash obtained from the plants mentioned, together with the name of the authority:—

Trees.	Part burnt.	Per centage.	Authority.
Oak,	wood,	3.30	.. Berthier.
“	branches,	0.40	.. Saussure.
“	bark,	6.00	.. Berthier and Saussure.
“	leaves,	5.5	.. Saussure.
Red beech,	wood,	0.612	.. Mollerat.
“	bark,	6.62	.. Hertwig.
Hornbeam,	wood,	0.60	.. Saussure.
“	sap wood,	0.7	.. “
“	bark,	13.4	.. “
Alder,	wood,	0.40	.. Karsten.
Birch,	wood,	0.30	.. “
Pinus picea,	wood,	1.50	.. “
“	seeds,	4.47	.. Will and Fresenius.
“ abies,	wood,	0.25	.. Karsten.
“	bark,	1.78	.. Hertwig.
“	needles,	2.31	.. “
“ sylvatica,	wood,	1.19	.. Saussure.
“	needles,	2.60	.. “
“	seeds,	4.98	.. Will and Fresenius.
Lime,	wood,	5.00	.. Berthier.
Poplar,	wood,	0.80	.. Saussure.
Elm,	wood,	2.28	.. Mollerat.
Ash,	wood,	2.30	.. “
Shrubs.			
Elder, .....	..	1.64	.. Berthier.
Hazel, .....	..	0.50	.. Saussure.
Wortleberry, .....	..	2.60	.. “
“ .....	..	0.68	.. Mollerat.
Blackberry, .....	..	0.71	.. “
Juniper, .....	..	1.84	.. “
Wild rose, .....	..	0.71	.. “
Heath, .....	..	1.41	.. “
Green weed, .....	..	1.62	.. “
Heckle, .....	..	1.66	.. “
Blackberry, .....	..	0.76	.. “
Broom, .....	..	1.48	.. “
Sumach, .....	..	1.71	.. “
Herbs.			
Potato straw, .....	..	15.00	.. Berthier.
“ leaves, .....	..	1.15	.. Mollerat.
Peas haulm, .....	..	5.05	.. Hertwig.
“ .....	..	11.30	.. Boussingault.
“ .....	..	8.10	.. Saussure.
Oat straw, .....	..	5.10	.. Boussingault.
Nettle, .....	..	10.67	.. Pertuis.
Thistle, .....	..	4.03	.. “
Rushes, .....	..	4.33	.. “
Wheat straw, .....	..	4.40	.. Berthier.
“ .....	..	7.00	.. Boussingault.
“ .....	..	4.30	.. Saussure.
Rye straw, .....	..	0.30	.. Karsten.
“ .....	..	3.60	.. Boussingault.
Maize straw, .....	..	12.20	.. Saussure.
Cane straw, .....	..	1.70	.. Karsten.
Fern, .....	..	2.75	.. “
“ .....	..	2.90	.. Mollerat.
“ .....	..	5.00	.. Pertuis.
Plantain leaves, .....	..	9.22	.. Abbene.
“ branches, .....	..	2.30	.. “
Acacia, .....	..	2.46	.. “
Vine, .....	..	4.66	.. “
Grape stalk, .....	..	8.89	.. “
Vine pith, .....	..	7.29	.. Blengirie.

The proportion of carbonate of potassa contained in the ashes of wood is also very variable, and it is always associated with a greater or less quantity of carbonate of soda. Other soluble salts are sulphates and silicates of these alkalies, and chlorides of the metals. If the ash is treated with water, these salts are separated, whilst carbonates, phosphates, and silicates of the alkaline earths remain insoluble. The value of a particular ash is, therefore, determined by the estimation of the relative proportion of its soluble and insoluble

constituents. In the appended table are given the experiences of BERTHIER and others on this point:—

Ashes.	Soluble.	Insoluble.	Authority.
White beech wood,	19-22	80-78	Berthier.
White beech charcoal,	18-00	82-08	"
Red beech wood,	16-30	83-70	"
Oak wood,	12-00	88-00	"
Oak charcoal,	15-50	84-50	"
Oak bark,	6-25	93-75	"
Lime wood,	10-80	89-20	"
Birch wood,	16-00	84-00	"
Alder wood,	18-80	81-20	"
Fir wood,	25-70	74-30	"
Fir charcoal,	50-00	50-00	"
Pine wood,	13-60	86-40	"
Pine needles,	12-70	86-30	Hertwig.
Mulberry tree,	25-00	75-00	Berthier.
Nut-tree wood,	15-40	84-60	"
Elder wood,	31-50	68-50	"
Wheat straw,	10-10	89-90	"
Potato straw,	4-20	95-8	"
Fern,	29-00	71-10	"
Bean straw,	32-91	65-97	Hertwig.
Pea straw,	27-82	72-18	"
Rye straw,	19-47	80-26	Fresenius.

Extraction of Potashes.—The American process for the extraction of potashes is thus described by MORFIT. The incineration of the plant is effected in dry pits, sunk into the ground to a depth of three or four feet. The plant is thrown in in portions, and burned until the pit is nearly full of ashes. The latter are then removed, mixed with about five per cent. of lime, and drenched with successive portions of fresh water. The ash-tubs or vats employed in this operation are usually formed from tar-barrels, by cutting them in half. A number of these are furnished with two cross-beams, upon which rests a false cullendered bottom covered with straw, and below this is a cock for the removal of the lie. The first liquor running through being saturated is passed at once to the evaporating pan; while the second or third runnings, being weaker, are reserved and poured upon fresh ash until completely saturated. The evaporating pans are broad and shallow, and made of iron with corrugated bottoms, to produce greater extent of heating surface; and as evaporation progresses, new supplies of strong liquor are poured in, and the heat is continued until a sirupy consistence is attained, when the fire is gradually slackened, and the contents of the pan, becoming solid, are dug out and placed aside as *crude potashes*. By subjecting this mass to the heat of a reverberatory furnace, most of the sulphur, and all excessive water and empyreumatic matters are expelled, causing a loss of ten to fifteen per cent. This modified product is white, with a bluish tinge, contains more carbonic acid than the original crude product, and takes the name of *pearlash*.

The process employed in Russia and Northern Europe is the same in principle as that above described, and is conducted in a similar manner, except that no lime is used in the lixiviation process. The difficulty experienced in the removal of the potashes from the evaporating pans may be avoided, in a great measure, by constant agitation of the lie while cooling. The salt thus obtained, however, contains twice as much water as in the ordinary method. By some producers a separation of the greater part of the difficultly soluble

sulphate of potassa—a salt largely consumed by the manufacturers of alum—is effected by evaporation and cooling from the lie, which has been saturated with the soluble constituents of the ash, and a much superior variety of potashes is obtained.

The insoluble portion of the ashes of plants, and which remains in the lixiviating vat, is employed in glasshouses for the production of green bottle-glass, and, on account of the phosphates it contains, is also valuable as a manure.

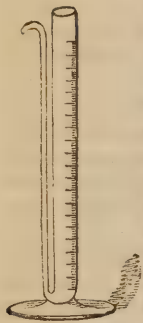
The production of potashes is principally carried on in those countries where, being thinly populated, wood is very abundant. In Russia, straw and weeds are burnt for the potassa they contain; and in some districts of France, yeast, the lees of wine, and distillery refuse are also applied to the same purpose; while in Java, potashes are extracted from the stems and leaves of the indigo plant, after the separation of the coloring matter.

The principal varieties of potashes met with in commerce are American, Russian, German, Saxon, and Dantzic. They vary but little in appearance, and derive their names from the locality whence they are imported. The proportion of carbonate of potassa contained in the crude ashes varies from forty to eighty per cent., and the residue for the most part consists of sulphate and silicate of potassa and chloride of potassium. According to the analysis of VAUQUELIN, American potashes contain of pure hydrated potassa—either in the free state, or combined with carbonic acid—74 per cent., Russian potashes 67, and American pearlashes 65·5 per cent. Various European specimens, also examined by this chemist, yielded from 38·5 to 62 per cent.

Valuation of Potashes—Alkalimetry.—The commercial value of potashes depends entirely upon the proportional amount of carbonate or caustic alkali contained in them; and it is, therefore, important to be able to effect the estimation of these salts otherwise than by a complete chemical analysis, as the tediousness of the operation, the great practice required in manipulation, and the cost of apparatus, render any such method nearly impracticable to the manufacturer. Several processes have been devised to ascertain the amount of available alkali in the crude product with sufficient accuracy for the purposes of commerce. Amongst these, the one most frequently adopted is that first broached by RICHTER, afterwards practised by DESCROIZELLES, and subsequently improved by GAY-LUSSAC. It consists in determining the quantity of an acid required to neutralize the alkaline reaction of a known weight of the salt to be examined, which, of course, represents the amount of available alkali present. Sulphuric acid is generally employed for this purpose; for while it wholly expels the carbonic acid, and combines with the whole of the free alkali, it does not extend its decomposing influence to the foreign salts in any important degree. The measure used in this process, termed an *alkalimeter*, is shown in Fig. 422. The cylinder is usually about twelve inches in height, and three-fifths of an inch internal diameter, and is graduated uniformly downwards into one hundred divisions.

For estimating the value of potashes, the following is the most convenient method. A quantity of sulphuric acid is taken and gradually added to about nine times its bulk of water, and the mixture is allowed to cool; 112.75 grains of perfectly pure anhydrous carbonate of soda are then taken and dissolved in about a half-pint of water, and the solution is heated. The

Fig. 422.



alkalimeter is now filled to exactly one hundred measures with the mixture of acid and water, and the latter is gradually poured into the soda solution to complete saturation. The number of measures of acid used is then carefully read off, and these are exactly equivalent to one hundred grains of pure potassa. If, therefore, eighty measures of acid are required, by adding to every eighty measures remaining twenty additional measures of water, an acid is obtained of which one hundred alkalimeter measures exactly represent one hundred grains of potassa—that is, one grain to each measure. If a greater or less quantity of acid is required for the saturation of the carbonate of soda, the quantity of water required to be added to the acid is diminished or increased according to such proportion, so that one hundred measures of the acid liquid shall contain exactly the quantity of the stronger acid used to effect the neutralization of the soda salt.

All that is now required, in order to ascertain the quantity of real potassa in any sample of potashes or pearlash, is to dissolve one hundred grains of the sample in warm water, filter, to remove all insoluble matters, and add the dilute acid in small successive portions, until, by the test of litmus paper, the solution is exactly neutralized. Each division of the acid added indicates one grain of pure potassa.

With regard to the performance of the operation, it is necessary to exercise great care to hit the exact point of saturation of the alkali. With caustic alkali this may be effected with ease; but in the case of the salt under discussion, the liberated carbonic acid, which imparts a red tint to the litmus paper, causes some difficulty. The first addition of the acid, however, does not produce effervescence, because the carbonic acid expelled, instead of escaping, combines with the carbonate as yet undecomposed, converting it into bicarbonate; but as soon as half the quantity of potassa contained in the solution is saturated, effervescence ensues, and the solution containing free carbonic acid now changes the blue color of litmus to purple or bluish-red. On the addition of more acid, with constant stirring of the solution, and with increased caution as the point of neutralization is approached, which is known by repeatedly testing with the litmus, until only one drop is added at a time, when the alkali is exactly saturated, the slightest excess of acid produces a permanently red stain after drying. The alkalimeter is then allowed to rest for a short time, in order that the liquid may drain from the sides, and the number of divisions of acid employed is carefully read off, and the per centage amount of potassa contained in the salt examined is at

once ascertained, being equivalent to the number of measures of acid used.

A modification of the above alkalimetric process has lately been proposed by MOHR which gives good results. Instead of sulphuric acid, he employs crystallized oxalic acid. The great disadvantage of this method is, that besides the solution of acid, a standard solution of soda is required as a counter test. In his process the alkali to be examined is dissolved in water, and the solution colored blue with tincture of litmus. As much of the test acid is then added as will suffice to impart a violet color to the fluid. The latter is then boiled, and receives a further addition of acid until the color is decidedly yellowish-red. The alkali is lastly oversaturated with acid, and the last traces of carbonic acid are removed by boiling, *et cetera*. The excess of acid used is now ascertained by addition of the test solution of soda to exact neutralization, and deducting this from the whole quantity employed, the quantity of crystallized oxalic acid required for the saturation of the alkali is ascertained. Every sixty-three grains of this acid represent forty-eight grains of pure potassa.

In the laboratory of the chemist, indeed wherever the examination of alkaline solutions, besides those of potassa, is frequently practised, an acid is prepared that may be adjusted for all alkalies, that is, of such a strength that one thousand grains measure will exactly saturate a certain quantity of each base. The mode of effecting this object is as follows:—An alkalimeter is used of similar construction to that previously described. Into it are poured one thousand grains of water, and the space it occupies is accurately graduated into one hundred equal parts. Opposite to the numbers 23.44, 54.63, 58.96, and 65.0, lines are traced—the first of which is marked *soda*; the second, *carbonate of soda*; the third, *potassa*; and the fourth, *carbonate of potassa*. Dilute sulphuric acid is now prepared, of specific gravity 1.127 at 60°, and is made by adding to one measure of concentrated acid four measures of water. This standard acid is of such strength, that when poured into the tube till it reaches either of the four marks above-mentioned, the exact quantity is obtained for the neutralization of one hundred grains of the alkali, the name of which is written opposite to it. If water be now added until it reaches the beginning of the scale, each measure of the mixture will exactly neutralize one grain of the alkali named, and at once shows the centesimal amount of pure caustic or carbonate of alkali contained in the sample under examination. The strength of the acid is verified by the means previously described, and the process is conducted precisely in the manner directed in the estimation of the potassa salt.

The various kinds of alkali of commerce usually contain a greater or less proportion of chlorides and sulphates. The presence of these does not interfere in the slightest degree with the above methods of estimation. In some cases, however, sulphides, sulphites, and hyposulphites are also present, and these, neutralizing a certain quantity of the test acid, render the determinations more or less inaccurate. The first of these salts evolves sulphide of hydrogen, the second sulphurous acid, and the last hyposulphurous acid, which is immediately decomposed into sulphurous acid

and sulphur. On the addition of an acid, therefore, to a portion of the salt under examination, the presence of sulphite or hyposulphite is indicated by the intensely penetrating nature of the sulphurous vapor eliminated, while a sulphide is shown to be present by the blackening of a slip of paper moistened with acetate of lead and a little ammonia, and placed in contact with the evolved gas. A single experiment serves for the detection of both gases, as it has been lately shown, though previously disputed, that the two may be simultaneously evolved. Should the salts of these acids be proved to be present, the error they would introduce is easily obviated by the addition of a little neutral chromate of potassa, the acid of which immediately transforms the sulphites, hyposulphites, and sulphides into sulphates, with separation of water and sulphur.

An alkalimetric process, varying in principle from those above described, has been devised by FRESenius and WILL, and consists in ascertaining the amount of carbonic acid contained in the sample to be examined, and which is displaced on the addition of an acid. As in the preceding processes, any insoluble matters must be separated by treatment with water and filtration, and if, besides carbonate, caustic alkali is also present, this must be converted into carbonate as follows:—The solution of the weighed portion of the sample after filtration is evaporated nearly to dryness, and solution of carbonate of ammonia is added in excess; the evaporation is then continued, and the residue is finally dried at a high temperature, so as to expel all traces of undecomposed carbonate of ammonia. This salt yielding its carbonic acid to the more powerful base, converts the whole of the latter existing as caustic into carbonate of the alkali. The dry residue is then transferred to an apparatus—Fig. 423—carefully rinsing the dish, and adding the washings to the salt. The rest of the

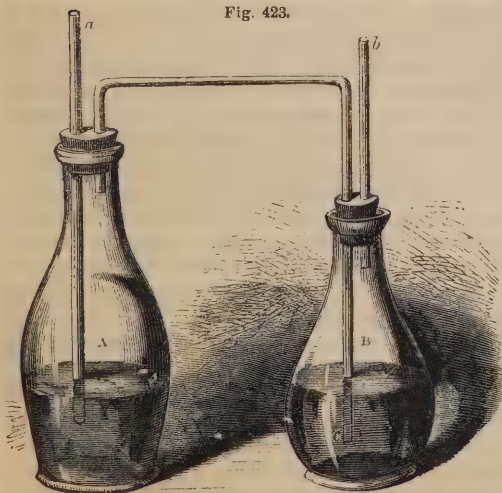
was made in 1752 by CARTHEUSER. He directs it to be prepared by adding to a solution of the neutral carbonate of potassa as much carbonate of ammonia as will yield to the potassa salt a quantity of carbonic acid equal to that already present. The proportions employed by DUFLOS are four parts of carbonate of potassa, four of water, and one of carbonate of ammonia. The operation is conducted in a retort, that the evolved ammonia may be collected. After boiling for an hour, the solution is left to cool, when a separation of crystals of bicarbonate ensues. These are removed, and to the mother-liquid is added an equal quantity of the ammoniacal salt, and the process is continued as before. Bicarbonate of potassa is also produced when a solution of neutral carbonate is saturated with carbonic acid, and this process is the one usually employed. The carbonic acid gas eliminated during the fermentation of saccharine solutions is frequently applied to the production of this salt, or it may be liberated from marble or chalk by means of dilute sulphuric or hydrochloric acid. Before coming in contact with the potassa solution, the gas is conducted through a bottle half filled with water, to wash away any impurities that may be mechanically carried over. When the solution no longer absorbs carbonic acid it is set aside, to allow the deposition of crystals, of which a further quantity may be obtained by concentration of the mother-liquid, and a further addition of carbonic acid.

Properties.—Bicarbonate of potassa, in the crystalline condition, has the form of an oblique rhombic prism, and is combined with an equivalent of water. Its formula is $\text{KO}, 2 \text{CO}_2, \text{HO}$. It is unalterable in the air, but when strongly heated loses half its acid and the whole of the water, reverting to the state of neutral carbonate. When heated in water, also, it is partially decomposed, and, by long boiling, completely, with production of neutral carbonate. The taste and reaction of bicarbonate of potassa is slightly alkaline. It dissolves in four parts of water at 60° , and in little more than its own weight of this liquid at a boiling heat. In alcohol it is nearly insoluble. It is occasionally employed in the preparation of pure neutral carbonate of potassa.

Physiological Effects.—This salt, as well as the preceding, is possessed of antacid properties. It is, however, much less corrosive than the neutral carbonate. Like this latter salt, it has also diuretic and antilithic properties; and being less unpleasant to the taste, as well as less irritating, it may be administered in much larger doses. It is frequently used also for producing effervescing powders.

SULPHATE OF POTASSA—Vitriolated Tartar, Salpolycrest.—This salt is most conveniently prepared by neutralizing with carbonate of potassa the bisulphate of this base, as obtained in the preparation of nitric acid, or by expelling the excess of sulphuric acid by heating the bisulphate to redness. It may also be formed synthetically by saturating carbonate of potassa with diluted sulphuric acid, and evaporating the liquor that crystals may be formed. Sulphate of potassa— KO, SO_3 —is especially distinguished by its hardness. The form of the crystal is that of a six-sided prism. These crystals contain no water of combination; but when heated,

Fig. 423.



operation is conducted precisely as described in the estimation of manganese ore—omitting the oxalate of potassa. Every twenty-two grains loss of weight in the apparatus represents forty-seven of potassa, or thirty-one of soda, according to the salt under examination.

Bicarbonate of Potassa.—The discovery of this salt

decrepitate, owing to the volatilization of a small portion of this liquid mechanically held. Exposed to red heat, sulphate of potassa fuses, but without decomposition, and at a white heat, volatilizes. The taste of this salt is bitter, and feebly saline. It dissolves in about eleven parts of water at 60°, and four at 212°. In alcohol, and in solution of potassa, it is quite insoluble. It is principally employed in the production of alum and saltpetre. Both sulphate and bisulphate of potassa are also used in medicine as gentle laxatives, and the latter salt occasionally to replace the vegetal acids in the preparation of effervescing draughts.

NITRATE OF POTASSA—Saltpetre.—This important salt is found abundantly as a natural product, usually associated with the nitrates of lime, magnesia, *et cetera*. It is obtained in a state of purity by decomposing carbonate of potassa by nitric acid. The solution by evaporation deposits crystals of the pure salt. It may be obtained also from the saltpetre of commerce, by pounding the latter, moistening it with one-sixteenth of its weight of nitric acid and a small quantity of water, evaporating the liquid to dryness with constant stirring, and repeating the process if the salt still contains chlorine.

Properties.—Nitrate of potassa— KO, NO_3 —is dimorphous. Its ordinary form belongs to the right prismatic system. More rarely, the crystals are obtuse, flattened rhombohedrons. Under both conditions it contains no combined water, but its crystals are never quite free from water lodged mechanically within them; and hence, on heating, decrepitation ensues. The taste of this salt is saline, accompanied with a sense of coolness. It is soluble in seven parts of water at 60°, and in an equal weight at 212°. At 616° it undergoes the igneous fusion, and at a strong red heat is completely decomposed with evolution of oxygen and nitrogen gases, leaving a mixture of potassa and peroxide of potassium. When mixed with combustible matter and heated, or when thrown in a state of fusion on some of the metals, rapid oxidation takes place at the expense of the oxygen of the nitric acid.

The saltpetre of commerce is derived principally from the East Indies, where, as also in Persia, Egypt, and Spain, it appears as an efflorescence on the surface of the soil. In some other countries, as the coast of the Adriatic, in Ceylon, North America, Africa, and Teneriffe, it is found on the walls of natural caverns formed in limestone rocks, and which contain also felspar and magnesia. It is also found widely distributed in some parts of Hungary, but in no case extending to any great depth below the surface of the ground, nor even to such a depth as the air cannot penetrate. Its appearance on the surface of the ground is explained by its ready solubility in water, as when its solution, in obedience to the law of capillary attraction, rises to the surface, the liquid is vaporized by the action of sun and air, and its place is immediately occupied by a fresh portion from below, which disappears in the same manner, until at last an incrustation of the salt is formed of considerable thickness, either in solid crystals, or as an effloresced mass.

Exudations containing saltpetre are not unfrequently met with upon new walls, and also, under certain cir-

cumstances, on old walls. Thus, in densely-populated towns, where the excrements of beasts of burden, refuse from slaughter-houses and from other trades of a similar kind, the water from the houses, the refuse of markets, *et cetera*, mix with the fluid in the drains, and are in a constant state of putrefaction—the coating of mortar on external walls, and especially near the base, gradually becomes covered with a white crystalline efflorescence, and the phenomenon is known as saltpetre rot. Indeed, whenever either accidentally or purposely a strong base, as lime, magnesia, or potassa, comes in contact with decaying vegetal or animal nitrogenous matters in presence of moisture, nitric acid is always generated, and, combining with the bases, produces nitrates; and these by contact with a potassa salt readily yield nitrate of potassa. The principle was, indeed, formerly extensively applied to the production of this salt.

Formation of Saltpetre—Nitrification.—Concerning the production of saltpetre, various theories have been from time to time promulgated, each of which has had large numbers of supporters, eminent for extensive chemical knowledge. GLAUBER, and subsequently STAHL, occupied themselves with this subject. About a century after the investigations of the latter chemist, LAVOISIER published a theory of the process; and since then, amongst others, KUHLMANN, THOUVENEL, THÉNARD, LONGCHAMP, GAY-LUSSAC, and LIEBIG, have devoted a considerable share of attention to the subject. The whole explanation of the process hinges upon the source of the elements of the nitric acid, and more especially upon the source of the nitrogen. The theory first published by LONGCHAMP supposes direct union of the nitrogen and oxygen of the atmosphere to be induced by electricity; and the nitric acid thus produced being brought to the ground in rain, combines with potassa and other bases capable of being converted into saltpetre by the action upon them of potassa salts. In reply to this, it may be observed that although, as first observed by CAVENDISH, lightning, in passing through the air, certainly induces combination of the elements of nitric acid, still this action is so limited, and of such rare occurrence, that its adoption as an explanation of the formation of saltpetre is quite inadmissible. LONGCHAMP, subsequently convinced of the untenability of his theory, adopted another one, in which he was supported by Dr. JOHN DAVY, PROUST, and others. This latter ascribes the union of the two elements to an action excited by the porous mineral constituents of the soil, similar to that of platinum black. The advocates of this view cite in defence of it the following experiments:—When earth forming nitre is freed from all its soluble salts by lixiviation, and is then exposed for several years to the action of the air, it yields a second crop of nitre, and these crops may be obtained three or four times in succession, although in different proportions. The supporters of this theory, supposing that all bodies containing nitrogen are removed by the first lixiviation, contend, therefore, that the nitrogen of the nitric acid subsequently produced, must have been derived from the air. That this conclusion is not justified by the circumstances of the case, was shown by GAY-LUSSAC, who, having estimated the amount of substances containing nitro-

gen, and compared this with the quantity of nitric acid actually generated, found that the proportion of the latter always corresponded with the quantity of nitrogenous matter present in the mixture, and that the yield of saltpetre was increased or diminished by an augmentation or decrease in the quantity of nitrogenized matters added. The conclusion that nitric acid is formed in such a case at the expense of atmospheric nitrogen, is, therefore, not in any way confirmed; indeed all experiments on the subject completely contradict the assertion that nitric acid may be generated in mixtures of earth destitute of nitrogenous matter. Considering, however, that nitrogenized organic bodies receive their nitrogen from the atmosphere in the form of ammonia, the primary origin of the nitric acid of saltpetre must be the ammonia of the atmosphere; and, in addition, it may be affirmed that ammonia is not only the ultimate source, but that it is also the immediate source of nitric acid; and hence the production of the latter may be expected wherever the ammonia and the conditions for its oxidation are found united. The truth of this theory is confirmed by the experiments of MARTIGNY, who found ammonia which had been confined with air over milk of lime, converted after six months into nitric acid; by those of KUHLMANN, who obtained a large quantity of nitric acid where a mixture of sulphate of ammonia, sulphuric acid, and bichromate of potassa, peroxide of manganese, or lead, were heated together; and by DUMAS, who has shown that when a current of moist air, mixed with ammonia, is passed over chalk moistened with a solution of potassa, at a temperature of 212°, there is formed after some time a considerable quantity of nitrate of potassa.

If, therefore, nitric acid is derived directly from the oxidation of the ammonia of putrefying organic matters, it appears probable that wherever the necessary bases are present in admixture, for fixing the acid, there saltpetre would be found. But, as in many other cases of decomposition, all the necessary conditions for the exertion of chemical affinities may be prepared, and yet the action will not ensue unless some impulse be given from without. This impulse proceeds most generally and energetically from some chemical action already in the course of operation. As has already been stated, the experimental conversion of ammonia into nitric acid has only succeeded at a high temperature or by the intervention of a free base, neither of which conditions frequently occurs in nature. The impulse which decomposing bodies can thus communicate, is, however, in all probability, sufficiently powerful to give rise to the formation of saltpetre at ordinary temperatures, and the time allowed for its production in nature very much exceeds the duration of ordinary experiments. It is highly probable that ammonia also plays a double part in the formation of saltpetre; first, in surrendering its elements to oxidation, and then also in saturating the acid, producing nitrate of ammonia. This salt then coming in contact with earthy and alkaline carbonates, decomposition ensues, nitrates of the earths or alkalis, and carbonate of ammonia being produced; thus $\text{NH}_4\text{O}, \text{NO}_5 + \text{MO}, \text{CO}_2 = \text{MO}, \text{NO}_5 + \text{NH}_4\text{O}, \text{CO}_2$. The ammonia therefore not only parts with its elements for the production of nitric acid, but also acts as a

carrier of the acid to a stronger base. The ammonia now become carbonate, and this salt possessing basic properties, it resumes its functions in a higher degree on account of the presence of moisture.

As already noticed, saltpetre is found in several countries, as a saline efflorescence on the surface of the earth. In India, the district of Tirhût is the most productive of this salt, and it is always more abundant in those parts containing a redundancy of carbonate of lime. An average sample of the soil analysed by STEVENSON, gave the following results:—

	Per centage.
Matter insoluble in acids,.....	50.0
Carbonate of lime,.....	44.3
Matter { Sulphate of soda,.....	2.7
soluble { Chloride of sodium,.....	1.4
in water, { Nitrate of lime,.....	0.9
{ Nitrate of potassa,.....	0.7
	100.0

The process for the extraction of the saltpetre is commenced by scraping off the surface from old mud heaps, mud buildings, waste grounds, *et cetera*, where the saltpetre has developed itself in a thin white efflorescence resembling frost rind. This saline earth being removed to the factories, is subjected to the process of lixiviation. This is effected in a large mud filter, lined on the inside with stiff clay. The filter has a false bottom of bamboo, covered with close-wrought grass mats, on which are placed vegetal ashes. Upon these the saline earth is laid. Water is then added to remove the soluble salts, and the solution thus obtained, filtering through the mats, drops into the empty space between the real and false bottom, and is conveyed away into an earthen receiver. In its passage through the wood ashes, the carbonate of potassa contained in the latter reacts upon the nitrate of lime, producing nitrate of potassa and carbonate of lime: thus $\text{CaO}, \text{NO}_5 + \text{KO}, \text{CO}_2 = \text{CaO}, \text{CO}_2 + \text{KO}, \text{NO}_5$. The solution is now evaporated in earthen pots, filtered, and put aside to crystallize. The impure salt thus obtained is termed *dhouah*. It contains from forty-five to seventy per cent. of nitrate of potassa. This is redissolved and recrystallized by the native merchants, and when thus purified is known by the natives as *kalmee*.—Stevenson.

In Ceylon the nitrous efflorescence on the walls of the natural caverns is detached, during six months of the year, with picks, together with a small portion of the rock, which latter, as it contains felspar, is doubtless the source of the potassa. The fragments are pounded, mixed with an equal portion of wood ashes, and water is poured upon the mixture. The earthy nitrates yield their acid to the potassa contained in the ashes, and the earths are precipitated as carbonates of lime and magnesia. The clear decanted lie, containing, besides the nitre of the rock, also that formed by the decomposition of the earthy nitrates, is evaporated in pits, exposed to the sun, and afterwards in pans by means of artificial heat. The crude saltpetre which crystallizes on cooling, is then fit for exportation.

During the period of the great war with France, at the end of the last and the commencement of the present century, the immense quantities of saltpetre, required for the manufacture of gunpowder, were produced in that country by an artificial process. The

great difficulty experienced by the government of that country, in obtaining the necessary supply of this indispensable material of warfare, induced them to offer a prize for the best treatise upon the principles of its production, and the best method of putting them in practice. The number of competitors was sixty-six. From the most valuable of these treatises, a process of manufacture was deduced, which, though tedious and costly, was perfectly successful, the execution of which was intrusted to BERTHOLLET, one of the most eminent chemists of that period, and who traversed the nation from one extremity to the other, giving instructions as to the mode of procedure. The process, of which the following is an outline, though no longer practised to any considerable extent, is of great importance. Animal refuse of all kinds is mixed with old mortar, or slaked lime and earth, and the mass placed in heaps, and protected from rain, is freely exposed to the air. From time to time these heaps are turned over and watered with fluids containing putrid nitrogenous matters, such as stale urine, cesspool liquors, or waters in which animal flesh or cheese has been soaked or washed. After a certain period a white mouldy appearance is observed on the surface of the heap, consisting of the nitrates of alumina, lime, magnesia, *et cetera*. When the process is at an end, the earth is said to be ripe, and is lixiviated with water in troughs in double bottoms, using only as much liquid as is necessary for the extraction of the salts. To the lie thus obtained, potashes, sulphate of potassa, or chloride of potassium is added in sufficient quantity to convert the nitrates of the earths into nitrate of potassa. If sulphate of potassa is used, milk of lime is also added to decompose the sulphate of magnesia that will be formed. After deposition of the heavy precipitate, the clear solution containing nitrate of potassa, chlorides of potassium and sodium, and a little sulphate of lime, is drawn or siphoned off, concentrated by boiling, and by repeated crystallization the salt is obtained comparatively pure.

Besides solid and liquid animal refuse, some vegetal substances are also applicable to the production of saltpetre. Thus, several weeds belonging to the families *solanaceæ*, *euphorbiacæ*, and *fungi*, pea, bean, and Indian corn straw, are especially valuable. In some countries, as for instance in Sweden, where saltpetre is one of the government taxes, vegetal matters are employed either with or without animal refuse. In the construction of the heap, the vegetal substance is first spread out upon a layer of earth; upon these the other solid matters are laid to a height of some feet, and the whole is covered with a second layer of earth. This heap is watered from time to time with urine, in quantity just sufficient to keep it moist throughout. During the summer, the heap, which has decayed to a uniform mass, is turned over once weekly, and in winter, once monthly, care being taken to keep the whole as loose as possible.

In Switzerland the earth below the flooring of stables, or in the neighborhood of dunghills, or in the cellars of dwelling-houses, where the remains of vegetal or other organic matters have been left to decompose, is the material used for the production of saltpetre. In Prussia a peculiar continuous process is practised. The

heaps are constructed with perpendicular sides; that opposed to the wind is simple and flat, while the opposite one forms a series of steps down to the bottom; on each step is a gutter, which carries back the excess of liquid poured upon it to a cistern. In this arrangement, the watering takes place at the back, while the evaporation proceeds principally at the sides exposed to the wind, so that the saltpetre is gradually drawn towards the latter part, whence it is removed, and an equal quantity of fresh earth is added behind. The great advantage of this method is that a heap is never totally destroyed, and the great difficulty experienced in the commencement of the process of nitrification is entirely removed. The preparation of saltpetre, by decomposing nitrate of soda, is pursued in some localities where potashes can be obtained at a low price. In this case the change is very simple, nitrate of potassa and carbonate of soda being produced. Thus, $\text{NaO}, \text{NO}_3 + \text{KO}, \text{CO}_3 = \text{NaO}, \text{CO}_3 + \text{KO}, \text{NO}_3$. All that appears difficult in this process is the removal of the carbonate of soda, but, as remarked by KNAPP, a greater difficulty arises from the presence of chloride of sodium in commercial nitrate of soda; for as soon as a little more potashes are added than correspond with the quantity of pure nitrate of soda, the excess decomposes chloride of sodium to no purpose; and in the opposite case the product is contaminated with portions of undecomposed nitrate of soda.

Purification.—The crude saltpetre as obtained by the above processes, as well as the rough salt imported from Ceylon and the East Indies, always contains more or less impurity, which may be organic, that is, vegetal or animal matter, or inorganic, as other alkaline and some earthy soluble salts, or both. The foreign matters most frequently present, and in the largest proportion, are the chlorides of potassium and sodium, in some cases exceeding twenty-five per cent. of the crude salt. These latter are of all impurities the most objectionable, and the most difficult to remove. The process of separation most frequently practised depends upon the fact that the solubility of nitre rapidly increases with elevation of temperature, while that of the two chlorides remains nearly constant. A roomy copper boiler is the one most frequently employed. A rough estimation of the amount of impurity present having been previously made, and the solubility of pure nitrate of potassa being known, namely, three parts to one of water, the crude salt is added to the boiling water, until as much nitrate of potassa is present as can be dissolved, the heat at the same time being increased until the saturated solution also enters into ebullition. The solution is now kept constantly stirred, and the scum which collects on the surface is removed. A large proportion of the chloride of sodium subsides, and is scooped out from the bottom of the pan. A further quantity of water is then gradually added, amounting to two-thirds of that originally employed, and afterwards an aqueous solution of common glue, containing one pound of the latter to every ton and a half of crude saltpetre operated upon, and the whole is again boiled and well agitated. The glue thus diffused through the liquid enters into combination with the organic extractive matter present,

and carries it to the surface in the form of scum, which is carefully removed; and after boiling for some time, the solution is perfectly clarified. The whole is then allowed to stand at rest for twelve hours, the heat being continued at about 190° , so as to prevent crystallization of the salt, which, if allowed, renders the after process much more tedious. The supernatant liquid is now carefully drawn off from the deposit of common salt and other matters into the crystallizing pan. This latter is a shallow copper vessel, the edge of which is firmly secured to a platform of oak. It is formed of two inclined planes, so arranged that the deepest point is at one of the narrow sides. As the liquor cools, the crystals quickly form, and if the liquor is left tranquil, they are of large size and clustered together. If, however, the liquid be constantly agitated while in the act of cooling, the salt separates in fine crystalline needles, termed *saltpetre flour*, and as it forms, is drawn out of the lie towards the top of one of the inclined planes of the pan, where it remains until the mother-liquor has drained from it. This method of crystallization, first recommended by BEAUMÉ and LAVOISIER, is far preferable to the old process in which the salt is allowed to separate from the tranquil liquid; as in this case, owing to the formation of larger crystals, and in clusters, a much greater proportion of mother-liquor is retained, and a second solution and crystallization is required to render the salt sufficiently pure for commercial purposes. The salt separated as above, when sufficiently dry, can contain only a very small quantity of mother-liquor, and consequently, also of the impurities therein contained. To effect the removal of the last traces of these, the crystalline mass is next washed in tubs provided with a false bottom drilled with holes. These tubs are filled completely with the salt, the latter being heaped up some inches above the rim. The washing-liquor is a saturated solution of *pure* nitrate of potassa, which, although it dissolves other salts that may be present as readily as would be the case with pure water, of course can have no effect upon the saltpetre. This liquor is poured upon the salt, so as thoroughly to wet the mass, and by means of a plug, is prevented from running off for a period of three hours, after which the plug is removed, and the salt well drained. This operation is again repeated, in this case with pure water, and these washings constitute the solution of nitrate of potassa which is employed for the first washing of a fresh portion of the salt. After being well drained, for which a period of some days is required, the saltpetre flour is dried with constant agitation in a pan economically heated by the flue of the boiler fire.

Refraction of Saltpetre.—A considerable proportion of the crude saltpetre of commerce always consists of foreign matters, and as its value is solely dependent upon the amount of pure nitrate of potassa which it contains, it is important to have some readily available means of ascertaining with accuracy the quantity of the pure salt, or, which answers the purpose equally well, the amount of impurities contained in a given sample. The determination of these impurities, or the loss which results from the purification or refining of saltpetre, is technically termed the *refraction*.

The foreign matters usually met with in crude saltpetre are chlorides of potassium, sodium, and magnesium, sulphates of potassa and lime, nitrate of soda, water, and traces of organic matter. The accurate quantitative analysis of such a mixture of salts is not a very easy problem; and yet their separation is essentially necessary, to render saltpetre available for the purpose to which it is almost wholly applied, namely, the production of gunpowder.

Several processes have from time to time been suggested for the refraction of saltpetre, many of which are however of little value, though even now extensively practised both in this and other countries. Whatever method be adopted, especial care must be exercised to procure a fair average sample of the salt to be examined.

The method of refraction principally employed in France, is that introduced by RIFFAUT, which, besides being very tedious, gives only approximate results. It consists in washing a weighed quantity of the dry crude salt, with a saturated aqueous solution of pure nitrate of potassa. This, although it cannot extract nitrate of potassa from the sample, effects the removal of all foreign soluble salts. When these are extracted, the salt remaining on the filter is dried and weighed, and the amount of loss sustained by the original sample is taken to represent the amount of impurity present. This method is liable to so many sources of error, as to render it quite inapplicable in cases where even a tolerable degree of accuracy is required. Under the most favorable circumstances, it indicates from one to three per cent. more nitrate of potassa than is actually present in the sample.

A better method is that suggested by GAY-LUSSAC, but which, as it requires great care and dexterity in its execution, is unfitted for practical use, except to the experienced chemist. In this process the nitrate of potassa is converted into carbonate by fusion with charcoal; and the quantity of potassa contained in the new salt is estimated exactly as directed when treating of the valuation of potashes, or ALKALIMETRY. Every forty-seven grains of potassa found, indicate one hundred and one grains of nitrate of potassa contained in the sample under examination.

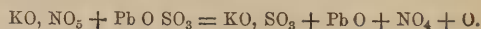
Various other processes are practised by different analysts, in which the amount of nitrate of potassa contained in a given sample of crude saltpetre is deduced from the quantity of nitric acid present, and therefore they consist in the determination of this acid by any available means. Amongst them the method of GOSSART, as modified by PELOUZE, is the most frequently applied. This consists in the determination of the amount of protoxide of iron converted to the state of sesquioxide, by a weighed portion of the salt to be examined. The theory of this reaction is represented by the following equation— $6 \text{ Fe Cl} + \text{KO}, \text{NO}_5 + 4 \text{ H Cl} = 4 \text{ HO} + \text{K Cl} + \text{NO}_2 + 3 \text{ Fe}_2 \text{ Cl}_3$. That is to say, every one hundred and sixty-eight parts, or six equivalents of iron converted from the state of protochloride to that of sesquichloride, represent fifty-four parts, or one equivalent of nitric acid. The process is conducted as follows:—Thirty-one grains of pianoforte wire are dissolved in about fifteen hundred

grains measure of concentrated hydrochloric acid; to this is now added 18·7 grains of the saltpetre to be examined, and the flask containing the mixture is immediately closed and heated till the liquid boils. The latter quickly assumes a brown color, and the dense vapors of hydrochloric acid and nitric oxide which issue from the flask prevent the access of air, which, if allowed to come in contact with the mixture, by its action upon the nitric oxide, which it converts to nitrous acid, would oxidize a certain quantity of iron, and thus render the estimate of the nitrate of potassa apparently higher than it really is. When the solution has become of a clear yellow color, and perfectly transparent, the flask containing it is removed from the source of heat, and the liquid is transferred to a convenient vessel and diluted with two pints of water. A solution of permanganate of potassa of known strength is now cautiously added from a graduated burette, constantly agitating the mixture; and as soon as the latter acquires a faint rose-red tint, the addition of permanganate of potassa is discontinued, and the quantity employed to sesquioxidize the iron read off on the burette. The proportion of nitric acid contained in the sample is now readily deduced as follows:—Suppose the test solution of permanganate of potassa employed to be of such strength, that one hundred alkalimetric measures are required to sesquioxidize fifty grains of iron; and that fourteen divisions were required to complete the oxidation of the iron left in the state of protochloride after treatment with the saltpetre as above directed, the amount of protochloride corresponding to the fourteen divisions is at once found by a simple calculation—for if one hundred measures of the solution of permanganate are required to sesquioxidize fifty grains of iron, fourteen measures will suffice for seven grains. If this quantity be now subtracted from the thirty-one grains of iron originally employed, the remaining twenty-four grains represent the quantity sesquioxidized by the 18·7 grains of saltpetre employed. Now, as thirty-one grains of iron require 18·7 of pure nitrate of potassa to effect its complete oxidation, twenty-four grains of iron will require 14·48 of pure nitrate; this represents the amount contained in the 18·7 grains submitted to examination, and by the calculation, as $18\cdot7 : 14\cdot48 :: 100 : 77\cdot43$ = the per centage amount of pure nitrate of potassa contained in the sample.

In the process recommended by STEIN, the proportion of pure nitrate of potassa contained in a given sample of saltpetre is estimated by the amount of arsenious acid which it can convert to the state of arsenic acid. This method, though it gives accurate results, owing to the length of time required to perform the analysis, is inapplicable for ordinary commercial determinations, and will, therefore, not be further considered.

In the Editor's laboratory the method of refraction usually pursued is that recommended by ZENNER. The process for the determination of the nitric acid depends upon the ease with which the nitrates of the heavy metallic oxides are decomposed by heat. It is conducted as follows:—From ten to fifteen grains of the salt to be examined are introduced into a wide-bottomed porcelain crucible, and, after fitting with a

lid, the latter is heated until the salt fuses smoothly and without bubbles. The loss of weight in this operation represents the amount of water present. A quantity of freshly-dried powdered sulphate of lead, amounting to eight or ten times the weight of the saltpetre, is then placed upon the latter, and the crucible is again weighed. It is now placed over the lamp and gently heated, when decomposition ensues as follows:—



As soon as the crucible becomes hot, red-colored fumes of nitrous acid are seen to escape from under the lid; when this has ceased, and no more can be detected by the smell, the lid is lifted. Should any nitrous vapors remain in the crucible, the heat is continued a little longer. After cooling, the crucible is weighed, and the loss sustained gives the amount of nitric acid contained in the salt. Every fifty-four grains of nitric acid thus liberated represent one hundred and one grains of pure nitrate of potassa. This process is recommended not only for its accuracy, but also for the simplicity of its manipulation, and the short time required for its performance. The presence of chlorides, sulphates, or earthy matters does not in the slightest degree interfere with its application; but should the total amount of impurities exceed five per cent., it is necessary to mix the saltpetre with about four or five times its weight of the lead-salt in a small mortar, and after having transferred the mixture to the crucible, to rinse the mortar with small quantities of the reagent, which are then placed on the top of the first in the crucible.

The quantity of sulphate of potassa contained in saltpetre is determined by taking a weighed portion, dissolving in water, acidulating the solution with nitric acid, and adding nitrate of baryta as long as a precipitate is produced. Every 116·6 grains of sulphate of baryta thus obtained represent eighty-seven grains of sulphate of potassa. The amount of chloride of potassium is estimated by adding to a solution of another portion, nitrate of silver. Every 143·5 grains of chloride of silver produced, indicate 74·5 grains of chloride of potassium. Lastly, the quantity of insoluble matter is determined by dissolving a given weight of the sample in water, filtering, washing, and drying the insoluble residue, and weighing it.

Should the saltpetre under examination be contaminated with chloride of sodium, or, still more detrimentally, by nitrate of soda, the above methods of estimation do not give accurate results. In this case, it is necessary to determine the respective quantities of the two bases—potassa and soda. This is effected most conveniently by converting these bases into anhydrous sulphates, and weighing. The dry mass is then redissolved in water, and the sulphuric acid estimated by precipitation as sulphate of baryta. Now, as one hundred parts of sulphate of potassa give one hundred and thirty-four of sulphate of baryta, whilst the same amount of sulphate of soda gives one hundred and sixty-four parts of the barytic salt, it is evident, that if the weight of the mixed sulphates of the alkalies, together with that of the sulphate of baryta, be known, the respective quantities of potassa and

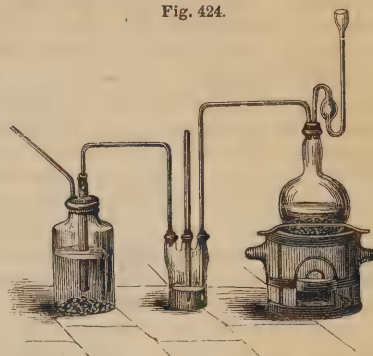
soda may be easily ascertained. Thus, if a larger quantity of sulphate of baryta be obtained than the ratio 134 : 100, the excess would be due to the salt of soda, from which the quantity of soda existing in the sample in the state of nitrate may be calculated, since every one hundred parts of sulphate of soda represent 119·7 of the nitrate.

The principal use of saltpetre in the arts, is in the production of gunpowder, for an account of which the reader is referred to page 335, *et sequitur*. In the East Indies it is employed for the preparation of cooling mixtures. On account of its powerful antiseptic properties, it is much used in the preservation of meat and animal matters in general. In the laboratory of the chemist, nitrate of potassa is chiefly employed as an oxidising agent. It is used also in the preparation of lucifer matches. The physiological effects of nitrate of potassa are, in small doses, diuretic and sedative; in doses of from half an ounce to one ounce, it is poisonous, exciting spasms, vomiting, bloody stools, convulsions, and in many cases death.

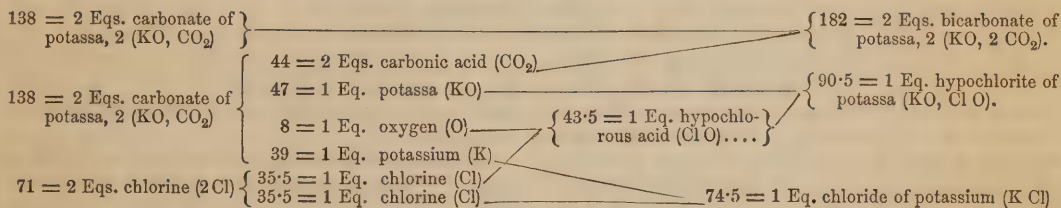
CHLORATE OF POTASSA.—This salt, when first prepared, was confounded with the one just described, but was distinguished as a peculiar salt by BERTHOLLET in 1786. The Editor finds it is most economically prepared by exposing equivalent proportions of carbonate of potassa and hydrate of lime to a current of chlorine. During the absorption of the gas the mass becomes hot, and evolves water; when saturated, it is gently heated to complete the decomposition. The fol-

lowing equation represents the change : $6 \text{ KO}, \text{CO}_2 + 6 \text{ Ca O HO} + 6 \text{ Cl} = 5 \text{ K Cl} + 6 \text{ Ca O}, \text{CO}_2 + \text{KO}, \text{Cl O}_5 + 6 \text{ HO}$. By treatment of the mass with water, the carbonate of lime is separated, and the chlorate of potassa is then freed from the more soluble chloride of potassium by evaporation, and repeated crystallization. The usual method of preparing this salt is by passing chlorine slowly through a solution of carbonate of

Fig. 424.

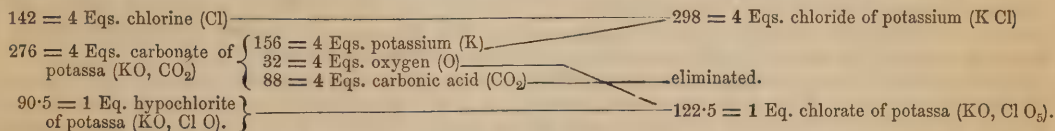


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In proportion as the quantity of chlorine increases, the bicarbonate becomes decomposed, carbonic acid is eliminated, and an additional quantity of hypochlorite

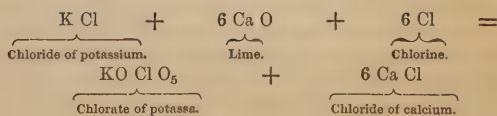
of potassa is produced. When the solution is strongly charged with hypochlorite, the action of the chlorine on the potassa salt is changed. Thus:—



The residual liquor, after crystallization of chlorate of potassa, contains, besides a small proportion of this salt, a considerable quantity of hypochlorite of potassa and chloride of potassium.

Manufacture.—Chlorate of potassa is now produced on a large scale by the following method, which has been found to answer better than any other. One part of chloride of potassium and two parts of hydrate of lime are reduced with water to a thin cream, and chlorine gas—prepared in the ordinary way from binoxide of manganese and hydrochloric acid—passed through the menstruum till it assumes a pinkish color, which is due to the formation of traces of hypermanganic acid.

A little manganese passes over during the operation, and when no more chlorine is required for the alkaline bases, water is decomposed and hypermanganic acid produced. The annexed equation represents the principal change:—



The vessel holding the solution is of any convenient form, and is provided with agitators of all shapes and sizes, depending upon the whim or caprice of each

manufacturer. It is connected with a similar one containing a fresh charge of the same materials, by means of a waste-pipe, through which all the escaping gas passes to be there absorbed. When the liquor in the former is ready to be drawn off, the gas is made to enter the latter, and the connecting-pipe between the two cisterns takes the unabsorbed chlorine to the first vessel, which, when empty, is re-filled immediately, so that very little time or gas is lost. The saturated liquor is, when drawn off, evaporated to 34° Twaddell, and the mother-liquor to 46°, if two crops of crystals are desired; if only one, then the menstruum is at once evaporated to 60°. The crystals, after being well washed, are drained on a cone having a small aperture at the bottom, and are afterwards dried upon iron plates heated by steam. The chloride of calcium is the only other compound present. Some manufacturers re-crystallize them, so as to produce a first-rate article. The principal manufacturers of this salt are, ALBRIGHTS of Birmingham, GAMBLES of St. Helen's, JAMES MUSPRATT and SONS of Liverpool, and FREDERIC MUSPRATT of Woodend, near Warrington, Lancashire. The annual production is nearly five hundred tons. The principal use to which it is applied are in bleaching, making lucifer matches, and for pyrotechnic purposes.

The Editor thinks that some means might be adopted for using this salt in the bleaching of palm oil, *et cetera*, instead of the chromate; it is cheaper, and it contains more of available oxygen.

Properties.—Chlorate of potassa— KO, ClO_3 —is a colorless, transparent, anhydrous, crystalline salt, having a glassy lustre. The crystals are oblique rhombic prisms. The taste of the salt is cooling and austere. If it be triturated, it appears phosphorescent. When heated to between 400° and 500°, it decrepitates and fuses; at a stronger heat, it loses the whole of its oxygen, leaving a residue of chloride of potassium. According to GAY-LUSSAC, it is soluble in thirty-three parts of water at 32°, in seventeen at 59°, and in five parts at 212°. It is slightly soluble in alcohol. Its action upon many combustible bodies is very energetic, and when rubbed with charcoal, sulphur, and phosphorus, the mixture inflames and explodes. Its principal use is in the manufacture of lucifer matches, and percussion powder for gun caps. It was proposed by BERTHOLLET as a substitute for saltpetre in the manufacture of gunpowder, and the attempt was made at Essone in 1788; but no sooner was the mixture of the chlorate with the sulphur and charcoal submitted to trituration, than a violent explosion took place, which proved fatal to several persons. Chlorate of potassa has also been used in medicine for imparting oxygen to the system; but, curious to say, as shown by WÖHLER, it passes off by the kidneys unaltered, and according to CHRISTISON, has no physiological or therapeutic action whatever.

CHROMATE OF POTASSA.—This salt, though much more important as a compound of chromium than of potassium, yet requires to be noticed under this head. The metal, *chromium*, so called from its tendency to produce colored salts, the name being derived from the Greek word signifying color, was discovered by VAUQUELIN in 1797, in the examination of red chromate of lead from Siberia. The most important native compound

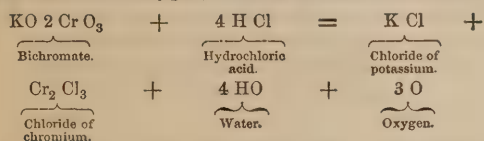
of this metal is a combination of oxide of chromium and iron, commonly termed chromate of iron, which is found abundantly at Unst in Shetland, and in other parts of Europe and America. DUMAS directs chromate of potassa to be prepared from the double oxide of chromium and iron— $\text{FeO} + 2\text{Cr}_2\text{O}_3$ —as follows:—The ore is to be pulverized and mixed with an equal weight of nitrate of potassa, and the mass gradually heated to redness. In this operation, chromate, silicate, aluminate, and occasionally manganate of potassa are produced, and the oxide of iron is set free. The soluble salts contained in the mixture are extracted by washing, and the residue, which still contains chromium, is digested with hydrochloric acid—which dissolves the oxide of iron and alumina—and again heated with nitre as before. The aqueous solution is then exactly neutralized with nitric acid, and by evaporation the alumina and silica are separated. The crystals of chromate are then freed from those of nitrate of potassa, and purified by recrystallization. It is important in the preparation of this salt to use a very small proportion of saltpetre, so that the whole of the alkali may combine with chromic acid, and constitute a neutral chromate; to oxidise the whole of the chromium, the fusion is repeated with those portions of the ore unattacked by the first operation. The process for the manufacture of chromate of potassa has lately been rendered more economical by the substitution of lime for the nitrate in the preliminary calcination. A mixture of the chrome iron ore and lime or chalk in very fine powder, being calcined, oxygen is absorbed, and a chromate of lime formed, which is extracted from the mass by water. The solution is then decomposed by means of a potassa salt, and the chromate of potassa produced is separated from the calcareous compound by crystallization in the usual manner.

Properties.—Chromate of potassa— KO, CrO_3 —is deposited from a concentrated solution in small prismatic anhydrous crystals. It has an unpleasant metallic taste, and an alkaline reaction. It is very soluble in boiling water. At 60° this liquid dissolves half its weight of the salt. In alcohol it is insoluble. Its coloring power is so great, that one part gives a distinctly yellowish hue to forty thousand parts of water. As met with in commerce, chromate of potassa frequently contains sulphate; the sophistication may be detected by acidifying a solution of the salt with hydrochloric acid, and adding chloride of barium, when, if a sulphate be present, insoluble sulphate of baryta precipitates. The principal use of this salt is in the preparation of the chromates of lead, zinc, *et cetera*, which are extensively employed in painting, and the former also as an oxidising agent in the ultimate analysis of organic substances.

BICHROMATE OF POTASSA.—This salt is of great importance in the arts and manufactures, and especially in calico printing. By a reference to the article on DYEING, Vol. I., page 643, *et sequitur*, the reader will become acquainted with the variety of purposes to which it is applied in this most useful and beautiful art. The principal manufactories of the bichromate or *chrome* are at Glasgow. It is obtained from the salt last described by adding a sufficient quantity of acid—usually sulphuric—to impart to the solution a sour

taste. The mixture is then set aside for a few days, when deep orange-red crystals are deposited. The change may be thus represented— $2\text{KO}, \text{CrO}_3 + \text{SO}_3 = \text{KO}, 2\text{CrO}_3 + \text{KO}, \text{SO}_3$. The use of nitric acid is much to be preferred; as if sulphuric acid be employed there is considerable difficulty in separating the sulphate from the chromate, while if nitric acid be employed the nitrate of potassa produced, being much more soluble than the bichromate, admits of more easy separation. For the same reason, if acetic acid be taken the salt is obtained in a still greater degree of purity. Owing to the higher value of these acids, however, they will probably never entirely supersede sulphuric acid in this manufacture.

Properties.—Crystallized bichromate of potassa— $\text{KO}, 2\text{CrO}_3$ —has the form of quadrangular prisms and tables, is anhydrous, permanent in the air, and of a beautiful orange-red color. The crystals are soluble in about ten times their weight of water at 60° , and much more so in boiling water. When heated to redness, they fuse without decomposition into a transparent red liquid, which on cooling concretes to a crystalline mass, and, owing to the unequal contraction of the crystals, afterwards crumbles to powder. At a white heat a portion of the chromic acid is reduced to a lower oxide, and the residue consists of sesquioxide of chromium, and neutral chromate of potassa. When this salt is dissolved in hydrochloric acid, and the solution boiled, a salt is produced containing an equivalent of chloride of potassium united to two of chromic acid— $\text{KCl}, 2\text{CrO}_3$ —in which the chloride of the alkaline metal acts as a base to the chromic acid. According to GREGORY, both chromates of potassa have a very deleterious action on the system when their solutions are frequently brought in contact with the skin—producing sores which are painful and difficult to heal. Bichromate of potassa is occasionally employed in conjunction with chromate of lead as a source of oxygen in organic elementary analysis. The solution of both chromates is possessed of powerful antiseptic properties. Large quantities of this salt are used in the bleaching of palm oil as a source of oxygen, which is liberated as follows:



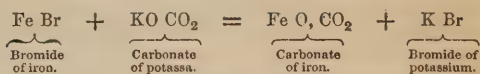
CHLORIDE OF POTASSIUM.—This salt may be prepared by inclosing potassium in chlorine gas, when the metal takes fire, burning even more brilliantly than in oxygen, and at the same time combination ensues between the two elements. It is formed also when potassa or its carbonate is dissolved in hydrochloric acid—in the case of the latter with evolution of carbonic acid. As, however, this salt is frequently obtained as a by-product in several chemical and pharmaceutical operations, it is seldom necessary to prepare it directly. As previously noticed, it is obtained in considerable quantities in crude saltpetre and in pearl ash, and exists also in the mother liquor of the chlorate of potassa. From these sources it may readily be obtained in a state of purity by successive crystallizations.

Properties.—Chloride of potassium— KCl —is an anhydrous salt, the form of the crystal of which is cubic. It has a saline and slightly bitter taste; dissolves in three parts of water at 60° , and in a much less quantity of boiling water. It is insoluble in alcohol. When heated, it decrepitates, and at a red heat fuses without decomposition. At a very high temperature, in open vessels, it slowly volatilizes in the form of white fumes, but in a covered vessel may be intensely heated without perceptible loss. Chloride of potassium is a salt of great importance in the arts on account of the facility with which it is transformed into other salts of potassa; hence, its use in the decomposition of the nitrates of lime, *et cetera*, in the production of salt-petre. It is also equally valuable in the preparation of potassa alum.

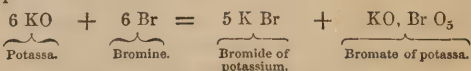
IODIDE OF POTASSIUM.—This important salt, like the chloride, may be prepared directly by combining the two elements, by heating them in contact with each other. The various methods for procuring it on the large scale, its properties, actions, and uses in the arts, have been detailed under the article IODINE, to which the reader is referred.

BROMIDE OF POTASSIUM.—Bromine and potassium are contained in sea-water, but whether the bromine is in combination with potassium or with some other metal, as, for example, sodium or magnesium, has not yet been ascertained, so difficult is the problem.

The process of the London college is the one usually followed in the preparation of this salt. One ounce of iron filings, and afterwards two ounces of bromine, are added to one and a half pints of water, and the mixture is allowed to stand for half an hour, constantly agitating. A gentle heat is then applied until a greenish color is developed. A solution containing two ounces and one drachm of carbonate of potassa to a pint and a half of water, is then added, and the precipitate of carbonate of iron produced is removed by filtration; and by evaporation of the filtrate the salt is obtained in crystals. In this process a bromide of iron is first formed, which is then decomposed by the carbonate of potassa, thus:—

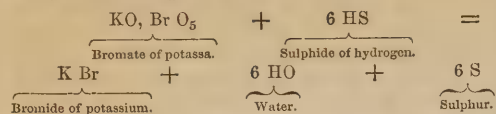


Another method of procuring this salt consists in adding to a hot solution of potassa, as much bromine as the liquid will dissolve. A brownish fluid is thus produced, through which sulphide of hydrogen is passed until it becomes colorless. Gentle is the heat then to be applied to expel the excess of the latter reagent, and the sulphur which has precipitated is removed by filtration. The filtrate on evaporation will then yield crystals of bromide of potassium. The action of bromine upon a solution of potassa is analogous to that of chlorine, as noticed under chlorate of potassa, and may be thus expressed:—



When sulphide of hydrogen is passed through a solution containing bromate of potassa, decomposition ensues, the hydrogen of the gaseous acid abstracts the

whole of the oxygen from the bromate, and, at the same time, the free sulphur precipitates, thus :—



The filtered solution contains, therefore, only bromide of potassium. Occasionally a modification of this latter process is employed, in which the oxygen of the bromate of potassa is removed by heating the salt to redness, instead of by the sulphide of hydrogen.

Properties.—Bromide of potassium—K Br—crystallizes in cubes or rectangular four-sided tables, has a sharp, pungent, saline taste, and is persistent in the air. When heated, it decrepitates, and at a red heat fuses without decomposition. It is very soluble in water, and slightly so in alcohol. At a red heat it is decomposed by chlorine, but not by iodine; and bromine is also disengaged in the cold by the mineral acids.

Adulteration.—Commercial bromide of potassium frequently contains chloride, and sometimes also iodide of potassium. The presence of the latter is most conveniently detected by the addition, to an aqueous solution of the salt, of protochloride of palladium, which in presence of iodide gives a brownish-black precipitate. Nitrate of protoxide cannot be substituted for the chloride of palladium, as in this case bromine is also precipitated. The most frequent adulteration, however, is with chloride of potassium, and yet the London college gives no test for the detection of this sophistication. The best method is that suggested by Rosé, and is conducted as follows :—The suspected salt is mixed with an excess of bichromate of potassa, and introduced into a tubulated retort with the addition of concentrated sulphuric acid, and a receiver is adapted, containing aqueous ammonia. On the application of heat, if the salt be pure, only bromine distils over, and the volatile alkali remains perfectly colorless. If, however, a chloride be present, *chloro-chromic* acid also passes over, and the ammonia becomes yellow; and in the solution chromic acid may now be detected by the production of a yellow precipitate, on addition of acetate of lead.

Physiological effects.—Bromide of potassium is a diuretic and cathartic. Like the preparations of iodine, mercury, *et cetera*, it appears to exercise that influence over the nutrition of the body designated by the terms, resolvent, alterative, and deobstruent. Under its continued use, PEREIRA states that enlargements of the spleen and liver, and swellings of the lymphatic glands have disappeared; and Dr. WILLIAMS is of opinion that it possesses unusual, if not specific powers, in the cure of diseases of the spleen. It has also been used advantageously in scrofulous tumors, and in bronchocele.

CYANIDE OF POTASSIUM.—This useful salt is most advantageously prepared from ferrocyanide of potassium or yellow prussiate of potassa, which is to be carefully desiccated, and reduced to fine powder, eight parts of which are mixed with three parts of carbonate of potassa and one of charcoal, both in impalpable powder. This mixture is to be exposed to a strong red heat in a closed

iron crucible. After cooling, the mass is to be finely powdered, placed in a funnel moistened with a little alcohol, and then washed with cold water. The colorless strong solution of cyanide of potassium which passes through, is then rapidly evaporated to dryness in a porcelain basin and fused at a red heat. This salt, as obtained by ignition of the above ingredients, without the charcoal, usually contains a little cyanate, which, however, does not interfere with its use for forming and dissolving cyanides of gold and silver for the processes of voltaic gilding and plating.

The preparation of cyanide of potassium in a state of perfect purity, is always attended with difficulty, owing to the action of the carbonic acid of the air upon its solution, and the tendency of the menstruum itself to undergo spontaneous decomposition, even when secluded from the air. It is obtained in a state of great purity by adding absolute hydrocyanic acid, or a strong solution of this acid, to an alcoholic solution of potassa; a portion of the cyanide falls down as a white crystalline precipitate, which should be washed with alcohol and dried. An additional quantity may be obtained from the mother liquor by evaporation of the latter in a retort. Cyanide of potassium crystallizes in colorless cubes, which deliquesce in damp air, at the same time becoming opaque. It is very soluble in water. In close vessels it may be heated to redness without alteration, but by exposure to the air absorbs oxygen, and becomes cyanate of potassa—KO, Cy O. The purity of this cyanide is best ascertained by its property of dissolving the red oxide of mercury, twelve grains of the pure salt dissolving twenty of the finely-pulverized mercurial salt. The principal use of cyanide of potassium is in electro-plating and gilding, also in photography. Being similar and equally powerful in its action upon the animal economy with hydrocyanic acid, and as the dry salt may be preserved in a well-stopped bottle without change, it might be substituted with advantage for the latter in medicine, as the acid so readily undergoes decomposition.

Ferrocyanide and ferricyanide of potassium, termed also yellow and red prussiate of potassa, are respectively compounds of the metal potassium, with the salt radicals, *ferrocyanogen*—Fe Cy₃, and *ferricyanogen*—Fe₂ Cy₆. The preparation, manufacture on the large scale, properties, *et cetera*, of these salts have been fully discussed under the article IRON, Vol II., page 451 *et seq.*

SULPHOCYANIDE OF POTASSIUM.—This salt is a combination of potassium with the salt-radical sulphocyanogen Cy S₂ = Csy. It is present in the saliva of man and some other animals. It is prepared by heating the powdered anhydrous ferrocyanide of potassium with an equal weight of powdered sulphur in an iron pot. The mixture is kept in a fused state for half an hour, at a temperature above the melting point of sulphur, but below that at which bubbles of gas rise through the melted mass. The latter consists of a mixture of sulphocyanide of potassium and sulphocyanide of iron, with the excess of sulphur. This is treated with water, the insoluble matters removed by filtration, and to the colorless or slightly red filtrate, first heated to boiling, carbonate of potassa is added as long as a precipitate is produced. The liquid filtered

from this precipitate, on evaporation, yields crystals of sulphocyanide of potassium, from which any adhering carbonate of potassa may be removed by solution in alcohol.

Sulphocyanide of potassium— $K\ Cy\ S_2$ —crystallizes in long white striated prisms, which are anhydrous, and resemble nitrate of potassa in appearance and taste. They deliquesce in a moist atmosphere, and are very soluble in hot alcohol, from which the salt crystallizes on cooling. Sulphocyanide of potassium communicates a deep port-wine color to strong solutions of sesquioxide of iron, and is, consequently, much employed as a test for that metal in its higher state of oxidation. Nitric acid must not be present when testing for iron with this reagent. The Editor considers the sulphocyanide a very beautiful indication of the presence of iron. In the most dilute solutions a red coloring is at once apparent.

BITARTRATE OF POTASSA—Tartar—Argol—Cream of Tartar.—This salt is a constituent of many vegetables, and especially of the grape. The substance known as argol or crude tartar, consisting of bitartrate of potassa, tartrate of lime, and coloring matter, is found as a concretion upon the inside of wine casks, in which newly-made wine has been kept for some time. From this deposit the pure salt is obtained. The following is the process of purification pursued at Montpellier, as described by FIGUES:—The argol is boiled in water, and the solution allowed to cool; the crystalline deposit thus obtained is washed with cold water, and then redissolved in boiling water, to which is added pipe clay to the amount of five per cent. of the weight of the salt, together with a small proportion of animal charcoal. The addition of these substances promotes the separation of coloring matter. When the latter has completely subsided, the clear liquor is allowed to cool slowly, when crystals of the pure bitartrate separate. At Venice, the process of purification consists in the separation of the grosser impurities by repeated solution and recrystallization of the salt, after which white of egg and wood ashes are added to the boiling solution of the crystals, and during the effervescence which ensues the impurities rise to the surface and are skimmed off. According to DUFLOS, the crystals are most readily freed from lime by placing them in contact with dilute hydrochloric acid, and subsequently draining and washing them.

Bitartrate of potassa— $KO, 2\bar{T}$ —as usually met with, forms a white crystalline mass, having an acid and gritty taste. The crystals, which are irregular six-sided prisms, contain one equivalent of water, which is not given off at a heat much below the point at which the salt is decomposed. Water at 68° dissolves the one hundred and eighty-fourth part, and at 212° one-fifteenth of its weight. When heated, bitartrate of potassa swells up, evolves various volatile products, gives out an odor of caromel or burnt sugar, and a mixture of charcoal and carbonate of potassa, termed *black flux*, remains. Heated with an equal weight of nitrate of potassa, it leaves a residue of pure carbonate of potassa.

Powdered bitartrate of potassa, or cream of tartar, is frequently adulterated with various white mineral and organic powders. The proofs of its freedom from these

are complete solubility in water, and, according to the Edinburgh College, its decomposing power over nitrate of lead. The principal use of bitartrate of potassa is in dyeing, owing to its power of dissolving metallic oxides. It is used also in medicine.

Physiological Effects.—In small doses this salt has a refrigerant and diuretic action; in doses of half an ounce it forms a brisk yet gentle purgative. It is frequently used in admixture with sulphur as a mild laxative. In excessive doses it produces inflammation of the stomach and intestines.

Of other organic salts of potassa, none, with the exception of the oxalate and acetate of potassa, are used to any great extent in the arts or manufactures. These latter are prepared by saturating a solution of carbonate of potassa with the respective acid, and evaporating to the crystallizing point, or to dryness. Oxalate of potassa— $KO, C_2O_3 + HO$ —is used in the laboratory principally in the estimation of manganese ores. An acid oxalate—termed *salt of sorrel*, or *salt of lemons*—is employed to remove ink-stains and iron-moulds from linen. Acetate of potassa— $KO, C_4H_3O_3 = KOA$ —is chiefly employed in medicine.

ANALYSIS.—The salts of this metal are distinguished from all other substances by the following tests:—Sulphide of hydrogen, sulphide of ammonium, and alkaline carbonates, effect no change in their solutions. *Tartaric acid*, added in excess to a solution of a potassa salt, produces, especially after violent agitation, a white, crystalline, quickly-subsiding precipitate of bitartrate of potassa. *Perchloric acid* has a similar effect. *Fluosilicic acid* affords a transparent, gelatinous precipitate, which, when it subsides, is iridescent, and dries into a white powder. An alcoholic solution of *picric acid* throws down sparingly soluble yellow crystals of picrate of potassa. When heated on a platinum wire before the blowpipe, potassa salts communicate a characteristic violet or purple tinge to the flame. This reaction is obscured by salts of soda. By the test recommended by HARKORT, potassa salts may, however, be detected before the blowpipe when soda salts are also present. It depends upon the fact, that oxide of *nickel* when fused with borax in the blowpipe flame, gives a brown glass; and this glass, when melted with a potassa salt, becomes blue. Of all the tests for the detection of potassa salts, *bichloride of platinum* is, however, the most delicate. This reagent produces, in solutions of these salts, a yellow crystalline precipitate of bichloride of platinum and chloride of potassium— $Pt, Cl_2 + KCl$. In applying this test, the *absence of salts of ammonia* must be previously ascertained, as these give rise to an analogous precipitation. A little hydrochloric acid is added collaterally with the bichloride of platinum, and if the precipitate does not appear after a short time, the mixture is evaporated to dryness at 212° ; and if potassa be present, on the addition of spirit of wine, the double chloride is left in the form of yellow shining crystals.

ESTIMATION.—In the determination of salts of potassa, they are almost invariably converted into the state of bichloride of platinum and chloride of potassium. The estimation is effected as follows:—The salt, first converted into chloride, is mixed with hydro-

chloric acid and bichloride of platinum in excess, and the mixture is evaporated to dryness at 212°. To the residue alcohol is added, and after standing some time, the whole is thrown upon a weighed filter, and the insoluble double salt of platinum and potassium is affused with spirit, until the washings leave no residue on evaporation. The salt is then dried and weighed. Every 243·5 grains of bichloride of platinum and chloride of potassium thus obtained, represent thirty-nine grains of potassium, or forty-seven of potassa.

It not unfrequently occurs in chemical investigations that a salt of potassa, and one of soda, exist collaterally, and it is desired to estimate the relative proportions of each. In such a case, the most convenient method is as follows:—The two bases are converted into sulphates by any available means, and weighed in this condition. After noting the weight, the mixed salts are redissolved in water, and treated with a solution of chloride of barium. The precipitate of sulphate of baryta thus obtained is collected by filtration, washed, dried, ignited, and weighed. From these data the respective quantities of soda and potassa may now be calculated; for, as one hundred parts of sulphate of potassa give one hundred and thirty-four of sulphate of baryta, and one hundred parts of sulphate of soda afford one hundred and sixty-four of sulphate of baryta, the larger quantity of the latter salt obtained than the ratio 134 : 100—is due to the salt of soda, and the proportion of the latter base present may easily be calculated, since one hundred parts of sulphate of soda represent 43·7 of soda. The proportion of potassa is then known by deducting the quantity of sulphate of soda found from the weight of the mixed sulphates. Every one hundred parts of sulphate of potassa remaining, represent fifty-four of potassa.

POTTERY.—*Potterie*, French; *steingut*, *porzellan*, *töpfen*, German.—The earliest exponents of the potter's art supply indubitable, and, in some respects, unique data, for elucidating the theology, the literature, the manners and customs of the most remarkable nations of antiquity. Hence, from this cause alone, the history and practice of this art excite a deep and peculiar interest, irrespective of any other considerations to which its operations may give rise. These, however, are such as present their own special claim to notice, since the art itself, in its varied and comprehensive application, embodies the most complete and perfect medium for the exhibition of industrial skill. No branch of manufacture presents so ancient and intimate an alliance between art and utility as that of the potter. One of the most ancient and characteristic channels of national industry, the production of pottery takes its rise from a date which, in the Eastern hemisphere, is lost in the darkness of remote antiquity. The extreme plasticity of certain earths and their almost universal diffusion; the ease with which they can be fashioned into forms suited to ordinary domestic requirements; the consistency also which even natural heat will impart to them—have necessarily conduced to the general adoption of this class of manufactures, even in the primitive stages of savage life. The peculiar condition of plasticity, from the earliest ages, has rendered the potter's clay the most obvious material for the

gratification of that inherent desire to form or model the lineaments of some ideal image, or some palpable reality, which is a distinguishing characteristic of man's nature, and is patent as well in the infancy of society as in the early days of any individual. At what period the indulgence of a mixed mimetic and creative faculty was first applied to meet the requirements of primitive life, is a point of chronology that can never be exactly determined. As well might the Editor attempt to pen a diary of the reminiscences of his childhood, or chronicle the months and days when he drew figures on the sand, as seek to investigate and define the original invention and first production of pottery. BRONGNIART urges that when the antiquity of an art may be established by a train of simple reasoning and by the most natural deductions, one is not to evade admitting the fact through the fear of appearing to rest content with common and ordinary considerations. This observation is very happily applicable in the instance of pottery. Monuments, almost infinite in number and variety, the authenticity of which cannot be questioned, and so simple and clearly intelligible that no deep study is required to appreciate their interest and value—demonstrate that the potter's art, from primæval times, has been intimately associated with productions the most useful to man, as well as the most beautiful in themselves.

The ceramic art, both in its theory and its practice, unites a combination of qualities unknown in any other expression of human skill. No other industry presents so many divers considerations, all of them of the utmost interest, and each one rich in economic and scientific application. Finding its materials at the surface of the earth, pottery exhibits products the most simple and yet the most varied—the easiest to fabricate, but still, though fragile, of incomparable durability. Man, when in his weakest and most isolated condition, is able to extract clays for pottery from the ground beneath his feet; these materials, the spontaneous gift of nature, he fashions on the instant in accordance with his will; and, without either science or preparation, he even gives to them forms of a hardness sufficient to satisfy the first demands of social refinement. The products of these substances—so simple in their character, so abundant, so easy to bring together, so readily endowed also with every quality best calculated to facilitate their practical application—are absolutely endless in their variety, while, in their most successful exponents, their beauty may be pronounced matchless. Every species of form—from the classical severity of the early Greek period to the florid luxuriance of the wares of Saxony, France, and, one may now fairly add, England—here finds a fitting and worthy medium. Artistic excellence, both in the painter and the modeller, can here develop its highest capabilities. A material, which science teaches to present the most lustrous surface, which is solid, imperishable, and admirably qualified for the application of varied and brilliant colors, offers such inducements to the painter for the practice of his art, that the pencil of the glorious RAFFAELLE himself was occasionally employed in its decoration.

The potter's wheel, an implement identified with the

most important class of fictile productions, may have been the first piece of mechanism invented by the grandsons of NOAH, and originally employed while the earth was yet moist from the waters of the flood; or it may have been produced in various parts of the antediluvian world, long before the tremendous visitation of the deluge. Certainly the most ancient mechanical appliance that industrial art has adapted to its use, the potter's wheel is no less distinguished for its simplicity; and, at the same time, it exhibits so perfect a contrivance for imparting, under expert direction, beauty and utility to shapeless masses of matter, that it has descended from age to age to the operator of the present day without any important modification. Indeed, so absolutely identical is the mode of working, with reference both to the mechanical and the manipulatory processes now in use in this primitive branch of fictile art, with the system prevalent some thousands of years before the Christian era, that were it possible to resuscitate the mummy of an ancient Egyptian thrower, he might immediately find lucrative employment with the MINTONS, COPELANDS, CHAMBERLAINS, KERRS, and others, of the present day. According to Genesis, one is warranted in concluding that the potter's wheel was known to all the early families, and that it was retained and used by them when they had been dispersed abroad over the face of the earth.

In countries where the drying influences of the sun and air are pre-eminently powerful, the desiccation of clays after rain must necessarily have attracted attention. The plastic nature of these simple substances while in one condition, and their compact mass when in another, together with the ease with which in the former state they could be manipulated, and in the latter, fixed into form, cannot fail, at an early period, to have indicated their applicability to those useful purposes that provide for some of the most urgent requirements of human life. The want of vessels that would contain liquids, and also resist the action of fire, would naturally arouse the exercise of man's inventive powers. The hard shells of certain vegetal productions, such as gourds and the larger kinds of nuts, together with the skins of animals, might be easily transformed into recipients for fluids. The preparation of these materials, however, implies the possession of tools, together with a previous knowledge of some elementary manual arts. But then, such vessels being obtained, and the action of fire and its use in the preparation of food being understood, but little of real assistance could thus be acquired. Vessels of this description would scarcely be competent to render available the known services of fire. In such circumstances, some savage tribes have been constrained to adopt the expedient of dropping hot stones into the liquids in their frail vessels, in the hope of so imparting to them some degree of warmth—a dilatory and unsatisfactory process, and one that would be gratefully abandoned upon the discovery that certain earthen substances possessed the property of resistance to the action of fire.

Whether the fashioning and hardening of clay was first practised by the potter or the brickmaker, must ever remain a matter of speculation. Probably both uses

of the common material were discovered about the same period, and under the same circumstances. Bricks, *thoroughly burned*, it is known, were employed at the building of Babel, two thousand two hundred years before the Christian era. And, again, it is also certain that pottery, properly so called, had attained to an important condition of usefulness in very remote ages, since the earliest authentic records allude to the potter's wheel as an implement, even then, of high antiquity. In all parts of the habitable globe the same requirements would be felt; and as similar means for satisfying them would everywhere abound, men would naturally be prompted to the exercise of that kindred ingenuity, which had been implanted alike in them all as a universal heritage: and thus, amongst races rude and uncultivated, and in all other respects utterly ignorant of the arts that minister to human convenience, it has been satisfactorily traced that earthen vessels had been in use centuries before the existence of any such people was conjectured. Vases, for example, have been discovered amongst the aboriginal Indians on the Musquito shore, which by them were treasured as vestiges of antiquity; and there is every reason for believing that these fictile works were the production of the ancestors of the people amongst whom they were found, since the remains of ancient potteries exist far up the Black River in that region. PLATO describes the ceramic art as amongst the earliest on record. VITRUVIUS, again, affirms that in the Augustan age the Romans made their water-pipes of potters' clay; and after the Roman conquest potteries were established in England, where the fabrication of similar pipes for the same purpose was introduced. These pipes were about two inches in thickness, and firmly joined together with common mortar, mixed with oil; and, to prove both the durability of the material, and the tenacity of the compound, some relics that were dug up about a century ago in Hydepark, London, were found to be in the most perfect condition, and as well suited for their use as when they were at first manufactured. A claim has been advanced on the part of the ancient Britons to a knowledge of the art of working pottery anterior to the Roman invasion; and the fact that cinerary urns of earthenware have been repeatedly exhumed from Celtic barrows in different parts of the kingdom, tends to warrant the assertion. Many writers are inclined to the opinion that the aboriginal Britons were indebted for these works to the Venetians. There appears no reason, however, for withholding from our Celtic forefathers the credit of having produced their own rude pottery, at a period antecedent to the earliest visit paid to their shores by adventurous and enterprising voyagers from lands lying nearer to the sun-rising. Remains of considerable Roman potteries are to be traced in various parts of England, and especially in Staffordshire, on the site of the great potteries of the present day.

There is something strangely suggestive in the relics of ancient pottery-kilns that still linger on the scene of their former active operations. The modern Staffordshire potter has derived no heritage from his Roman predecessor. There had been no continuity of work. Centuries of disuse had obliterated the very memory

of those remote artificers, and tradition had not even whispered of their scene of action. The potter established himself in Staffordshire, altogether unconscious of his vicinity to the spot in which long-buried laborers in his own handicraft had exercised their mutual calling. He saw that the natural materials suitable for his purpose were there abundant; and, having settled down, he plied his wheel, and threw his clay, and burned his pots—absolutely ignorant the while that he was reviving operations with which that district, in ages long past away, had been familiar. It was not until after many years of laborious occupation, that the upturned fragments of unwonted vessels casually revealed the ruins of an ancient furnace, and significantly declared that the potter's wheel was again revolving above the potter's tomb.

The antiquity and the nobility of the potter's art is demonstrated by repeated references to it in Holy Writ, and especially in similitudes which emanate directly from the Divine imagery. Indeed, from Proverbs, the twenty-sixth chapter and twenty-third verse, one would almost be led to suspect that the art of glazing earthenware vessels had been discovered seven hundred years before the Christian era. The words are, Burning lips and a wicked heart are like a potsherd covered with silver dross. Now it is a well-known fact that silver is generally refined by means of lead; the two metals usually occur together, and if lead be strongly heated in an earthen vessel a partial glaze is communicated to the surface, and this probably led to the discovery of a glaze.

Not only do the Scripture texts now alluded to establish for the operations to which they refer a very early date, but, what adds materially to the peculiar interest of the principal and most essential processes, they show that the mode of fabrication remains up to the present time substantially the same. By the ancients also the plastic art was employed for the highest and noblest purposes. Homage to the dead, and victory to the living, were typified in the votive products of the potter's skill. Eminence in the art was distinguished by public patronage, and chronicled by poets and historians. The profession of ceramic artists was held in high honor, and a college of potters was established at Numa eight centuries before the Christian era.

The term *Pottery*, which is derived from the Latin *Poterium*, the name given by the Romans to drinking vessels, does not convey any signification that denotes either form or substance.

The word *Ceramic*, the generic title by which works in this department of art-manufacture are now known, is derived from the Greek. The Greek word, however, differs from its Latin synonym, in the circumstance that it primarily signifies the *horn of an animal*; and it has obtained its secondary and generally recognized signification from the early use of horns for drinking vessels, as also from the more or less literal adoption of the form of drinking-horns in the plastic materials with which such vessels have been fabricated. Representations of genuine *drinking-horns*, the primitive *ceramic* vessels, are of frequent occurrence in illustrations of ancient festivals; and, though they appear

much varied in their constructive details, the original type is distinctly apparent in them all.

The addition of the heads of animals at the extremity of the horns seems to have been very popular; and numerous examples are extant in which the heads of the eagle, dog, and other creatures, appear thus cumstanced.

The name thus originally applied to drinking vessels alone, was next adopted by the potter in reference to such of his productions as were designed for somewhat similar uses, and in which the same forms were introduced; and then it was gradually extended in its application, until it comprehended the entire range of fictile manufacture.

Notwithstanding the fact that articles of domestic utility were the first to exercise the skill of the potter, but little is known of the forms and composition of these earliest vessels. Their fragility indeed, coupled with their trifling intrinsic value, would naturally render it improbable that more than a few occasional relics should survive the period of their original fabrication. Some few primitive specimens still extant, that from their character seem obviously to have been destined for household uses, BRONGNIART objects to recognize in that capacity, in consequence of the permeable nature of the clay of which they are composed. But it may be suggested that this eminent savant would scarcely have advanced such an opinion, had not the early practice of saturating these vessels with oil for the purpose of obviating their porosity escaped his observation. The lapse of centuries and long disuse would have caused the total evaporation of the counteracting medium; but that porous clay, by the application of oil, may be rendered impermeable by ordinary liquids, does not admit a doubt.

It would naturally have been most desirable that a ceramic museum, or an essay on ceramic manufactures, should commence with examples of the first pottery that ever was made. This the very nature of the fictile art has rendered impossible; and yet, though the actual objects may be wanting, their pictorial representation has been preserved in the varied decorations of other and later productions of the same class; and thus, through the agency of pottery when in a more advanced condition, the image and purpose of the earliest works of the potter have been preserved and handed down to modern times.

Like the first rise of nations, the first applications of art and the original productions of manufacture are for the most part mythic and fabulous. After a while, probable traditions arise; and then, as the stream of time flows steadily onwards, veritable history at length stands confessed with well-defined lineaments. Such is precisely the condition of the ceramic art. The very weakness of its primitive elements is such as to baffle the most penetrating research. Gradually some works appear impressed with the capacity of endurance. In due time the number of these clay-constructed conquerors of time increases, and they assume variously diversified forms. There succeeds but a brief interval, before the history of pottery supplies one of its most graphic chapters to the history of mankind.

BRICKS.—The sun-dried products of Egypt, Assyria,

and Chaldea, embodying the earliest existing illustrations of fictile manufacture in its simplest application, are the only examples of their era that have survived the ravages of time.

The *brick*, without doubt, was one of the primitive efforts of plastic labor. Its geometrical form would of necessity be suggested by the want of some constructive materials, with which buildings might be erected with a greater uniformity of surface and precision of outline than could be obtained by rough coatings of mud. When once adopted, the palpable utility of bricks would render their introduction universal, and their use permanent. The use of bricks, indeed, has continued with but slight modifications from the building of the Tower of Babel to the present day.

BIRCH, in his learned History of Ancient Pottery, displays much research in treating upon the historical value attached to these silent, yet eloquent witnesses of the past. He affirms that the bricks of Egypt not only afford testimony to the truth of Scripture as to their composition of straw and clay; but also that, by the hieroglyphics impressed upon them, they transmit the names of a series of kings, and thus testify to the existence and date of edifices, all knowledge of which, except for these relics, would have utterly perished.

The bricks of Assyria and Babylonia, in addition to similar information, by their cuneiform inscriptions denoting the localities of the buildings for which they were made, have determined the sites of ancient Mesopotamia with a precision and completeness that could have been obtained from no other sources.

The general form of all these bricks is rectangular, those presenting a curved outline being of very rare occurrence. In so arid an atmosphere as that of Egypt, a country in which rain seldom falls, sun-dried bricks would effectually resist the action of any moisture to which they might be exposed, and they would endure for ages. VYSE states that the pyramids of Dashour, Illahoon, Howara, Abû Roash—the walls of Sais—the fortresses at Samneh, Centra Pselcis—the walls also of the Memnonium at Thebes, and the great wall that inclosed Egypt on the Eastern side from Pelusium to Heliopolis, a distance of one thousand five hundred stadia, or furlongs, were constructed of these sun-dried bricks. And, in addition to these more important works, the same materials were in constant use for the erection of private tombs and other edifices. Sir GARDINER WILKINSON adds that this material was employed in the great wall built by Sesostris across Egypt—the Gisir-el-Agoos—and for a small temple at Ekmin.

The rich alluvial soil of both the Delta and the Fayoum, at a remote period of Egyptian history, must have determined that the brick-manufacture should be established in those districts. The mud and slime yearly deposited by the Nile were peculiarly adapted for pottery purposes. BIRCH states that an analysis proves about one-half of the substance of this deposit to consist of argillaceous earth, one-fourth being carbonate of lime, while the residue comprises oxide of iron, carbonate of magnesia, and water. Close to the river's banks the deposit is much mixed with sand, which it loses in proportion as it is carried by the water further from them, so that at a certain distance

it consists of pure argil or clay, which at the present day forms excellent bricks, tobacco-pipes, and stucco. Amongst the earliest bricks in existence, those may undoubtedly be reckoned which were made for the construction of the various brick-built pyramids, although it is not possible at present to determine the relative antiquity of all these edifices. Several of them, however, have been ascertained to be tombs of monarchs of the twelfth dynasty. Bricks of this class, formed of Nile mud held together by chopped straw, continued to be manufactured in Egypt until about the tenth century before CHRIST.

The next step in the progress of the brick manufacture was the substitution of kiln-baked for sun-dried clay. An earthenware of a dull, coarse appearance, without any surface, polish, or glaze, was produced by this process; and it was employed for making sarcophagi, sepulchral cones, figures, vases, and other objects, in addition to the simpler bricks. All this baked pottery is *terra-cotta* in its simplest form. The external color is always some shade of red, though both the tint and the texture vary considerably in accordance with the degree of heat to which the pottery may have been exposed. A comparatively low temperature was sufficient for producing the soft pale tint, that appears to have been so generally preferred; in this condition, however, the *terra-cotta* is absorbent, though not sufficiently porous to allow water to escape. The absorbent property of this Egyptian *terra-cotta* is found to have been determined by the temperature of the furnace in which it was baked. The average size of the sun-dried bricks used by the ancient Egyptians was seventeen inches in length, eight inches in width, and in thickness five inches; those that were baked were generally somewhat smaller, and they appear to have been chiefly used in constructions that were exposed to a contact with water.

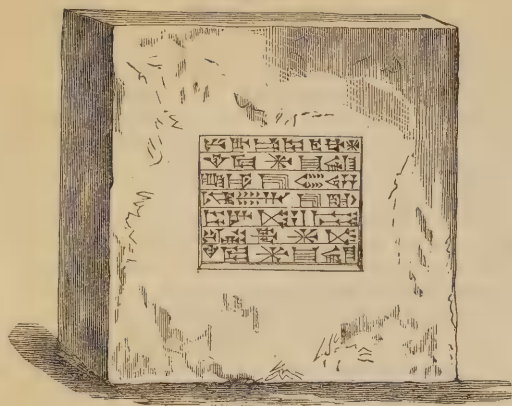
Both the Assyrians and the Babylonians used sun-dried bricks, as well as those that were baked in the furnace. The former were chiefly employed in the construction of the massive and lofty mounds upon which the more important edifices were constructed, the latter being substituted when more finished and careful brick-work was required. The kiln-baked bricks are generally of a pale-red hue, and they bear an inscription in the arrow-head character, which is impressed on the mass in true intaglio, and not obtained in a sunk bas-relief as in the Egyptian examples. In the Assyrian bricks the inscriptions cover one of the sides, or they sometimes run along the edge; but the Babylonian brick-makers stamped their inscriptions with moulds that covered only a comparatively small portion of the surface of each brick, somewhat after the Egyptian fashion. The inscription upon the specimen from Babylonia—Fig. 425—now preserved in the collection of the Royal Society of Literature, is read by Sir H. RAWLINSON as follows:—

(of) NEBUCHADNEZZAR,
the king of Babylon,
founder of Beth Digla, or Saggalu,
and of Beth Tzida,
son of NEBOPALASAR (I am).

Dr. HINCKS and Mr. LAYARD read *Beth Shaggah* in-

stead of *Beth Digla*. The rectangular bricks of Assyria vary in size from a square of twenty-two inches to one

Fig. 425.



of twelve inches, many of the varieties being elongated rectangles; their thickness also varies from four and a half to three inches. The Babylonian bricks are smaller, their maximum dimensions being a square of fourteen inches by four inches in thickness. Occasionally bricks of various shapes, and variously colored, are found throughout Mesopotamia.

The inscriptions that impart a peculiar value to the kiln-burnt bricks of Assyria consist of various formulæ, that have more or less direct reference to the edifice of which it was intended that they should form parts, together with the name, titles, and sometimes some steps in the genealogy of the reigning king. The formula upon each brick in a building was the same, with some unessential but very significant variations, such as the interchange of certain cuneiform equivalents. It is these variations, as BIRCH observes, that teach the secret of the language. The inscription on the bricks of the N.W., or oldest palace of Nimrud, which is in three lines, Sir H. RAWLINSON has read as follows:—

This is the palace of ASAR-ADEN PAL, powerful king, king of Assyria;
Son of ABED-BAR, king of Assyria;
Son of PUL, powerful king, king of Assyria.

By the Greeks sun-dried bricks were occasionally used for the construction of fortifications, since they were found to offer a more effectual resistance to the battering-ram than such as had been submitted to the action of the furnace. The walls of Mantinea afford a celebrated example. The same primitive and simple materials were also employed in the walls of the temples of the Leprean Demeter in Africa, and of the Stirian Demeter at Styros, and in those of the shrine of Æsculapius at Panopeus. Kiln-baked bricks, however, formed very commonly the walls of their less important buildings amongst the Greeks; and, in some instances, they may have been introduced by them into their nobler edifices. But Greece was a land abounding in stone, and the Greeks preferred the natural building material of their country to the productions of the kiln. Greek bricks were named from their dimensions

measured in palms—*didōron*, of two palms, or six inches in breadth, the length being one foot; *tetradōron*, of four palms, a square of one foot; and *pentadōron*, of five palms, a square of fifteen inches. In addition to these, with the view both to render their works more solid, and to improve their appearance, the Greeks occasionally made use of bricks of half the foregoing dimensions. VITRUVIUS describes another Greek brick under the title of *lydron*, which was six palms in length and four in width—that is, eighteen inches by twelve inches.

Bricks were used in profuse abundance by the Romans, both in the imperial city itself and throughout the empire. It was the boast of AUGUSTUS, indeed, that he had found a brick-built Rome, but that he left it a city of stone; from the time of TRAJAN, however, the ancient system of brick construction again became prevalent, and was never subsequently discontinued. The Romans frequently used their bricks in layers, alternately with masonry of rough stones, and they also as commonly constructed edifices of every description entirely with bricks. The clay of the Roman brick is remarkable for its hardness, and it generally has a fine red color. The baked bricks were designated *cocti* or *coctiles*, and the various sizes in constant use were further distinguished by the terms *bipedales* and *sesquipedales*, or two feet and eighteen inch bricks. Very minute particulars respecting the bricks of the Romans are given by both PLINY and VITRUVIUS, and the examples that are continually found in this country in considerable numbers fully corroborate the accuracy of their statements. The general sizes of the existing Romans bricks are seventeen by eleven inches, and fifteen by fourteen inches, the prevalent thickness being about two inches. Upon some of the earlier Roman bricks, the names of the consuls who were in office at the time of their fabrication may still be traced. The inscriptions stamped upon other specimens proved that the wealthy Romans of the imperial city derived no unimportant portions of their revenues from these, the simplest of fictile manufactures. The largest number of Roman bricks—or, possibly, of bricks that may have been made by Anglo-Saxon potters after the Roman fashion—that is now known to exist and to be in use in any one spot in England, may be seen forming parts of that most venerable and interesting edifice, the abbey church of St. Alban.

TILES.—In addition to the large bricks, whether sun-dried or furnace-baked, that were made for constructive uses of whatsoever kind, the ancients also manufactured vast quantities of thin tiles, of various sizes, and employed them for a multiplicity of useful purposes. Roofing-tiles were made much after the manner of similar appliances at the present time. Small flat tiles, and large ones also, were in habitual use for inlaying. Wall surfaces were variously decorated by this process, which was also applied to the adornment of door-jambs and other similar parts of buildings. Still smaller tiles, or tesserae, produced the inlaid or tessellated pavements that are so happily characteristic of ancient architecture. For all these purposes the tiles employed were formed in the East of a paste or body that would readily receive the glazing, with which in those regions their

surfaces were uniformly covered. The glazed tiles of the Egyptians, of which examples remain of a period as early as that of the sixth dynasty, were composed of a sandy friable compound, containing but little true clay, and exhibiting in different specimens considerable variety in the proportions and sometimes in the nature of its constituents, according to the manufactory or the period of production. This comparatively impracticable material was employed by the Egyptian potters because their silicious glaze—the use of lead in glazing not having yet been discovered—required to be applied to fabrics also silicious, and in which the sand was held in a granular condition—a result that was effected in the tile-body by the clay. The glaze itself, apparently formed of pulverized silica and soda, obtained its colors from the admixture of metallic oxides. An oxide of copper produced the well-known and deservedly famous Egyptian celestial-blue glaze that still retains its lustre untarnished, and will endure a comparison with the finest productions of modern science. The green glaze is of a kindred nature with the blue; and manganese, gold, silver, tin, and probably the suboxide of copper were the agents that produced the violet, yellow, white, and red hues. Of these colors, the blue is the one that is pre-eminently characteristic of the potters of Egypt.

The Assyrians applied a glaze or enamel to some of their kiln-dried bricks, on one face only, which was also enriched with various architectural devices, and so they provided themselves with substitutes for inlaying-tiles. The colors used by them were blue, yellow, white, red, and black. The specimens that remain are comparatively few in number, and in both their enamel and their hues they have lost much of their original effectiveness. That the Babylonians adopted a similar usage, is attested by the fragments of glazed ware that are scattered throughout the ruins of ancient Chaldea. By the Eastern nations of antiquity tiles of another class were in constant use for the reception of inscriptions, and in very many instances they were made to discharge the duties now assigned to writing-paper. The Assyrians were the great writers upon tiles, and they also employed cylinders and prisms for the same purpose. Documents of every conceivable variety were engraven on these singular but imperishable tablets, and the writing itself was executed with a minuteness, as well as a delicacy and precision, that are truly extraordinary. Many of these fictile records are of simple terra-cotta of the finest quality, while others are coated with a vitreous enamel. After the ancient national spirit of Egypt had in a great measure passed away with the departure of Egyptian independence, the papyrus often yielded on the banks of the Nile to terra-cotta, as the material for writing. Egyptian inscriptions on tiles, however, differ from the Assyrian in this important quality—that they were written in the ordinary black ink with a reed, and not incised with a sharp graving instrument before the tile was placed in the furnace.

Tiles were extensively used by the Greeks, both for roofing and for the flues of baths, and also in the construction of many of their tombs. The roofing-tiles are of large size, flat, and square, sometimes with flanges, and they have semicylindrical imbrices or rain-tiles to

cover their lines of junction. Two of the flat tiles in the British Museum measure two feet three inches, by eight inches. Many of these tiles are variously stamped with brief inscriptions in oblong labels. The imbrices are without inscriptions, but have painted ornaments. Another variety of Greek roofing-tiles were placed on the ends of the flat tiles for the purpose of additional security; these tiles, which are very ingeniously adapted for the duties required from them, are sometimes found to have been inscribed. The sepulchral tiles are of two kinds: those of the first variety are flat, and they were used to form a floor on which the remains of the deceased were placed; the other tiles are curved for the purpose of forming an arched covering. Drain-tiles, as well as those used for flues, were made by the Greeks of terra-cotta, and it is highly probable that they both employed the same material in the formation of the hollow floors of their own hypocausts, and transmitted that application of it to the Romans. The well-known *Keramicus*, as its name significantly declares, was a quarter of Athens almost exclusively devoted to the manufacture of bricks and tiles. Bricks and tiles were but rarely in use amongst the Etruscans; and the latter, when employed by that remarkable people, were apparently for the most part restricted to sepulchral purposes. Some late tiles of this class have been discovered, which are impressed with brief commemorative legends; and a single instance has been recorded of an Etruscan monumental tile, upon which the figure of the deceased had been incised, somewhat after a mediæval fashion, in addition to the customary inscription.

By the Romans tiles were used in great abundance, and they were adapted to various requirements. Roman tiles are found in much greater quantities than bricks, so much so, indeed, that it is by no means uncommon to apply the one term—Roman tiles—as well to the bricks as to the tiles themselves. The Latin equivalent for this word tile—*tegula*—is derived from the verb *tegere*—to cover—which expresses the primary application of Roman tiles. Thus ISIDORUS writes, *Tegula, quod ædes tegat*—a tegula or tile—because it covers houses; and he adds, *Imbrex, quod accipiat imbres*—an imbrex, or curved joint-tile—because it receives, that is, *wards off*, the showers. The tile-makers were distinguished by the title of *Tegularii*. Roman tiles closely resemble the bricks in their composition and mode of production, but their paste is generally somewhat inferior in quality, and the tile is always much thinner than the brick in proportion to its superficial extent. The flat roofing tiles, in common with those devoted to other uses, have inscriptions stamped upon them, their own special characteristic being their flanges. These flanged tiles were used for roofing both public and private edifices, for hypocausts, and for pavements, and numerous instances occur in which they appear banded into the Roman wall masonry. The flanges of two adjacent tiles, which generally rise two and a quarter inches above their flat faces, were covered by an imbrex set inverted over them, and by a repetition of this process the required roofing was completed. The end-tiles are found to have been suitably modified in form and adjusted to their office; the existing specimens are provided with spouts, and decorated either with the

brush or in relief. Some roofing-tiles, however, were made quite flat, and were hung, lozenge-wise, from one corner, overlapping one another like scales, or like feathers, as the Romans evidently preferred to draw the similitude, since they designated this style of tile-roof *peacock-work, opus pavonacum*.

Flue-tiles, which are necessarily hollow, almost invariably measure sixteen and a half inches in length, by six and a half inches in width and five in depth. They have their surfaces scored either with wavy lines or more systematic patterns.

Drain-tiles, or terra-cotta pipes, are larger than those used for flues, and they were formed in a manner consistent with their object.

Wall-tiles, employed by the Romans for casing interior wall surfaces, are large thin squares of terra-cotta, and they generally were decorated on one side with incised figures and patterns.

The small paving-tiles, so well known as *tesserae* and *tessellæ*—the latter term a diminutive of the former—the components of *tessellated pavements*, declare their square form under their title, which is evidently derived from the Greek *τεσσαρες*—*tessares*—*four*. They were made by cutting larger tiles into small cubes, or else they were formed in the first instance in distinct moulds. They vary in size from about an inch to a quarter of an inch square. The red portions of the mosaic work of pavements were produced by these small terra-cotta cubes, which were also used, though less frequently, in the formation of Roman mosaics for other purposes. It may be observed, that of the Roman tessellated pavements now known to be in existence none are earlier than the Augustan age, while the greater number date from the succeeding century.

There remains to be noticed one other distinctive application of their large flat tiles by the Romans, which is their use of them both in the formation of their graves and for preserving their commemorative monumental inscriptions. In close conformity with the Greek usage, some tiles laid flat formed the flooring upon which the body might rest, and others set sloping in opposite directions provided a simple ridged covering to protect it from the superincumbent earth. The vases that contain burnt bones are sometimes found to have been protected in a similar manner. The inscribed tiles, having their Greek or Latin legend generally written across them from side to side, were placed very much in the same manner as modern gravestones.

The inscriptions that are preserved upon the various tiles that have come down from the Roman times, abound in highly interesting as well as very valuable information. Considerable numbers are inscribed with the names or initials of the consuls of the year when particular specimens were manufactured. Still larger numbers set forth the names of the potteries and of the estates, with their proprietors, from which the clay was procured and where the tiles were made, together with notices of the manufacturers, and various brief descriptive or auspicious sentences and mottoes. The consular tiles, as they may be distinguished, are found only in Italy; they appear to have been thus stamped, in conformity with some law of about the time of TRAJAN, as a guarantee of the quality of the

clay used in the fabrication of them. Large collections of these tiles, obtained from almost every great edifice of ancient Rome, are still in existence, and many are yet in use upon the roofs of the churches of the modern city. The tile-inscription, whatever its character, was produced from a stamp or die in a low sunk relief, the raised letters being on a level with the face of the tile itself. In the centre of the circular composition upon a tile now in the British Museum, is a small medallion formed of a figure of victory, which was the mark of the potter; this is encircled by two bands of letters; those of the outer band are larger than the others, and with them the inscription commences. It may be read thus:—*OPUS DOL (IARE) DE FIGUL (INIS) PUBLIANIS (EX) PREDI AEMILIAES SEVERAES*—*Pottery from the Publian potteries, from the estate of Emilia Severa*. This, though a characteristic, is by no means a perfect specimen of these remarkable inscriptions. As a matter of course, in other specimens, the productions of different establishments and various makers, the central devices exhibit a variety of characters; they are not very numerous, however, and sometimes they are altogether omitted. The most complete stamps, says BRICH, have the date of the emperor or of the consulship, the name of the estate which supplied the clay, that of the pottery which baked it, and of the potter who prepared it, sometimes even of the slave who moulded the tile, and the very dimensions of the tile itself. In a few instances also the tiles have inscriptions, indicating the places where they were to be used. The greater number of these appear to have been directly associated with the Roman soldiery, by whom in many instances they were made, and in whose quarters, camps, and places of interment they were applied to their destined uses. These relics have served to trace out the stations of various legions, and even their line of march from station to station. In some instances the tiles specify, not a particular legion only, but certain cohorts of those legions. The numbers and the titles of the legions are given in these singularly interesting inscriptions, as *the Second, August; the Sixth, Victorious, Pious, and Fortunate*. The letters are always sharply expressed, as if from well cut metallic dies, and they are more generally arranged in the form of a foot than of a circle. The route of the twenty-second legion has been traced through Germany by the tiles that lingered at its successive stations; and in this country these tiles have declared what legions they were that occupied quarters at places most distinguished in Roman Britain. Thus the tiles of the sixth and ninth legions have been found at York; those of the twentieth, Valerian and Victorious, at Chester; and others of the second, at the ancient Isca Silurum, or Caerleon.

CHINESE CERAMIC MANUFACTURES.—It is not known whether there have been preserved amongst the Chinese any specimens either of terra-cotta or of glazed pottery of a date earlier than the great tower of Nankin, which was completed in 1431, after nineteen years' work; several similar edifices having been successively erected and destroyed upon the same site. It consists of nine stories in height, and is constructed

entirely of glazed tiles and slabs of earthenware. At the present day the manufacture of common pottery is carried on to a great extent in China. Some vessels of this class, of very large size, are employed by wealthy Chinese as reservoirs for gold fish and aquatic plants, or for containing and storing up fruits and grain, and for other like purposes; but the smaller productions of the terra-cotta potteries of China, which are greatly encouraged by the government, are almost exclusively devoted to providing for the requirements of the humbler classes of the vast population. As an article of export, the common opaque pottery of China has been completely set aside by the beautiful and universally admired ware, distinguished by the title of PORCELAIN, which is formed from a fine and hard paste, possessing the peculiar quality of being *translucid*. Thus porcelain occupies a position midway between pottery and glass. It is presumed to be of Chinese origin, and it certainly was known and extensively manufactured in China from a very early period. The Chinese, indeed, claim for their ceramic manufactures the same far-extending antiquity that they assign to the history of their extraordinary empire. The isolation, however, which it has been the policy of the natives of China to maintain during so many ages, coupled with the guarded secrecy that so generally has enveloped their manufacturing processes until very recently, has precluded the possibility of national intercourse, and rendered hopeless the attainment of any credible and satisfactory information relative to the rise and progress of a particular industry in that country.

The first European who is recorded to have penetrated into China, and to have explored Chinese productions on their own soil, was the Venetian, MARCO POLO. Writing in the thirteenth century, this famous traveller alludes to the extent and importance of the porcelain manufactures in the Celestial Empire, and he states of one place, Kinsai, that there was nothing further to be observed, than that cups or bowls and dishes of porcelain wares were there manufactured. MARCO POLO returned to Venice in the year 1295, and died there in 1323. It seems to be highly probable that Chinese porcelain had been exported in considerable quantities to other Eastern countries, many centuries before it was seen in China by MARCO POLO. Thus mention is made of a service consisting of forty pieces having been sent in 1171 to NOUREDDIN, the caliph of Syria, by his lieutenant, SALADIN, who afterwards became the hero of the crusades. This present may be considered to have travelled by way of Egypt, into which country and into Persia there can be no doubt of porcelain having been introduced direct from China, at a very early period, as an article of commerce. In 1474 the Venetian ambassador at the court of Persia considered it to be his duty to submit to his government a special communication upon the subject of this art-manufacture. Fifteen years later, amongst other rare and costly presents, an ambassador from the sultan of Egypt brought to LORENZO DI MEDICI some large vases of Chinese porcelain—*vassi grandi di porcellana*. Early in the following century the Portuguese, who were the first adventurers that doubled the Cape, imported the finest wares of the East, in large

quantities, into Europe, and from that period the different European nations gradually became familiarized with porcelain. CAVENDISH, the celebrated traveller in the time of Queen ELIZABETH, is generally supposed to have presented to his royal mistress the first pieces of oriental porcelain that came into England; but it has been also considered, that a few specimens of this precious ware had found their way to these shores as early as the commencement of the sixteenth century. Archbishop WAREHAM's silver-mounted bowl of the pale green thick porcelain, preserved at New College, Oxford, is one of the earliest specimens known now to be in existence in this country. In the year 1600 the English East India Company was formed, but it did not succeed in establishing a regular importation of *china* until after it had been for thirty years in operation.

From the earliest period the Chinese have systematically refused to export the finest, richest, and most valuable of their porcelain, except in very rare instances. It has also been their uniform practice to keep the composition of this manufacture a profound secret; and accordingly they have always endeavored to mislead all inquiring strangers, with the most marvellous tales respecting the nature and the preparation of the materials. Thus MARCO POLO has recorded that the Chinese collect a certain kind of earth, as it were, from a mine, and laying it in a great heap, suffer it to be exposed to the wind, rain, and sun for thirty or forty years, during which time it is never disturbed. By this means it becomes refined and fit for being wrought into the vessels above mentioned. Such colors as may be thought proper are then laid on, and the ware is afterwards baked in ovens or furnaces. Those persons, therefore, who cause the earth to be dug, collect it for their children and grandchildren.

Other early writers have stated that the porcelain-composition is formed from marine shells, egg shells, gypsum, and other strange substances, which are tempered and thickened, in order to their being adapted to their future application, by being buried in the earth for eighty or one hundred years. Hence Dr. JOHNSON's fanciful derivation of the term porcelain itself—*pour cent années*. Lord BACON entertained the idea that there were strata or beds of the porcelain-clays in China which, being buried beneath the surface of the ground, by length of time became congealed and glazed into that fine substance which afterwards produced the China wares. At length some light was thrown upon the subject by the French Jesuit missionary, D'ENTRECOLLES, who learned many particulars respecting the production of porcelain, both from his converts and from Chinese books upon the subject, and was permitted in person to witness the actual processes of the manufacture. He fully detailed all the particulars in a letter, dated Jao-tcheou, September 1, 1712, which, together with specimens of the two principal materials, he transmitted to Paris. These specimens formed the basis of a series of experiments by RÉAUMUR that ultimately led, when the proper materials had been discovered in France, to the production of the fine porcelain of Sévres.

The high antiquity of the art of making porcelain, and the perfection to which it had attained amongst the Chinese long before any specimens had reached Europe, had for many years been well-authenticated facts, before any definite and precise information had been obtained from records preserved amongst the Chinese themselves. This equally valuable and interesting source of information was reserved for M. STANISLAUS JULIEN, the eminent Chinese scholar, to lay open before us in his translation of a work upon the history of the porcelain of King-te-Tchin, published by him at Paris in 1856, with an elaborate preface and notes obtained from the writings of various Chinese authors. Having referred to the remarkable circumstance, that the Chinese possess an exact chronology from the most remote antiquity to the present time, M. JULIEN states that their official annals record the Emperor HOANG-TI to have been the inventor of pottery, two thousand seven hundred years before the Christian era. Porcelain, the same chroniclers declare to have been first fabricated under the HAN dynasty, who flourished about 185 before CHRIST, thus claiming for the discovery of porcelain an antiquity approaching to two thousand years, and a priority of at least one thousand six hundred years over the first manufacture of this ware in Europe. After sketching out the progressive development of the porcelain manufacture under different dynasties, M. JULIEN proceeds to enumerate fifty-six establishments for its production; after which he describes minutely the great manufactory of King-te-Tchin, that for more than eight centuries has enjoyed the especial patronage of the Chinese emperors. Three thousand furnaces are now in constant operation at King-te-Tchin, which may be said to send their productions to the whole world. Their works may be grouped in two great classes—the one consisting of imitations of the ancient porcelains of the empire, and the other comprising new varieties of both form and color. Amongst the porcelains held in the highest esteem in China, as well as by Europeans, and which were made at early periods, are the celebrated *crackle* vases that are covered with a minute and delicate network of fine surface cracks, produced during the process of manufacture by plunging the heated porcelain in cold water, or by mixing stearite with the glaze. The cracks having been filled up with some thick, colored composition, or with a flux that has been tintured ruby-red by dissolved gold, the porcelain receives its finish. The *egg-shell* is another early porcelain in the highest repute. Its texture is so slight and delicate as to be almost transparent, and yet jars and vases of considerable size were made of it, as well as cups, plates, and other smaller objects. It attained to its highest perfection during the second half of the fifteenth century of this era, when it was fabricated as thin as *bamboo paper*. Some of the finest examples of this porcelain are of a pure white; in others the glaze is creamy, and minutely granulated; and many others are painted chiefly with a cobalt-blue of exquisite beauty. The true cobalt became exhausted in China about 1500, when foreign cobalt was for the first time introduced into the Chinese ceramic manufactories. A native pigment,

found in abundance in all the provinces of the empire, and which is presumed to be a cobaltiferous manganese, is still used by the Chinese artists, who now obtain their true cobalt from England.

Not the least remarkable portions of M. JULIEN's work are those which describe the practice of making, at King-te-tchin, an inferior species of porcelain for the express purpose of exportation, and which also direct attention to the fraudulent and deceptive practices of Chinese porcelain dealers in their transactions with foreign purchasers. Such impositions have not restricted their sphere of action even to the wide limits of the Chinese empire; nor are the inexperienced and unwary the only persons who have by these means been misled. In his highly interesting and most valuable work, *On the Manners and Customs of the Ancient Egyptians*, Sir GARDINER WILKINSON states that great curiosity and surprise were excited by the discovery in certain of the most ancient tombs at Thebes of small bottles of porcelain, unquestionably of Chinese manufacture, and bearing inscriptions in that language. These bottles are about two inches in height; one side of them is ornamented with a flower, and the other bears the legend. They are formed, not of very fine porcelain, but of such as might have been produced before the processes of the manufacture had attained to an advanced degree of perfection—a circumstance that was considered to corroborate their supposed production at a Pharaonic period, no less remote than that of the eighteenth dynasty—before CHRIST 1575 1289—in a tomb of which era one of the specimens was found by ROSELLINI. Subsequent investigations have proved that the characters of the writing upon these bottles were not introduced into China until about 40 before CHRIST, and also that the verses inscribed upon two of their number are to be found in the works of Chinese writers of the eighth century of this age. Similar bottles have since been purchased in China, where they are commonly used to contain snuff, medicines, and other articles of which small quantities only are required. These modern bottles have precisely the same inscriptions with those of the Theban tombs. Another of these bottles has been obtained at Khorsabad, and at Candy they have been seen exposed for sale in a large basket. Hence it is evident that they are exported at the present time from China, and would easily reach the Arabs of modern Egypt, by whom they were, in all probability, placed in the tombs for the deliberate purpose of deception. Such are the evidences that archæologists of this day adduce, before they accept the authenticity of a startling discovery; and, in this particular instance, it is in consequence of these results of careful inquiries that the learned writer upon Egyptian antiquities, who first noticed the little Chinese bottles, is quite prepared to abandon all notion of their antiquity. It has been suggested by MARRYAT that the small seals of pure white Chinese porcelain, highly vitrified, that have been dug up both in Cornwall and Ireland, may, in like manner, have been purposely deposited to try the assumed credulity of archæologists. These seals are all alike in form and size; the handle is formed of the figure of a monkey sitting upon an exact cube rather more than half an inch

square, and on the bottom of this cube is engraved the motto of the seal. It does not appear that such seals are now made in China, though it is quite possible that they may yet be discovered there in abundance. However they may have found their way, either to Cornwall or to the depths of an Irish bog, this one thing is certain—that, by some means, there they have been seen.

While the history of the porcelain manufactures of China to a certain extent has been laid open through the intelligent perseverance of M. JULIEN, all reference to the primitive operations of the Chinese ceramists still continues to be raised but little above

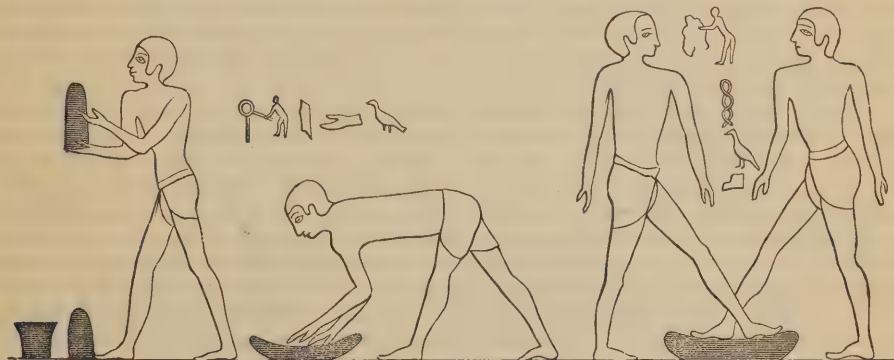
conjecture and speculation. When seeking to trace the progressive outline of the history of the ceramic art, it, accordingly, becomes necessary to have recourse to the accredited traditions of Egypt, Assyria, and Greece.

EGYPTIAN POTTERY.—The memory of the earliest miscellaneous pottery of Egypt has been preserved through the instrumentality of hieroglyphics, which commence from the remote era of the third and fourth dynasties, before CHRIST 3000-2000, and represent various kinds of fictile vessels, the earliest of a red earthenware, in use for the ordinary purposes of domestic life. A succession of these curious sepulchral pictures enables

Fig. 428.

Fig. 427.

Fig. 426.

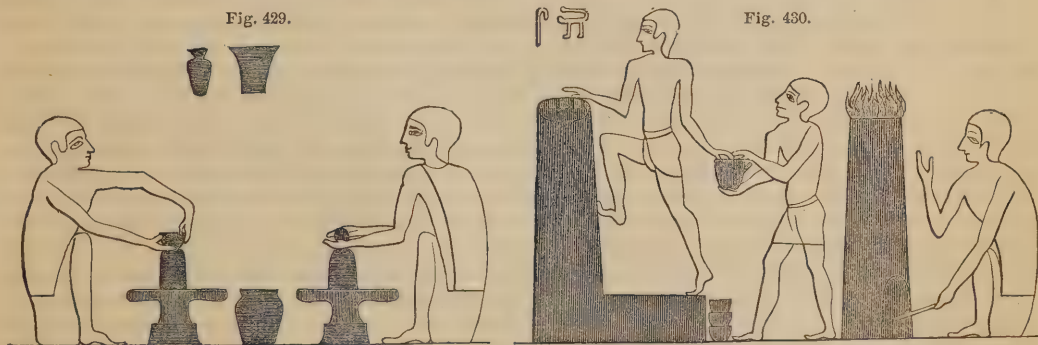


one to trace the progress of the potter's art amongst the ancient Egyptians, and its practice also, from the almost primæval period of the third dynasty, until the power of Rome had extended its influence along the valley of the Nile. Vessels of every variety of form, size, and application are thus represented; and by the same means mankind is rendered familiar with the simple manufacturing processes prevalent amongst the potters

of Egypt. In the tombs that the living Egyptians prepared with such sedulous care for their own final rest, and which they delighted to fill with graphic pictures of Egyptian life, the clay is seen in the act of preparation, and the artificers at work upon it; and close at hand are the furnaces in which their productions were to be baked. The wall-paintings of the tombs excavated at Beni-Hassan while the sovereigns

Fig. 429.

Fig. 430.



of the twelfth dynasty were in power, have supplied illustrative examples—Figs. 426, 427, 428, 429, and 430. After the clay had been dug up, it was prepared by kneading with the feet—a process denominated *hi hat*—Fig. 426. The clay in this state was divided into suitable masses by the workmen—Fig. 427—and carried by them—Fig. 428—to be wrought on the wheel or by the lathe. The wheel is represented twice in Fig. 429; it was a flat table, circular or hexagonal in form, and it appears to have been turned with the left hand, whilst the right was engaged in forming the

required vessel. The various objects, when formed, were placed in a blast furnace, cylindrical in shape, from the head of which the flames issued forth—Fig. 430.

With the advance of civilization, the potters of Egypt very considerably extended the range of their operations, and introduced into their various productions many important improvements. Egyptian pottery, however, does not appear at any time or under any circumstances to have aimed at a high art-character. It was a manufacture designed for purposes of practical utility, and its decorations were held to be altogether

subordinate to its usefulness. At the same time, the Egyptian potters were by no means destitute of some sense of the beautiful, both in form and in adornment, though in their most perfect works they fall far short of the artistic excellence generally prevalent in the fictile productions of the Greeks. True Egyptian vases may be said to be distinguished by the absence of a high mechanical finish, by the prevalence of forms which are evidently imitations of well-known fruits and flowers, by their pointed bases, and by the extreme smallness of their necks and orifices. There are also certain peculiar national conventionalisms of style and treatment, that impart a peculiar Egyptian character to the pottery of Egypt so long as the country itself maintained its own independence. Subsequently, after the substitution of Greek and Roman power for that of Egypt herself, the pottery of the Egyptians in many respects became assimilated with the cognate productions of Greece and Rome. It must be added that the more artistic of the ceramic works of the Egyptians exist in comparatively small numbers, while in the greater proportion of them the simplicity of their character scarcely rises above rudeness. The most important feature in early Egyptian pottery consists in their hieroglyphic legends, which very greatly enhance the value of the relics themselves, since they enable students to determine the age of specimens that are identical, both in their composition and in their type and ornaments, and to assign them their proper places in the history of Egyptian art.

In addition to their bricks, the Egyptians manufactured various objects in clay, which they considered capable of receiving a sufficient degree of hardness from the action of the sun. The perishable nature of such wares has not permitted many objects of this class to remain. The few that have been preserved are of a late date, and they almost exclusively consist of the small figures so commonly used in Egypt as votive offerings, together with various decorations for the interior of tombs. These relics were evidently fabricated in imitation of more valuable and costly works, for which they may have been originally substituted; or they may, in the first instance, have been designed to provide for the requirements of such as could not obtain fictile productions of a higher order.

The earliest and simplest pottery that the Egyptians placed in the furnace to be baked by an artificial heat, was formed from the ordinary unctuous and plastic clay which is regularly deposited by the inundations of the Nile. The earthenware thus produced is coarse and porous, without polish, and of a dull dark-red color, externally tinged with a purple hue, or inclining to a reddish-yellow when the action of the fire had been but comparatively successful. Improvements were gradually introduced into the paste of their terra-cotta by the Egyptian potters; and their manufacturing processes also, in course of time, underwent such modifications as enabled them successfully to undertake the production of an almost infinite variety of objects. The great majority of these works may be included under the comprehensive title of *Vases*—vessels varying in dimensions from being several feet in height, to being scarcely a single inch, and of corresponding circum-

ferences; and adapted, in their diversified forms, to the special requirements of every imaginable use. Those destined to contain liquids are of a jar shape. The Nile water, intended for oblations, was placed in others that are tall and thin, with a spout. Bread, roast meats, and water fowl were placed, says BIRCH, in deep dishes. Oils and drugs were kept in tall conical jars, carefully covered and tied down—ointments, salves, and extracts, in small pots. Other cosmetics were held in a jug with a spout; wine, honey, and other liquids were deposited in open-mouthed jars, out of which they could readily be drawn. Almost every purpose to which jars and other vessels of pottery, together with baskets and vessels formed of the common metals, are put in this country, was discharged by some species of terra-cotta vase, in the case of the ancient Egyptians. In vases of different kinds water was raised from the Nile and distributed by the water-carriers, and conveyed to the lips of both men and animals. Other vases were used in making and storing wine, in bringing it out for use, and in drinking it. The butcher, the poulterer, and the cook, had each their own vases, in which they disposed of their viands. Even the weaver used terra-cotta vessels to hold his flax, and reeled it out of them. Jars held the colors of the artist, and the cements of the plasterer. The grains of corn, before they had been pounded in the mortar, and the flour after it had been thus produced, were kept in vases. Vases held the embalmer's bitumen, and the water used by the scribes. Vases also provided the hod of the laborer, the smelter's bucket and crucible, the jar of the cow-doctor, and the pail of the milk-man.

The pots which contained and preserved the mummies of the sacred ibis at Memphis were formed of a coarse red pottery, or, in some instances, of a finer glazed ware. Similar vessels were also used as receptacles for the mummies of certain sacred animals. Sepulchral vases of various forms were employed in their interments, by the humbler Egyptians, for receiving the intestines, after they had been removed from the bodies and had been embalmed. The *shabti*, or sepulchral figures, which were deposited with the mummies, and formed a part of the funeral relics, were made of terra-cotta, and, in some few instances, of sun-dried clay. The models of coffins or mummy cases, which HERODOTUS records to have been shown by the Egyptian undertakers to the relatives of the deceased, were produced in terra-cotta. The sepulchral cones, again, that were introduced for the purpose of decoration into the interior of the Egyptian sepulchres, were of the same material. These singular objects, that have excited so much curiosity, and caused such diversified speculations, vary from six to twelve inches in length, and are about three inches in diameter at their base. They bear stamped inscriptions, always of a funereal character, and, in almost every instance, stating the name of the person to be commemorated, and conveying some personal information respecting him. Figures and scenes, also, of a sepulchral import, are occasionally introduced instead of inscriptions. The inscriptions upon these cones contribute, in no slight degree, to elucidate the interior organization of

ancient Egypt, and to illustrate its political and social condition, by setting forth a long list of public functionaries with their relative degrees of precedence. As the eye ranges over these tickets of the dead, remarks BIRCH, one is forcibly reminded of the visiting cards of the living. Sacred scribes, royal officers and secretaries, clerks and accountants, priests, viceroys, counsellors, seal-bearers, scribes of the treasury and of the granaries, chamberlains, prefects, incense-bearers—all of them tenants of the sepulchres of the ancient No-ammon or Diospolis, and of still more ancient Noph or Memphis, seem to have left these relics behind them as if to make a call on posterity. Recent discoveries at Warka in Babylonia have proved that these cones were used as bricks, in the formation of the interior walls of the sepulchres, where they were arranged in patterns, their inscribed bases being outwards.

In addition to their varieties of form and size, the vases of the Egyptians may be distinguished by their having either two or more handles, or a single handle, or by their being altogether unprovided with any such appendage. The British Museum contains many highly interesting specimens of each class. The similarity that is so evident between these vases and the painted representations of them that frequently occur in the hieroglyphics, corroborates, in the most satisfactory manner, the descriptive fidelity, and consequently the historical truthfulness of the Egyptian picture-writings. This pottery of Egypt also most clearly indicates that, while it retains certain qualities peculiar to itself, it is the evident prototype of the more beautiful ceramic productions of the Greeks.

Amongst the objects made from baked clay in Egypt during the era of the Roman dominion, are lamps that bear a close resemblance to the terra-cotta lamps of Roman Italy; they take but a low rank, however, as works of art. Lamps of early date, and of higher artistic qualities, have not been preserved in Egypt.

Polished Egyptian Pottery.—The smaller and finer productions of the Egyptian potters, and such as were destined for uses immediately connected with the refinements of life, were either polished by a mechanical process, or covered with a vitreous glaze, so thin as to escape detection. Different clays were employed in the production of the polished vessels that were adapted to various uses; a distinct and beautiful variety is of a uniformly rich red color throughout, which was evidently held in high esteem by the Egyptians themselves. Many of the existing specimens are elegant in their design, and modelled with much skill. This ware, however, notwithstanding its merit, is inferior to the red pottery of the Romans; at the same time, it undoubtedly possesses the required property of cooling liquids poured into it. According to BRONGNIART, the analysis of the polished red ware is—

	Centesimally.
Silica,	56.13
Alumina,	18.54
Oxide of iron and manganese,	9.00
Carbonate of lime,	5.24
Manganese,	1.07
Water,	5.56
Carbonic acid,	4.46

100.00

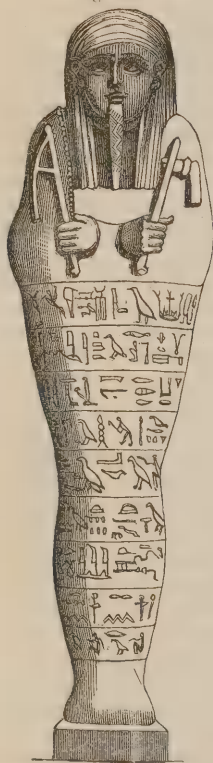
Some vessels of this ware have been found in the tombs at Thebes. Other varieties are formed from a brown or a black paste—in the others again, the paste is of a light-red tint. A white chalk coating generally covers the vessels and other objects of these classes, which may be considered generally to have been made in imitation of similar objects in more precious materials. Amongst the more characteristic specimens of this polished ware that remain, are small cruses or *lecythi*, for containing liquids, of which small quantities only were required. Some of these *lecythi* are double, and have their globular bodies and tall necks united by a narrow band of the terra-cotta. Other examples have oval bodies, narrow necks, and pointed bases; another kind of jug has a compressed body and wide open mouth, and sometimes it appears with two handles; again, other vessels are egg-shaped, while in some human and animal forms are introduced.

To this same class of polished pottery belong the vases that were made in Egypt after the subjugation of the country by ALEXANDER the Great, and which have been distinguished by the title of Græco-Egyptian. The texture of this pottery is comparatively fine and homogeneous, though, in some examples, it is very coarse and mixed up with white or grey particles of a stony nature. In color, different specimens vary from a deep to a pale tint of red or grey. Vases of various forms, and large bowl-like jars, are the principal works of this class that have been found; and they are adorned with figures, flowers, architectural devices and patterns, that are painted in black or red upon the clay.

Glazed Egyptian Pottery.—The substance already described as having been used in the production of their highly glazed tiles, was also commonly employed by the Egyptians for fabricating a vast number of other objects, all of them peculiarly characteristic of their makers. To this glazed pottery of Egypt the term *Porcelain* has very generally been applied: but this use of the word is altogether incorrect, since the glazed fictile works of the Egyptians possess neither the hardness, the compactness, nor the translucence of that peculiar class of ceramic productions. The nature of the material that, in this glazed pottery, was substituted for potter's clay, also distinguishes it from what might be appropriately styled glazed terra-cotta. The constituent parts of this pottery have been found to consist of silica, alumina, carbonate of lime, magnesia, and water; but it does not appear that these substances were combined in any definite or fixed proportions. Whatever amount of clay was incorporated with the compound, was evidently employed for the purpose of holding together the arenaceous portions of the mass; and on the other hand, the presence of the sand was necessary in order to secure the adhesion of the silicious glaze or enamel, which, with its coloring obtained from metallic oxides, was to cover the surface of every object. This peculiar and very beautiful ware was both extensively used in Egypt, and also considered to be of sufficient value to be imported into foreign countries; as is proved by the circumstance, that objects formed of it have been discovered in Greece and Italy. In Egypt this ware was manufactured as early as the sixth dynasty.

The vases made of glazed pottery are of small size, few of them being more than twelve inches in height; and such vases as were produced in this manner, were evidently designed rather for decorative than for useful purposes. They vary in form and in their style of adornment, many of them being evidently modelled in imitation of similar productions in the precious metals. Examples have been observed that are inlaid with a compound of a different color from the body of the vase. Inscriptions occur amongst the devices and patterns introduced into these works by the Egyptian potters; and it is worthy of particular notice that an Assyrian style of art is apparent in some specimens of the glazed

Fig. 431.



pottery, themselves undoubtedly of Egyptian production, that have been discovered amongst the relics of ancient Egypt.

In addition to the *shabti* or *shabshab* of terra-cotta, the same kind of sepulchral figures were made in great abundance in Egypt, of the brightly-colored glazed pottery. So numerous, indeed, are these singular relics, that the production of them must have constituted a staple manufacture in the potteries of ancient Egypt. Known to have been used only in Egypt, where they were universally employed by persons of all ranks in their burial ceremonies, the *shabti*—Fig. 431—which vary in height from about a single inch to about nine or ten inches, may be supposed to represent, and to have been substituted for, the human victims that at one time were sacrificed at the funerals of the great and wealthy. It appears from the formula inscribed upon the *shabti* themselves,

that the use of these figures was to aid the deceased in his labors of preparing and irrigating the ground, and raising the crop in the mystical fields of the Aaheura, or Aahlu, probably the bean-fields of the Egyptian Elysium, and in the transport of the food from the west to the east.—*Birch*.

In addition to this formula from the sixth chapter of the Great Ritual of the Egyptians, the inscriptions upon the *shabti* generally set forth in hieroglyphics the name, style, and titles of the deceased; and they are arranged in horizontal lines down the front of the figure, and in perpendicular ones upon its back. Some of the figures are found to have been executed with the utmost care, and with no common skill. The inscriptions are either incised or produced in intaglio from a stamp, or sometimes they are merely written upon the surface of the glazed ware. Examples have been noticed which had been made ready for sale, having the formula inscribed

upon them, and with blanks left to be filled up with such names and titles as might be required. The *shabti* are generally repetitions of the same type, which represents the deceased as swathed in bandages, after the manner of a mummy set upright, the head and hands alone being exposed to the view. The head has a peculiar covering, with pendent ends. From the chin depends the beard, apparently inclosed in a beard-case; in the right hand is a pickaxe, while the left hand holds a hoe and a cord, to which, and hanging over the shoulder, there is attached a basket containing the seed-corn. The figure stands on a plinth, and sometimes at the back there is a small slab for the purpose, as it would seem, of attaching it to the wall of the tomb. At the era of the eighteenth and nineteenth dynasties, *shabti* of a different and rarer type prevailed. They represented the deceased as standing, and habited in the costume of the period. The prevalent color is the bright Egyptian celestial-blue; but some *shabti* are of a dark blue or purple hue, and a few others have been observed that are either green or brown.

The same material was also employed by the ancient Egyptian potters for the manufacture of innumerable small figures, and other objects, to be worn as amulets by both the dead and the living, together with bugles and beads of various sizes and forms, for which there once existed a demand so great, that they yet remain in prodigious numbers. The amulets comprise statuettes, on a diminutive scale, of the deities of the Egyptian Pantheon, with the sacred animals, and their various emblematic insignia; and they were adjusted to the requirements of the wearers, by being made in the form of pendants, studs, ear-drops, fibulæ, and rings. Concentric rows also were strung together, which would produce necklaces, bracelets, and anklets. Vast quantities of beads and bugles were used in forming the decorative or mystic network, so commonly placed about the mummies of the dead, and associated with amulets. The more elaborate of the beads that were applied to this singular use, were made in the form of different fruits and flowers, instead of having the spherical, globular, cylindrical, or annular forms more generally prevalent. In addition to the beaded-work, mummies have a pectoral ornament, also of enamelled pottery, which is almost universally in the form of an Egyptian pylon or doorway, and is decorated with different symbolical groups and figures, all of them having some sepulchral import. There yet remains to be noticed another class of sepulchral ornaments, of a kindred nature with the beads and bugles and amulets that cover the external bandages of the embalmed dead of ancient Egypt. These are the various other amulets and beads, which were evidently made for the express purpose of being suspended about the necks of the mummies. The figures introduced into these objects appear to have been selected upon some definite principle, and in conformity with a fixed rule; and they comprehend almost every mystic form or device that the Egyptians were wont to associate with the interment of their dead, and which were ordered to be placed upon certain parts of the body of the deceased, for the purpose either of conferring blessings or of averting evil. Finger-rings—*tebu*—formed

entirely of enamelled pottery, and adorned with characteristic and appropriate devices, were common in Egypt, and it is probable that they were used as well for sepulchral purposes as for the personal decoration of living Egyptians. Many of these relics that yet exist, are impressed with the names of well-known Egyptian kings, a circumstance that leads to the inference that these rings were worn, either in life or death, by personages of exalted rank, since the use of the king's name seems to have been restricted to functionaries of state—as the royal arms appear in England to have been introduced, in the middle ages, only into the monumental heraldry of those who had formerly held offices either immediately under the crown, or about the person of the sovereign.

The enamelled rings of Egypt, like the beads and statuettes and other decorative objects, were much prized by the Greeks and Etruscans. They have been found in the sepulchres of Etruria in settings of the exquisite gold filagree-work of the Etruscans, intermixed with precious stones and beads of gold, precisely as one would now testify admiration for the small cameo gems of WEDGEWOOD. In a tomb at the Polledrara near Vulci, in Italy, a heap of Egyptian beads and bugles was discovered, which had apparently formed a network covering, after the fashion of Egypt, to some bronze objects; but, the strings having yielded to the influence of time, the beads and bugles had fallen to the ground. Another tomb—one of those at Egyptian Thebes—contains a painted representation of the processes of finishing and stringing these simple and familiar objects. Three men are seen hard at work: one stands, and files bugles of green enamelled ware; a second is seated, with a basket full of these bugles before him, some of which he has arranged in a row for a necklace; and the third is drilling a hole in a piece of wood.

Their enamelled ware was employed by the Egyptians for the purpose of *inlaying* some of their figures, and for decorating their coffins by a similar process. In figures, when vitreous pastes were inlaid, says BIRCH, the portions made of this material were the extremities, as the fingers and toes, the beard and eyes, and parts of the dress, such as the collar round the neck, the bracelets, and anklets. One of the finest specimens of this application of the Egyptian enamelled ware in inlaying, adds the same able writer, is a head-dress or wig, found at Thebes, which formed part of a small figure of a king, probably about three feet high. The mass of which it is composed is of a deep-blue color, the fashionable head powder of the day being probably of that hue. So regular is the arrangement of the curls, that they appear to have been pressed out of a mould. A rich fillet or diadem, which passed round the head, is inlaid with small tesserae, about half an inch long and one-eighth of an inch wide, of bright-red paste, imitating jasper, and of gilded porcelain. In some instances the enamelled pottery is found to have been used with other substances, as ivory and various stones, for the purpose of inlaying. It was also applied to inlay a variety of domestic objects, some minutely small and others of a considerable size. The British Museum contains, besides other inlaid objects, a box of dark

wood, taken from a tomb at Thebes, that has on the lid and sides a square border formed of tesserae of blue enamelled pottery, alternating with similar pieces of ivory stained red. Two other remarkable Egyptian specimens in the national collections are tiles, one of which is rectangular and measures six by four inches; it is of the celebrated blue ware, on which is traced in a darker blue outline the figure of the royal scribe, ADMENEMAPT, worshipping OSIRIS; the other tile, which is circular, is inlaid with a very curious representation of a spider in the centre of its web.

Besides their enamelled beads the Egyptians have left, as illustrations of their social and domestic history, specimens of their draftsmen made of the same material, and various miscellaneous articles, that may have once been used either as personal ornaments, or as children's toys—the two classes of objects may often be grouped together—or for the various decorative requirements of daily life.

The same vitreous glaze which they used with such excellent effect in their enamelled silicious pottery, the Egyptians also applied with a similar aim to a vast number of works of a highly artistic character, executed by them in steaschist, or some other hard substance of the same kind. This steaschist, which closely resembles the jade employed by Chinese artists in many of their carvings, is a material that may be worked to great advantage by skilful hands. The Egyptians produced in it amulets, rings, and other objects, which are still distinguished for the sharpness and precision of their carving and their delicate finish. The stone, when cut and inlaid with niello-like incised work, was coated with enamel and subjected to the action of the furnace, the result being a species of glazed stoneware that at once bore a close resemblance to true pottery and was altogether distinct from it. Amongst the most highly finished and beautiful of the examples of these singular works of Egyptian art, that are known to be yet in existence, are signet rings and inscribed amulets. The form generally prevalent for rings executed in this manner is the scarabæus beetle, called in the language of Egypt *kleper*, or creator, and regarded by the Egyptians with peculiar reverence as the sacred emblem of the Deity, who made, as they held, all things out of clay. The hieroglyphics engraved upon these scarabæi are executed in flat intaglio, sometimes with a wonderful accuracy and delicacy, completely rivalling those on gems. On some only a solitary hieroglyphic is put; but on others as many as three lines of these symbols are inscribed. They are of all ages—from the fourth dynasty down to the Roman empire; the principal period of their manufacture was, however, the reign of TOTHMES the Third, of the eighteenth dynasty, one-tenth of these amulets bearing his name.—*Birch*. The same judicious writer directs attention to the fact, that many of these carved works attest a certain community of art in Egypt and Assyria. It is also observable that the devices, legends, and mottoes of the rings, amulets, and other objects clearly indicate that they were adapted to certain distinctive conditions of different classes of the Egyptian community.

The busy and enterprising multitudes who consti-

tuted the races that are now distinguished as ancient Egyptians, have transmitted both the salient points and the minor details of their national history and of their private life, in part written in their mystic hieroglyphics, and in part conveyed with graphic fidelity by means of the varied productions of their arts and manufactures. From both these channels of information it is evident, that a consideration of primary importance with the living Egyptian was the preparation and appropriate decoration and furnishing of his tomb. To this very circumstance posterity is mainly indebted for what is known, if not of Egypt, certainly of the Egyptians. They considered it to be right to adorn their sepulchral chambers with painted scenes and incidents, as they occurred daily on every side of them; and with the mummies of their dead they had been taught to deposit vases filled with various substances for the use of the deceased, together with a multiplicity of personal ornaments and other objects. Hence all these relics have come down preserved, as if for especial information, from century to century in their silent treasuries. The uses to which they were put by their makers have insured their preservation; and the relics themselves, in their turn, have reciprocated the good deed, by declaring in what manner the ancient Egyptians used them, and by elucidating the several purposes which they were intended to serve. Nor is the value of the ancient pottery, either preserved or represented amidst the remains of ancient Egypt, limited in its historical capacity to the land and the people of the Pharaohs and the Ptolemies. Certain fictile relics still in existence bear inscriptions which declare that they were fabricated to contain and to preserve tribute—*han*—of wine, incense, and the like, in the storehouses of the king; and there is every reason for believing that the same vessels conveyed these offerings from distant tributary lands to the banks of the Nile. The father of European history has left it on record that in his time—before CHRIST four hundred and forty years—wine was exported from Syria to Egypt in such amphoræ as are represented, tribute-laden, in the triumphal procession of TOTHMES III., and which may be seen in the national museum. Some of these very vessels, therefore, may have been sent to one of the last of the Pharaohs, who reigned in the lifetime of HERODOTUS; while others, in all probability, formed a part of the tribute paid to his more powerful predecessors. These productions of the potter may accordingly be regarded with a twofold interest, since they both call one back to the Egypt of antiquity, and also afford an insight into the condition of art amongst some Asiatic people, otherwise unknown, who were contemporary with the Pharaohs of the nineteenth dynasty.

ASSYRIAN POTTERY.—With the exception of bricks both sun-dried and kiln-burnt, and of inscribed tiles and cylinders, the ceramic productions of the ancient Assyrians and Babylonians have not been discovered in any great numbers in Mesopotamia. Nor have the bas-reliefs and cuneiform writings—so far as the latter have been read—that recent researches have brought to light in this remarkable region, done much to elucidate the practice of the potter's art as it may be presumed to have

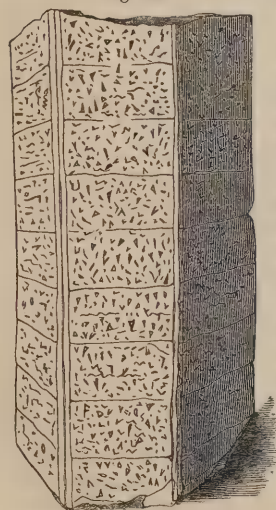
once flourished upon the banks of the Tigris and the Euphrates. The Assyrian sculptures are art-written records, not of the Assyrian people, but of their kings: hence, any illustration of Assyrian life that these most interesting relics may afford, is rather incidental and subordinate in its character, than a primary and direct motive of the composition. Not thus did the Egyptians apply their hieroglyphics. Their Pharaohs, indeed, appear in the full and significant grandeur of their pre-eminence; but with them their people are habitually associated. Egyptian life, in every phase of its varied conditions, and in all the diversified yet ever characteristic associations of Egypt itself, was what those active and imaginative sons of the Nile delighted to depict: and hence they stand alone amongst the nations of antiquity, in their love for that graphic species of history which records and transmits to distant generations complete biographies of a people.

In addition to the innumerable sun-dried bricks that were used for constructing the enormous mounds upon which the cities of ancient Assyria were erected, a few rude figures only of unbaked clay have been found beneath the pavement-slabs of the Assyrian palaces; and these were probably placed there as propitiatory offerings. The few objects of unglazed terra-cotta which have been discovered, consist of vases and other vessels of various forms and sizes, many of them being evidently made expressly for sepulchral uses, with some lamps of peculiar shape, and some small figures and architectural ornaments. Of these the larger portion may be assigned to different periods subsequent to the fall of Nineveh, while certain specimens have been found in circumstances which prove them to have been coeval with the ancient Assyrian edifices. One saucer-shaped patera LAYARD found built into the back of a wall of the N. W. Palace at Nimrūd, evidently through the mistake of the workman. Another vessel in the shape of a cylindrical jar, eighteen inches high, and nineteen inches in diameter, was found in the same palace between two colossal bulls at the entrance of a chamber; it is of a pale yellow clay, and ornamented with Assyrian mythological figures. Other vases were discovered inside sarcophagi, also made of earthen materials. Similar objects, the greater number being sepulchral, were picked up at Kouyunjik above the ruins of the palaces in the mounds; they closely resemble the ordinary Roman pottery of the same class, and they were probably produced in Roman times, by the races who established themselves upon the huge mounds after the fall of the buried cities. Vases of the same class have also been found at Khorsabad, and examples of terra-cotta coffins have been exhumed at Kalah Shergat. The ornaments of all are of a very simple character, and there is but little to distinguish as Assyrian such of these works as are not unquestionably of a high antiquity. It has been remarked that this terra-cotta ware evidently continued to be made till a late period in the country that once had been Assyria, since vessels have been discovered there having covers inscribed with Hebrew and Syriac characters. The old Assyrians would certainly have written upon these vessels their own arrow-headed inscriptions. They may be as late as the fourth century after CHRIST. It must be added,

however, that it is by no means impossible for some few ceramic relics of the old Assyrian period to be intermixed amongst this more recent pottery. The terra-cotta figures and architectural ornaments of the Assyrians, like those of Babylonia, were probably coated with rich gilding, and consequently they may for this reason have perished through the cupidity of the spoilers. The few relics of this description that have been discovered are small in size, and by no means worthy of high admiration as works of art. Besides the figures, some moulds for making small figures have been found formed of terra-cotta—also some seals, now in the British Museum, about an inch in diameter, of which the material is fine dark clay, and which had been stamped with the device of a king stabbing a lion with a sword. LAYARD informs us that in removing one of the slabs sculptured with the hunting scenes of Ashurbanipal at Kouyunjik, several small terra-cotta figures of dogs were found, standing, made of a coarse clay covered with a blue, red, or black paste, and having names inscribed on them in cuneiform characters, such as, *the guardian of the house*, *the lion-tamer*, and others. RAWLINSON supposes these to be images of certain hounds, formerly favorites with the king, which had been killed in hunts of lions and other wild animals.

Very different from the formulæ which they impressed with stamps upon their kiln-baked bricks were the legends that, in accordance with a custom peculiar to themselves amongst the nations of antiquity, the Assyrians inscribed upon cylinders, prisms, and small tiles of very fine and sometimes highly-polished terra-cotta. Thus they wrote the records of the king's victories and the annals of his reign; thus their title-

deeds, and deeds attesting and confirming the sale of land and other properties, were written; and thus their astronomers noted down the results of their observations and calculations. A chamber filled with terra-cotta archives and miscellaneous records—books, they would now be called—was found in the palace of SENNACHERIB at Kouyunjik, one of which, a hexagonal prism of terra-cotta, inscribed with the records of a king's reign, now deposited in the British Museum, is represented in Fig. 432. Probably this chamber was the



private library of that monarch. Similar collections have been discovered in other parts of Assyria, from which there have been obtained about twenty thousand inscribed tablets, containing the native literature of the country as it issued, not from the press, but from the kiln. Thus, while the paper and parchment learning of the Byzantine and Alexandrian schools has almost disappeared after a few centuries, the granite pages of

Egypt and the clay leaves of Assyria have escaped the ravages of time and the fury of barbarism.

In addition to their terra-cotta writings, the Assyrians, in common with the Egyptians, employed the same plastic material that formed their cylinders precisely in the same manner as sealing-wax was used in Europe in the middle ages, and is still in use at the present day. The clay, when in a moist state, was either impressed upon the face of the document, or appended to it by means of a slip or cord. One of these seals, found with the terra-cottas supposed to contain the royal archives at Kouyunjik, was stamped with the signet of SABACO, who reigned in Egypt seven hundred and eleven years before CHRIST, and was contemporary with SENNACHERIB.

Glazed and Enamelled Pottery was evidently in use amongst the Assyrians for various religious, sepulchral, domestic, and architectural purposes, much in the same manner as with the Egyptians. The Assyrian productions of this class, however, are proved by such remains of them as still exist to have been inferior to those of Egypt, both in their manufacture and in their artistic qualities. Very few vases of this ware have been found in a state of good preservation amidst the wreck of the Assyrian palaces; but fragments abound in that country of ruins, which demonstrate the existence of this ware in ancient times under a considerable variety of forms, though never, as it would seem, in any great abundance. Some of the shattered fragments now in the British Museum are parts of vessels that were lined with a coarse blue glaze; others, found in different localities, are of a pale lilac hue, or they have yellow patterns on a blue ground; or the ground is white, upon which there are stripes of brown and purple: but the most prevalent color is a fine bright blue, verging towards a green when the surface has been slightly decomposed. The body of this ware is formed of the fine clay deposited during the inundations of the great rivers, the glazes being a vitreous silicated substance variously colored with metallic oxides. A recent analysis has shown, that the opaque white employed in the decoration of an Assyrian enamelled brick was produced with tin, the yellow with antimoniate of lead, the brown with iron, and the blue and green with copper; the flux and glazes proved to consist of silicate of soda and lead. The enamel—as was proved to be the case from its having trickled down the sides when in a melted state—was placed only upon one surface of the brick, with the view to securing its adhesion; and the brick itself was laid horizontally, with the enamelled face uppermost, when in the furnace. This brick was probably slightly baked before it was painted, and then when the colors had been applied to it after it had become cold, it was a second time placed in the furnace. The walls of Nimrūd were evidently faced with these enamelled bricks, that were variously colored and otherwise decorated, and thus formed an effective species of mosaic. Architectural cornices and other decorative accessories were also formed in a somewhat similar manner from different pieces of this enamelled terra-cotta.

BABYLONIAN POTTERY.—In their construction from sun-dried bricks almost identical with those that were

raised by the Assyrians higher up the streams of the great rivers, the vast ruined mounds of Babylonia yield various ceramic relics, that bear a close general resemblance to the corresponding remains which have been discovered under similar circumstances in Assyria. These examples of pottery are not sufficiently numerous to supply detailed information respecting the fictile processes of Babylonia. The pottery of these mounds, also, is composed of productions of very different periods, the works of distinct races. Some without a doubt was made in the days of Babylonian greatness; but the greater portion must be assigned to eras subsequent to the fall and ruin of the city and empire of the Chaldees, when various races succeeded each other in the occupancy of what once had been Babylon.

The cups, vases, and other vessels of terra-cotta in use by the Babylonians, appear to have been of a simple character. The paste is generally of a light red color, but sometimes of a yellow hue, with a tinge of green; and it has not been submitted to the action of a very high temperature. The figures were produced in moulds; and the vases, formed upon the wheel, were devoid both of painting and any other decoration. In the case of the larger specimens, modelled figures and heads were sometimes introduced at the handles for the purpose of adornment. A few small pieces of very fine terra-cotta have been found in this region, in the form of bas-reliefs of great interest. One, the best of the series, now in the British Museum, represents a man holding by the collar a very large and noble-looking dog. The design has been modelled by the hand, and it is remarkable for its spirit and freedom. This specimen was obtained near Babylon. Other small bas-reliefs of female figures have been found at Warka; but they have all been produced from moulds, and may be assigned to a less remote period. The larger statues, such as would be made to represent the gods and heroes of Babylon, may be considered to have been formed of terra-cotta. Such was the image made of clay and metal, recorded by DANIEL to have been seen in his dream by NEBUCHADNEZZAR; and such, too, was that other image of Bel, declared by the same prophet to have been composed of clay, and then covered with a coating of brass or bronze. The colossi mentioned by DIODORUS, were probably produced in the same manner; and the famous golden idol of NEBUCHADNEZZAR may have been a work of the king's potters, overlaid—as was the custom amongst the Babylonians—with rich and costly gilding.

Gilding, overlays of silver, and variously-colored glazes were applied by the Babylonians to the bricks with which they constructed their more important edifices. The walls of the Median Ecbatana are described by HERODOTUS as having been built with bricks of different colors; and the supposed temple of Belus at the Birs Nimrūd affords another remarkable instance of the same polychromatic construction. In 1854, Sir H. RAWLINSON dug out from the angles of the stages of the brickwork three inscribed cylinders, from which he has discovered that the Birs Nimrūd was dedicated by NEBUCHADNEZZAR to the seven planets; the building was, accordingly, constructed in seven stages or platforms, each one smaller than the one below it,

and formed of bricks differently tinted. Mr. LOFTUS has added much very valuable information to what had been previously ascertained upon the subject of Babylonian pottery. At Warka he found walls formed of sun-dried bricks, banded at intervals with layers of reeds; some of these bricks were stamped with inscriptions. Kiln-dried bricks of small size, and red brick cones similar to those constantly to be seen in Egypt, were discovered at the same place; the latter had their bases colored red, and they were embedded in a cement of mud and straw as building materials. At Warka, also, Mr. LOFTUS found an edifice built of similar cones, three and a half inches long, and laid horizontally, their crests and bases alternating, and embedded in cement. They were formed of a dull yellow clay; but, their bases having been dipped in black or red paint, they thus might be arranged in such a manner as would form various ornamental patterns. Ornamental brickwork constructed of bricks of the ordinary shape and executed with singular skill, together with enamelled bricks of various hues decorated with stars having seven rays; a pavement of vitrified slabs; glazed lamps of terra cotta; and most curious coffins of enamelled ware in the shape of gigantic slipper-baths—were amongst the fictile relics discovered by this indefatigable explorer at Warka, which appears to be identical with the ancient Ur of the Chaldees. The Warka coffins were found in prodigious quantities, piled up to the height of forty-five feet. They were formed of pale straw-colored paste, imperfectly baked; the whole being covered with a blue glaze that has acquired a greenish hue through age. These singular relics Mr. LOFTUS assigns to the Sassanian period of Babylonian history, when Warka must have been a vast necropolis; they are variously ornamented with raised bands and patterns, and also with numerous small figures in low relief, and they have richly adorned lids of the same material with themselves that cover the openings. Several specimens have been added to the oriental collections in the British Museum.

Fragments of glazed or enamelled pottery are intermixed with the debris of the common terra-cotta wares throughout the ruins of ancient Babylonia, and they consist of the remains of vases and different vessels in addition to the colored bricks so much in favor with the Babylonians.

Documents inscribed upon cylinders and slabs of fine terra-cotta after the custom prevalent amongst the Assyrians, have been discovered in the ruinous heaps that have of late attracted so much attention in the ancient Babylonia Proper. These terra-cottas exhibit great varieties in their forms, but, so far as they have been deciphered, appear to comprise precisely the same classes of records with those of Assyria. In one fragment, at the edges there are the names and seals apparently of the witnesses who attest a deed. Another fragment of the utmost value is a part of a great cylinder, now in the museum of the India House, and containing, according to Sir H. RAWLINSON, a transcript of the statistical tables of NEBUCHADNEZZAR, in which the temples either built or endowed in Babylonia by that monarch are enumerated. Several other Babylonian cylinders are preserved in the various museums of Europe. Sir H. RAWLINSON states that they are seven in number, or

rather that there are seven distinct historical records preserved on as many different cylinders. Of these records, the one that describes the Birs Nimrūd, is repeated in each of the three cylinders that he himself discovered in that celebrated heap of ruins.

ETRUSCAN POTTERY.—As in Egypt and Assyria, so also in Europe, the first appearance of the potter's art is coeval with the first dawn of civilization. In Etruria, that region of Italy which lies to the north of the Tiber, from a remote antiquity the remarkable race were established who gave their name to the country where they flourished, and whose half-legendary history is the earliest that appears in European annals. It is a custom prevalent amongst writers upon ancient art, to describe the Etruscans as having obtained from Egypt the original germ of all their art-industries; it would, however, be difficult to demonstrate the fact of any intercourse between Etruria and Egypt, antecedent to the earliest operation of Etruscan art. The fact appears to be that the Etruscans, like every other people, *in the first instance*, were the inventors of their own arts, and applied their inventions to meet the requirements of their daily lives. It is true that there is conclusive reason for considering the sombre and severe spirit of the Etruscan race to have been rather receptive than productive; and, consequently, this remarkable nation is found readily to have accepted and appropriated to its own use whatever improvements in the arts it might have discovered during the progress of time, through a gradually-extending intercourse with foreign visitors. Thus the arts of Egypt, transmitted through the Greeks, may be said ultimately to have reached Etruria; and thus the Etruscans, having been instructed in their style by the artists of Greece, conformed to the Greek system, and in fact appropriated it as their own. But, on the other hand, it is no less certain that the primitive Etruscans were possessed of sufficient inventive powers to produce an indigenous pottery suited to their own wants, and the materials for which nature had strewed in abundance at their feet.

The earliest, and as would naturally be expected, the simplest relics of Etruscan pottery that yet remain, must be attributed to an era long subsequent to the general practice of the ceramic art in Etruria—that is, they appear to have been produced in the eighth and seventh centuries before this era. They chiefly consist of vases of a dark color, fabricated from a coarse brown ware, and in some instances apparently modelled in imitation of vessels formed of wood. These vases vary considerably in size, and many examples are adorned with figures in relief; but no instances have been observed in which paint was used as a decorative medium. They have been for the most part discovered at Cervetri—the ancient Caere—Vulci, and Chiusi; and it is evident that they were not by any means first efforts in the practice of the potter's art. Indeed, seven hundred years before CHRIST, the Etruscans had been a flourishing people. It is a subject for much regret that the history of European pottery, which opens upon Etruscan ground, should not be able to trace out its course clearly from its original fountain-head; but the antiquity of Etruria, as a country regularly inhabited by a race who enjoyed at least a comparative civilization,

intercepts the researches of the historical inquirer, and convinces him that he must be content to commence his record with the earliest actual specimens of Etruscan fictile works, that time has been willing to transmit to the present age. The want of a literature amongst the Etruscans, also, adds seriously to the difficulties which attend the investigation of the ancient arts of Etruria. Roman writers, however, have supplied much information that might naturally have been expected from the Etruscans themselves. It is chiefly by this means that the knowledge possessed of the more important works of the ancient Etruscan potters is derived, since the Romans, in the early days of Rome, unable to execute such works, were obliged to have recourse to Etruscan artists for the plastic decorations of their temples. Such testimony is conclusive in establishing the fact, that the Etruscans at a very early period had established a school of art peculiarly their own, which, in its characteristic features, had attained to a high degree of perfection.

According to PLINY, the art of working in terra-cotta was principally cultivated at an early period in Italy by the Etruscans. The same writer states that the art of statuary was so old in Italy that its origin was unknown. One may reasonably infer that in the days of PLINY the origin of the potter's art in Europe was equally obscure; and thus, accordingly, it may be safely conceded to the Etruscans—the people amongst whom that art appears to have been known and practised from a remote antiquity. BIRCH suggests that the Etruscan potters may have worked from foreign models, and perhaps from the statues of the Egyptians, with which they first became acquainted when PSAMMETICUS I. threw open Egypt to the commerce of the world in the second century of Rome, six hundred and fifty-four years before CHRIST. But Etruria had attained to celebrity for its pottery before Egypt had been made accessible by Etruscans; and, in fact, there exists no really valid reason for withholding from the Etruscan potters the credit of producing their own pottery from their own designs, until the potent influence of Greek art appears to have prevailed over the native sympathies of the Etruscan people. The change thus effected may be said to have taken place during the first half of the fifth century previous to the Saviour. Prior to that period the arts of Etruria may be regarded as Etruscan, and therefore independent of Hellenic influence.

With the exception of vases, of which vast numbers have been found, but few productions of the Etruscan potters have been preserved until the present day. The safety of the vases has been the result of the free use made of them by the Etruscans themselves in their sepulchral rites. They deposited numerous vases in their tombs, and closed them up in the same security that they so studiously sought to obtain for the remains of their dead. And the fictile relics rested undisturbed for centuries, until the inquiring and exploring spirit of modern times should exhume them as monuments of ancient history. The statues and reliefs in terra-cotta for which the Etruscans were celebrated, with their architectural works executed in the same material, would almost inevitably perish in the sharp vicissitudes of succeeding years; and, indeed, such examples

as do exist owe their preservation to the circumstance of their having been deposited, like the vases, beneath the surface of the ground.

Bricks and tiles appear to have been but little used by the Etruscans, except for sepulchral purposes. The recesses of the chambers that held the small sarcophagi within which the ashes of the dead were deposited, were closed by tiles bearing inscriptions; and similar tiles, at a much later period, were used to cover such bodies as were interred, and not burnt. Various decorative accessories of the tombs of an architectural character, were also modelled in terra-cotta; and there is every reason for believing that friezes, antefixæ, and other architectural details formed of the same material, were in general use. Recent excavations in Etruria, however, have failed to produce examples of genuine architectural bas-reliefs, such as were so freely introduced into their buildings by the Romans. Terra-cotta sarcophagi have frequently been found, which are identical both in their general character and their style of adornment with the more costly works of the same class in alabaster, tufo, and other similar materials. Some few are of sufficient size to receive a human body laid at full length. The British Museum contains two such sarcophagi, which have been obtained from Vulci: their sides and ends are covered with bas-reliefs, and on the covers there repose recumbent effigies of Etruscan females, modelled at full length. The paste of which these terra-cottas are composed, is either a pale red or a pale yellow in color. But Etruscan terra-cotta sarcophagi more generally are very small, and appear at first sight to be models rather than actual depositories of the remains of the dead. They were intended to be the receptacles of the ashes after cremation, and they may be regarded as the prototypes of the sepulchral urns which the Romans ranged in rows of small cells or niches, around their *columbaria* or sepulchral chambers.

The effigies that rest upon sarcophagi are the only statues of full size in terra-cotta by Etruscan artists, which are known now to be in existence. The few examples that have been discovered closely resemble in their artistic treatment the early bronzes and sepulchral wall-paintings of Italy. It does not follow from this circumstance that the terra-cotta figures were modelled from types either in metal or from paintings; on the contrary, the resemblance between these figures, executed by different processes, simply confirms the independent and consistent action of the artists of Etruria. A most remarkable recumbent effigy in pale red terra-cotta, having the clay intermixed with volcanic sand, was found at Cervetri, where other somewhat similar figures have also been discovered, all of which are genuine Etruscan, and apparently older than the foundation of Rome. Besides the monumental figures, some few curious and interesting busts have been found, formed of clay, in the sepulchres of Etruria.

The VASES of the Etruscans admit of the following classification:—

1. Vases of brown terra-cotta.
2. Vases of black terra-cotta.

3. Vases of red terra-cotta.

4. Vases painted.

Also a small class of vases of a yellow ware.

The brown vases have already been stated to be the oldest existing specimens of Etruscan pottery. Their color is a greyish brown, and sometimes the clay is red in the centre. They are in various shapes, the most curious being an example in the British Museum in the form of a *Tugurium*, or ancient Etruscan cottage—Fig. 433—with a movable door and a vaulted roof that

Fig. 433.



apparently was intended to represent the beams of the timber-covering of an actual dwelling. The ashes of some deceased Italian, who may be considered to have lived and died before the name of Rome had been spoken amongst men, were inserted through the door, which was then secured by a cord. The smaller vessel was then placed within a large two-handled vase of equally rude character, and thus protected from the superincumbent mass of earth.

It is a remarkable fact that hut-shaped sepulchral urns have been discovered in several parts of Germany, which closely resemble those that once were buried in the tombs of Etruria. The German specimens are distinctly Teutonic; and they are to be attributed to an age before the predominance of Roman art, but while bronze weapons were in use. One found at Mount Chemnitz in Thuringen, is cylindrical with a conical roof or cover; a square orifice in this vase represents the doorway or window of the hut, through which the ashes of the dead were introduced, when the whole was secured by a small door fastened with a metal pin. Similar vases have been exhumed at Roenne, Parchim, and in the island of Bornholm. A vase of this description, found at Aschersleben, has its cover modelled in the form of a tall conical thatched roof, and it has the door with its ring still remaining. Another, with a taller body and flatter roof, with a door at the side, was discovered at Klus, near Halberstadt. The larger vases were used to contain and preserve the ashes of the dead; and they are found in some instances to have been placed, for greater security, within vases of coarser fabric and a different shape, or to have been protected by some covering of stones or tiles. The

other smaller vessels held the offerings, consisting of different viands, that the Teutonic races deposited with their dead.

The ancient brown vases of Etruria are not uncommonly found beneath beds of lava. Many of them are highly polished by friction, so that they have the appearance of basalt, but they have no glaze upon their surfaces.

Next in the order of time are the black vases, some of which are thick and heavy, while others are thin and light. The black surfaces of many of these vases have a lustrous jet-like polish, which occasionally may have been produced upon the lathe. They frequently exhibit traces of the imitation of other Etruscan works of art in both wood and metal; but they show no signs whatever of any imitation of foreign productions. In the earliest examples the ornamentation consists simply of rude zigzags, spirals, and festoons of lotus-like flowers and similar devices, hatched upon their surfaces. Somewhat later animal forms, with human figures, heads, and other objects, make their appearance. These figures are commonly disposed so as to form friezes running round the body of the vase. They are generally in a bold relief, which has been obtained either from the impress of dies, or by modelling, or by passing a cylinder cut in intaglio round the vase while the clay was moist. The treatment of the figures in these friezes is peculiar, and it not uncommonly indicates that the rudeness of the work has resulted rather from the intractable nature of the material, than from the incapacity of the artist. The early usage of producing ornaments by means of incised lines, is occasionally introduced for the purpose of carrying out the details of the reliefs. The designs of these friezes are obscure and uncertain; and, in connection with the absence of inscriptions having reference to either the subjects, the artists, or the potters, they serve to corroborate the assumed high antiquity of the vases. When inscriptions do occur, they appear to be merely the potter's memoranda, which were scratched in with a pointed instrument at the bottom of the vases after they had been finished. Vessels differing very greatly from one another in form and size, and evidently no less different in their several uses, have been found of this ware; amongst them are cinerary vases of the most singular character, being rude representations of the human figure. Collections of these vases have been found in many sepulchres, which contain various vases and other objects, the use of which is unknown. Large vases sometimes contain numerous smaller ones; spoons also and vase-stands have been found with them. It is probable that JUVENAL referred to pottery of this class, when he spoke of the *black saucer of Numa*; and that this is the black ware that PLINY records to have been fabricated by the corporations of potters in the days of NUMA, seven hundred years before CHRIST. HORACE, MARTIAL, and JUVENAL also appear to have had it in view in certain well-known passages of their writings. The tombs which have produced these vases in the greatest abundance are in the vicinity of the ancient Veii, Cære, Clusium, and also at Volaterra and Cortona; but they very rarely occur to the south of the Tiber. An analysis of the

paste of the black Etruscan vases has given a mean result of—

	Centesimally.
Silica,	63·24
Alumina,	14·42
Oxide of iron and manganese,	7·80
Carbonate of lime,	3·25
Carbonate of magnesia,	2·12
Carbon,	1·83
Water,	7·34

100·00

The vases of red ware, which may be assigned to the earliest period of existing Etruscan pottery, are found in the same ancient sepulchres with the black vases, but in much smaller numbers. These vases are of a dull red hue, and of a gritty material, apparently containing an admixture of the tufo of the soil. If large in size, their bodies are reeded, and ornamental patterns are boldly modelled about their necks; sometimes they have handles; and the characteristic Etruscan frieze appears in some of them, with representations of animals, chariots, hunting scenes, and banquets. They generally are found standing in flat circular dishes or saucers, of similar ware, but made of a finer paste, and ornamented with other friezes impressed upon them in bas-relief with a cylinder. Some few vases of this class, instead of a decided red, are of a pale salmon tint; and they have a slightly freckled appearance, which is produced by black specks of some volcanic substance mingled with the clay. The Etruscan sepulchres also continually produce vases of a pale yellow color and of a fine quality, some of which are probably of very ancient date, while others appear to have been manufactured at subsequent periods.

Some vases found at Cære, composed of a pale reddish-brown clay, specked with black volcanic sand, and sparkling with mica, are amongst the earliest specimens of the *painted* pottery of Etruria. They are adorned with various patterns, and also with flowers and figures, painted in white upon a black back-ground, or upon the clay in its natural color; the peculiarity of the work being that the painting was executed after the manner of an opaque fresco, and not burnt in upon the vases in the furnace. These painted vases may have been produced a century or more anterior to the mythic arrival of the Greek potters, who, according to PLINY, were brought by the fugitive DEMARATUS from Corinth to Etruria between the years five hundred and twenty and six hundred and sixty before CHRIST. To this incident has been attributed the first introduction of archaic Greek vase-painting amongst the Etruscans. The Etruscan sepulchres have yielded many vases having pale buff back-grounds, upon which figures of animals are painted with fantastic and floral borders, all in a deep-red, that may be assigned to this period.

Next in the order of chronological succession are the red or orange-colored vases with black figures, the subjects being generally mythological, and the execution of them indicative of at least some progress in the art of pictorial representation, though still there is much of rudeness that lingers about them in combination with a strange uncouthness in many of the figures. In other examples the adjustment of the colors is reversed, and

the figures are red upon a dark ground. These figures are relieved by lines of black, obtained by cutting down through the red pigment to the black glaze of the vase. This same arrangement of the tints prevails in the finest and most perfect specimens of Etruscan and Italo-Greek vase-painting. The figures are red upon a ground of polished black. These vases were produced after Greek art had found a second home in Italy; and, consequently, though both made in ancient times and at the present day discovered in Italy; they may be classed with the works that were produced by Greek ceramic artists. The shade of the ground in some of the Etruscan vases is a dark-brown; in others the clay is ash-colored; and in both cases the designs are painted in black and crimson, with incised lines executed with a graving-tool, to mark the outlines of the figures with more distinctness, and also to impart the effect of energetic action to the development of the muscles. The figures are very generally represented on a ground *semée* with flowers. In addition to those vases found in Etruria, which must be distinguished as Italo-Greek from their having been made by Greeks resident in Italy, many imitations of Greek vases of every kind were made by Etruscan potters throughout the period in which their own artistic powers were experiencing a continual decline. In these examples certain Greek attributes are rendered after an Etruscan manner, and the whole work is destitute of both originality and feeling. The subjects generally show traces of Etruscan influence, and often resemble the relieved friezes of the true Etruscan solid black ware. A paler ware was also manufactured at the same time, with unimportant subjects, and figures badly drawn and painted of a pallid tint, and with a glaze of a leaden hue. Other pale vases of still later date have been found in the sepulchres of Orbetello and Volaterra, with figures armed after the Roman fashion, painted of a light tone, the accessories being white, and the glaze devoid of lustre; and, in their turn, these last vases are succeeded by others, in which various figure subjects, with old Latin inscriptions, are painted in opaque white upon a black ground. Their date is about two hundred years before CHRIST.

The *inscriptions* which are associated with the subjects that appear upon Etruscan vases, like those on the Greek, are either painted in an opaque white or red upon the glaze, and are descriptive of the figures and incidents represented in the paintings, or they are incised; in the latter case the inscriptions generally refer to the proprietors of the vases. Many of these inscriptions are very difficult to read, from the rudeness of the Etruscan language in which they are written, and also in consequence of the obscurity of the legends themselves.

The same sepulchres that have supplied such abundant and diversified stores of the ceramic productions of the ancient Etruscans, have also preserved numerous examples of their exquisitely engraved gems, of their noble bronzes, and their beautiful and delicate gold filagree work. However admirable many of their vases may be, with their pottery the Etruscans never were so successful as with their works in metal. And the Etruscan artists evidently felt that they were able to

exercise a more complete mastery over metals than over clay, since it is found that in their best and most characteristic pottery they have assimilated their fictile productions to their bronzes. This assimilation ceased as soon as the ceramists of Greece had established themselves in Etruria. From that time the Etruscan potters conformed to the Greek system, and the finest ceramic works that thenceforth were produced in Etruria must be distinguished as Etrusco-Greek—they were the productions either of Greeks who had settled in Etruria, or of Etruscans who had been instructed and directed by Greeks. The grand distinction, then, between the two great classes of Etruscan sepulchral deposits is this, that the most admirable pottery is Etrusco-Greek, while the best metal-work is genuine Etruscan. Still, in the same deposits pottery is found in abundance, which is no less truly Etruscan than the works in metal, and which, at the same time, possesses many qualities that are eminently meritorious. In treating of the pottery of Greece, it will appear that the most precious relics of that wonderful art-manufacture have been discovered in far greater numbers in Italy than in Greece itself. In Etruria the Greek settlers produced in abundance a pottery that was thoroughly Greek, and their Etruscan contemporaries both imitated their productions and conformed to their style. A few lingering traces of the old native feeling and association may occasionally be discerned in vases, which appear to indicate that they were produced by Etruscans in Etrusco-Greek times, while the Greek style was in the ascendant, and yet before Etruscan usages and habits had been altogether superseded. It is remarkable that, in the prolific deposits which have been discovered wherever the cities and cemeteries of Etruria have been explored, vases have been found that were genuine Etruscan in the same group with others no less essentially Greek. At Corneto, the ancient Tarquinii, the discoveries have been rich in the most characteristic specimens of pure Etruscan vases, black and solid, with embossed figures. The same may be said of Sarteano and Perugia, and more particularly of Cervetri or Cære, and of Veii, now Isola Farnese, and of Vulci, or Ponte della Badia. At Veii and Vulci, with the embossed black ware, painted vases and others of every variety produced in Etruria have been found. The sepulchres at Vulci have also yielded immense quantities of plain solid black vases, and of others that are painted black only, which were found in immediate association with bronzes, ivories, gold filagrees, and other objects peculiarly Etruscan. And, with these evident relics of the native pottery of Etruria were discovered, in equally great numbers, vases of the Italo-Greeks in the utmost variety, and of the highest excellence. These vases were in all styles and of all epochs of art, including both those with maroon figures upon buff grounds, of the primitive archaic period, and the various productions of the latest decadence. The sepulchres themselves were most simple and unpretending; but their ceramic contents, which for the first time were systematically explored in 1829, have never been surpassed in value and interest. The finest known specimens of vases with black figures, including such as have the black figures represented upon white

grounds, have been found at Vulci. No less remarkable also for beauty of form, for excellence and energy of drawing, and for the vivid richness of their glaze and color, are the Vulcian vases with red figures. The numerous inscriptions, also, with which these vases abound, and the occurrence in them of subjects new to classical authorities, combine with their admirable artistic qualities to enhance their importance; so that these deposits may be considered to have effected more for the advancement of our knowledge, not merely of ancient pottery, but of ancient art also, than any previous discoveries. Very remarkable discoveries of Greek pottery have been made in many other parts of Etruria, but none that may be put into comparison with those that disclosed the long-hidden treasures of Vulci. Many of the finest and most characteristic specimens from almost every principal discovery in Etruria, have been added to the ceramic collections of the British Museum.

GREEK POTTERY.—Under this collective term it will be understood that the productions of Greek ceramic artists are alike comprehended, whether their works have been preserved and discovered within the limits of Greece, or either to the West or East of Greece Proper, in Italy and Asia Minor. Whatever the region that may have produced it, as the result of modern investigations, in all true Greek pottery the impress of the arts of Greece is equally apparent; and all the relics of those arts may, accordingly, with the most strict correctness, be grouped together.

The Greeks resembled other nations in their having established a pottery manufacture of their own for their own use, at the earliest dawn of their history, and, indeed, before their history had succeeded to the era of mythic legends. The earliest productions of the Greek potters also, like those of other countries, comprised works in the three varieties of sun-dried clay, kiln-baked terra-cotta, and a similar terra-cotta covered with a glaze, which last class of fictile productions has commonly, but erroneously, been designated porcelain. In addition to building materials, the ancient Greeks formed various objects in sun-dried clay, which they applied to the internal decoration of their temples and dwellings; and PAUSANIAS has recorded the existence in his time of a statue of PROMETHEUS in this material. As a matter of course, these fragile productions have long ceased to exist, and have left the practical elucidation of the pottery of the Greeks to those other works which, instead of representing the lineaments of PROMETHEUS himself, have acquired both strength and durability through the action of the Promethean element, fire.

The use of simple unglazed terra-cotta amongst the ancient Greeks was very extensive. It provided for the requirements of daily life, and it was equally ready to supply what might be demanded for more important purposes, whether in religious and votive matters, or in connection with incidents of public interest, or for every species of decoration. Terra-cotta, also, was in constant request with the Greeks in connection with their sepulchral and commemorative usages. Friezes and other architectural members of the Greek temples were, in some instances, executed in terra-cotta; but

the examples that remain in Greece are of a period after the establishment of the Roman dominion, and those of Southern Italy and Grecia Magna can scarcely be considered purely Greek. Statues, statuettes, and miscellaneous figures, with bas-reliefs, and other objects in more salient relief, were produced in the same material in great numbers. Terra-cotta was also employed by the sculptors and other artists of Greece for modelling their compositions, before they proceeded to execute them in more costly materials. Objects of various kinds in terra-cotta once existed in immense numbers at Athens, as may be inferred from a passage of Demosthenes. It appears that there were competitive exhibitions of these plastic works at Athens and the other cities of Greece on certain festive occasions, a circumstance that will account for the artistic excellence to which they commonly attained. Such works continued to be produced until a late period of the Roman empire; and yet, but few examples of fine Greek terra-cottas have been handed down. They were but sparingly used in the tombs, and, therefore, they have perished amidst the wreck of shrines and palaces; and with the homes of the Greeks who made and fashioned them, they have disappeared from the face of the earth. Neither have the terra-cotta moulds, that were certainly used for the casting of bronze statues, been discovered. Small figures, however, made by the same process by inferior artists, which once were used by the Greeks as ornaments or as household gods, and which closely resemble modern plaster casts, have been found in abundance near the sites of many of the cities of antiquity. The paste employed in producing their terra-cotta figures by the Greeks, is distinguished from that of the vases by its being softer and more porous. It yields easily to the touch of a steel instrument, and emits a dull sound when struck; nor does it attain to any great degree of hardness when submitted to a high temperature. Its color varies from a deep-red to pale-straw; and a similar degree of variety may be observed in the texture and density of objects from different localities. The terra-cotta of antiquity may be distinguished from modern works of the same class, by its greater lightness as well as by its softness.

The terra-cotta figures and architectural ornaments of the Greeks, were constantly painted by a body of artists who appear to have devoted themselves entirely to such occupations. They adopted both a conventional system of polychromatic adornment, and also such coloring as might be considered to have been based upon the natural and appropriated distribution and harmony of the different tints. Gilding was occasionally introduced, though, as it would seem, only with a sparing hand. The colors employed were apparently in most cases derived from coarse earths, of the same kind as those from which the ware itself was fabricated. Colors of metallic origin were more rarely introduced. Egypt supplied smalt for the cerulean blue; a Cyprian blue was also used, and subsequently indigo. Other colors were obtained from various parts of Greece, or from Greek colonies and dependencies. PLINY, as quoted by BIRCH, speaks of a painter upon terra-cotta in the words, *figlinum opus encausto pinxit*; but it has

not yet been ascertained whether any examples of encaustic painting upon Greek terra-cotta have been discovered.

Amongst the almost innumerable variety of objects that the ancient Greeks made in terra-cotta, were small cones or pyramids, about three and a half inches high, and perforated near the top. They were commonly inscribed, and they are supposed to have been attached to the necks of cattle. They are frequently found in the fields in Attica and other parts of Greece. Similar cones have also been found, which are perforated vertically. Some specimens, almost of a bell-shape, were discovered near Sebastopol and at Kertch. Small flat discs of pale-red or yellow terra-cotta, pierced with two holes, and ornamented on one side with a star in relief, and with the letters A and E on the other side, have been found in excavations at Tarsus. Others have been discovered in Lycia.

The Greeks habitually made from baked clay the lamps which provided light within their dwellings. They are found to have assumed a great variety of shapes, many of them exactly resembling those discovered at Rome, and others differing most essentially both from the prevailing Roman types and from one another. The distinguishing characteristics of the Greek lamps, are the superior fineness of their paste, and its paler hue after leaving the furnace, their smaller size and more delicate art, and, above all, their inscriptions. The Greek lamps of terra-cotta that have hitherto been discovered are all of the period of the Roman dominion, and consequently they may be grouped with corresponding works produced in other parts of the empire. In the neighborhood of ancient Greek cities they exist in great numbers. Several hundreds have been taken from excavations at Tarsus and at Calymna, and many other places have been almost as prolific in these interesting fictile relics of the Greeks.

GREEK VASES.—Fictile vessels of various shapes and sizes were employed by the Greeks, as they were by the Egyptians, for every conceivable purpose which it would be possible for them to accomplish. They performed the several duties which are, in this country, assigned to casks, boxes, cases of whatsoever kind, baskets, and such articles of furniture as are intended to contain and preserve different articles, as well as those offices which are considered to be peculiarly appropriate to pottery and porcelain. The vases of the Greeks accordingly admit of a ready classification, not only in their artistic capacity and their chronology, but also in reference to the uses which they were severally intended to fulfil. By far the greater number of these vases was decorated with painted figures and various devices, and their surfaces were covered with a glaze; but there were some varieties of vases which, in addition to the glazed examples of the same classes, were made in great quantities in simple unglazed terra-cotta. The most capacious of these terra-cotta vases, were tubs or casks called *pithoi*, and they were calculated to contain enormous quantities of wine, honey, corn, or other stores. They have the shape of either oblong or globular caldrons, with wide mouths. When full the *pithos* had its mouth closed with a large circular stone entitled *kithon*. Fragments only of *pithoi* have

hitherto been found in Greece itself; but Italy has yielded some complete specimens of gigantic dimensions. Others have been discovered in Asia Minor, and still more recently in the Crimea. They were constructed by a peculiar process, which may be described as plastering the clay upon a frame-work of wood. The *pithoi* are best known from the circumstance of Diogenes having established himself in one of them, as in a domicile well suited to the simple requirements of a philosopher, from which he stretched out his body on

the occasion of his celebrated interview with Alexander. This incident is represented in some works of ancient ceramic art—Fig. 434—one of them, a fragment of a lamp, being in the British Museum.

The terra-cotta vase that was in most general use, both for commercial and domestic purposes, was the *amphora*. It is either cylindrical in form or egg-shaped, and always has two handles. The cylindrical amphora—Fig. 435—has a tall neck, on either side of which the handles rise from the shoulders to the head of the vase. Its base is generally a solid cone, for the purpose of fixing it in an upright position upon the deeply sanded floor of the storehouse in which it would be deposited. Amphoræ of the form represented in Fig. 436, are much less common than those of the cylindrical figure. These vessels of the long shape are represented upon Athenian and other Greek coins. Upon the silver tetradrachmæ of Athens, they appear lying horizontally with an owl perched upon them, and they probably allude to the Attic export trade in oil, which was shipped in these vases. Throughout Greece itself, and

Fig. 434.



Fig. 435.

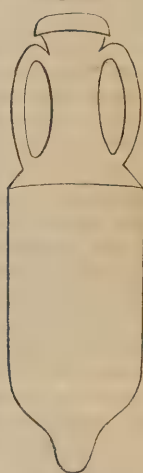


Fig. 436.

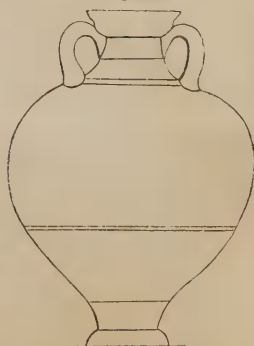


Fig. 437.



wherever Greek influence had ever extended, there the remains of amphoræ have been discovered. In many

instances the vessels themselves have been preserved ; but the more prevalent relics are the handles, which are constantly found in great abundance when all other parts of the vessels have disappeared. These handles are either slightly curved, as in Fig. 435, or they rise perpendicularly from the body of the vase, and are attached to its head by horizontal shoulders, after the manner of Fig. 437. The handles are solid, and vary in height from about ten to twelve inches, the amphoræ varying from three to four feet. A peculiar interest attaches itself to these amphora handles, in consequence of their being generally impressed with a stamped inscription contained within a circular medallion, or an oblong, oval, or lozenge-shaped cartouche. These inscriptions record the names of local magistrates and merchants, with that of some month ; and they sometimes are accompanied with a device typical of the place of their manufacture. Thus the Rhodian amphoræ are stamped with a head of Apollo surrounded with rays, or with a full-blown rose, which was the emblem of Rhodes so long as the island retained its independence, the Apollo Helios—the sun—being identical with the famous colossus. In many examples the medallion is found to have been stamped upon the body of the vase. The paste from which the amphoræ of Rhodes were formed, is singularly pure and tenacious. The color is pale externally, deepening within to a bright salmon hue. The clay of the Cnidian amphoræ is coarser than that of the Rhodian. In color it is darker and duller, and it breaks with a rugged instead of a sharp and clean fracture, displaying particles of a black micaceous sand. The composition of these vases exhibits other varieties in specimens fabricated in different localities, and the types apparent in the stamps comprehend various devices.

Greek vases in terra-cotta have been occasionally discovered, which were evidently designed for a diversity of uses. There is a vase of a pale clay in the British Museum that is covered with a coating of lime, and when found contained human bones ; this is evidently a sepulchral vase. Several other vases, also

Fig. 438.



apparently sepulchral, have been discovered in Italy. Others again, from their forms and the style of their decorations, may be presumed to have been made for ornamental purposes. The most remarkable are those that have been modelled in the forms of the heads of BACCHANTES and other figures. This last class of

terra-cotta vases comprehends many curious specimens of the *rhyton*, a drinking goblet, modelled in the shape of animals' heads, Fig. 438, or having long reeded bodies, with *œnochoæ* or jugs and other vessels ornamented with figures in high relief. Many of these objects have evidently been adapted, from works in metal, to the plastic materials that have survived the destruction of their metallic models. The tombs of Italy, and sometimes those of Greece, have been found to contain vases of simple terra-cotta, that had been substituted for the glazed ware more generally employed in the sepulchral rites then prevalent in those countries. Such vessels exhibit a great diversity, both in their sizes and forms and in their decorations. Color was freely introduced as a means for executing the decorations of terra-cotta vases of every class ; modelling in relief, however, must be regarded as the system of ornamentation more generally prevalent.

GREEK GLAZED VASES in their general characteristics resemble those fabricated in unglazed terra-cotta, their own distinctive qualities consisting in their peculiar excellence as works of ceramic art, together with the glaze that is suffused over their surfaces. The paste or body of which these vases are composed is remarkably fine and light, tender in its texture and very porous, deeper in tone than the ordinary terra-cotta, and giving forth a metallic sound when struck. In different vases, however, which possess in the same degree all the other characteristic qualities of their class, the texture varies considerably, being sometimes so hard as scarcely to admit of being cut with a knife, while in other cases it is sufficiently soft to receive impressions from a finger-nail. Natural clays, selected from their fitness for the purposes required to be fulfilled by them, appear to have been almost exclusively used by the Greek potters ; and, indeed, it is doubtful whether they ever introduced any foreign substances into their clays. As a matter of course they may have mixed together clays which, as their experience had taught them, were distinguished by contrary qualities, both before they were placed in the furnace and while exposed to the action of the fire ; and thus pastes may have been obtained which were either more or less *fat* or *dry*, and might prove more readily fusible, or might be more refractory in resisting the influence of a high temperature. For the vases of the red ware it has been supposed that the paste received an admixture of oxide of iron ; and certainly, in some of these specimens, the paste has been found to contain this metallic oxide somewhat largely. At the same time, it is most true that many clays are naturally impregnated with that substance. In the Greek vases of Campania the pastes have been proved to contain a considerable proportion of the oxide of iron, as is apparent from the following mean of eight analyses of this pottery, made by M. SALVETAT at Sévres :—

	Centesimally.
Silica,	55.88
Alumina,	18.88
Oxide of iron,	15.8
Lime,	7.48
Magnesia,	1.63
Loss,	0.33
	100.00

BRONGNIART gives the following as the mean result of his analyses of the paste of Italo-Greek vases:—

Silica,	55.49
Alumina,	19.21
Oxide of iron,	16.55
Carbonate of lime,	7.48
Magnesia,	1.76

The comparative results of several other analyses of this paste, show the wide range of the proportions assumed by the component elements in vases from different localities. In these analyses the silica varies from 55 to 32; the alumina from 24 to 15; the lime from 10 to 7; and the oxide of iron from 24 to 12.

The ordinary paste of Greek vases in other localities has a natural character, and is comparatively free from the presence of the metallic oxide.

In the paler pastes the proportion of the lime is increased. The ware has been found to fuse at 40° Wedgwood, and it certainly was exposed by the Greeks only to a low temperature. It is remarkably porous, allowing water to exude. Its extreme lightness was considered by the ancients one of its most important qualities. Certain sites in ancient times enjoyed a high reputation for their plastic clays. The excellent materials for their pottery, however, were found by the Greeks to have been distributed by nature through every region in which their artists practised their vocation.

The colors used by the artists who painted the glazed vases of the Greeks, were chiefly black, white, brown, yellow, and red; the last three being variously modified in their tone. These hues were protected, at the same time that their brilliancy was enhanced, by a fine thin glaze, which is both lustrous and transparent. The white and other hues used upon these vases are not enamels, but opaque clays, or *engobes*, painted, after sketches of the designs had been executed, upon the clay. In many specimens, from which the coloring has peeled off, the sketches exhibit an admirable freedom of hand, and the most spirited treatment. The glaze was spread over the entire external surface of the vases, except the under part of their bases, and then the vases were baked; and afterwards the painting was completed. The additional colors that were laid on after the firing, were also subjected to the action of the furnace, but at a comparatively low temperature. The white paint has been considered to have been a white alumina or pipe-clay, or a carbonate of lime; or a mixture of carbonate of lime and oxide of iron. The same oxide has been detected in the rich crimson of the oldest vases, and iron in another proportion in the lighter red. The yellow is an ochre. BRONGNIART, contrary to an opinion accepted by many persons, denies the presence of manganese in the black paint used by the Greek vase-painters, and attributes that important color to a metallic oxide. Various other theories exist with reference to the true nature of this black, which assumes different hues under different conditions. On the vases of Vulci, for example, it has a greenish hue. It often approaches a deep grey on the Campanian vases, while on those of Nola and Cære its blackness is rich and glossy, like that of polished jet.

The Greek glaze differs essentially from the lead and

tin enamels of Assyria, and the copper enamel of Egypt, since it is an alkaline silicate, containing a certain portion of oxide of iron. The black glaze employed in the Greek vases, especially those found in Campania, has been supposed to be, in great part, due to volcanic ashes spread by the brush over the parts required, the vase being then exposed to the heat necessary for their fusion. The analysis of this Campanian glaze, according to SALVETAT, produces the following results:—

Silica,	46.30
Alumina,	11.90
Lime,	5.70
Soda,	17.10
Oxide of iron,	16.10
Loss,	2.90
	100.00

Except in the quantity of soda, this compound differs but little from some volcanic ashes. In other analyses of the black glaze, the results have given—

Silica,	63.00	or	55.49	and	55.88
Alumina,	20.00	"	19.21	"	18.88
Oxide of iron,	4.00	"	16.55	"	15.80
Carbonate of lime,	9.00	"	7.48	"	7.48
Magnesia,	2.00	"	1.27	"	1.63
Water,	2.00	"	—	"	—
Loss,	—	"	—	"	73
	100.00		100.00		100.00

In executing the subjects painted upon vases, the early practice, as exemplified in vases about seven hundred years before Christ, was to sketch the figures and patterns in red upon a reddish body, and then to color the composition with a black glaze, after which the vases were fired. Engobes of white and red were added in parts, and portions of the figures were picked out by incising through the glaze with a pointed instrument. Somewhat later the design was sketched in black instead of red. In other early examples the ground of the vases is of an ash-color, and the designs were executed in black, white, and red, with incised lines. In these vases the grounds were very commonly represented as being *semée* with flowers. To this class of vases there succeed those with black figures laid upon light grounds. They have the inner lines of the figures cut down to the ground of the vases with the graving-tool, and their accessories have been picked out in crimson or maroon color, and white. About four hundred years before Christ the vases attained to their highest degree of artistic perfection, when the figures and other objects appeared in red upon grounds covered with the black glaze, which had followed the contours of the several objects. In these vases, in place of the earlier incised lines, the inner lines were executed in black with the brush—a technical change which greatly facilitated the free and effective action of the artist. The subjects represented upon the vases of this period are such as may have been suggested by the contemporary works of the great painters, and by those also of the favorite authors of the day. They for the most part represent mythic scenes, genuine historical subjects unfortunately being rare. The sepulchral *lecythi* of the same period, and the *alabastra* or unguent vessels, were formed of a fine white clay covered with a white pigment, on which designs have been traced in black,

red, and brown. The progressive decline of Greek art after the time of ALEXANDER the Great, is very clearly indicated by examples of vases still in existence, and which are to be referred to that period of decadence. In their shapes the vases gradually became less and less elegant. The subjects introduced upon them lost their noble simplicity, and became confused and exaggerated. Modelling in relief was intermixed with the painted compositions. The figures that still were painted became indistinct in their outlines, and were often crowded with details carelessly designed, and accompanied with the most unsatisfactory efforts to accomplish perspective and the effect of distance. The designs in these later vases, whatever they may be, were drawn in red upon a black ground, the inner markings of the figures having been less carefully indicated than was invariably the case in earlier examples. Patches also of white and red have been introduced into the accessories, which effectually destroy the monochrome simplicity of the earlier paintings.

The true glory of the vases of the Greeks consists in the gracefulness and beauty of their shapes. It is in their application of form in art that the Greeks may justly claim to have excelled all other nations. Whatever the particular aim of the Greek potter, the plastic material under his command assumed a chaste simplicity or a dignified nobleness of form. Greek vases, accordingly, are to be studied not merely in consequence of their archaeological and artistic interest, but also as examples of the most masterly treatment of the ceramic art. In many instances, peculiarly adapted to the requirements of Greeks who lived in ancient Greece, these vases may have ceased to fulfil the requirements of an existing generation. While, therefore, the modern potter judiciously declines to produce mere servile imitations of even the noblest Grecian models, he finds in the humblest as well as the most important vases of the Greeks, subjects for careful and thoughtful study; and he learns from them by what means he may improve the practical application of his own art, without sacrificing its originality or perverting its usefulness. And when they proceeded to apply painting to their beautifully formed vases, the Greeks did more than increase their commercial value, and improve their appearance as objects of daily use. The vases thus were empowered to transmit to distant ages the traditions of the Greek schools of art; and they became an inexhaustible source for illustrating the mythology, the manners, customs, and literature of Greece.

At first sight it might be supposed that all the Greek vases hitherto discovered, however great their variety, and however large their numbers, were either directly or indirectly designed for the express purpose of taking a part in the sepulchral and monumental ceremonials

of the Greeks. Such an opinion might have been deduced from the circumstance that every known example has been obtained from some Greek sepulchre. But upon more mature reflection, in the great majority of instances these vases appear to have been used in many ways by the living, before they were consigned to the still more secure guardianship of the dead. It has been proved that vases that had been won as prizes in the public games, were afterwards placed in the victors' tombs. In scenes painted upon other vases obtained from sepulchral deposits, various kinds of vases are represented in use; and the very forms and adornments of many varieties can scarcely fail to be accepted as conclusively demonstrative of the purposes to which they had been applied, previous to their final consignment to the sepulchres.

At a very early period of Greek history, fictile vases were not employed to receive and preserve the ashes of the dead. The Etruscans, as is proved by their cemeteries, buried their dead; the bodies being laid upon couches in the sepulchral chambers, with their personal ornaments, their arms, furniture, and vases. After the heroic age, when cremation was generally prevalent amongst the Greeks, vases began to be used as receptacles of the ashes; but they also continued to be placed in the sepulchres for votive purposes, and as either memorials of the past or in imaginary association with the future. Amongst the Romans the custom prevailed of employing fictile vases in their religious rites, including such as were connected with the inter-

Fig. 439.

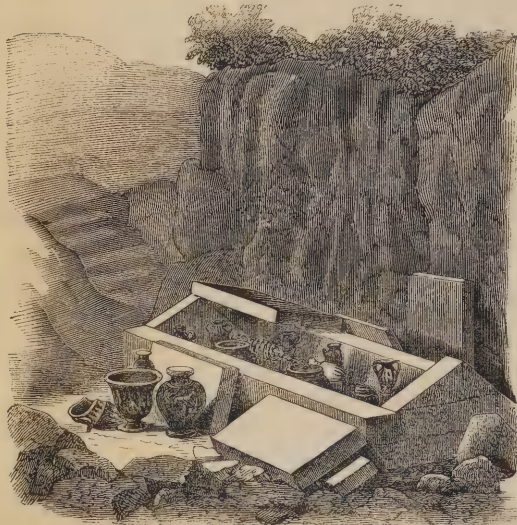


ment of the ashes or remains of their dead. For such purposes the finest vases of the Greeks were conveyed to Rome, where, after the libations had been duly performed, the vases themselves were broken, and the fragments—like the broken sword-blades in the Celtic barrows—deposited in the corners of the sepulchres.

The character of the sepulchres in which the vases have been found varies considerably in different localities of Greece, Italy, and Asia Minor. Thus, the places of interment in Greece itself are graves small in size, and sunk to the depth of several feet below the surface; while in Italy, sepulchral chambers and stone-built

tombs predominate. The chambers from which the largest and finest vases have been obtained, are excavations in the rocks, such as the Etruscan tomb at Veii, represented in Fig. 439. Others of the early tombs of Italy were tunnelled in the earth. In Southern Italy, and particularly in Campania, they are large chambers beneath the surface; or smaller tombs, formed of slabs of stone, somewhat after the manner of mediæval stone-coffins, contained both the remains of the dead, and the vases that were deposited with them. Fig. 440 represents a tomb of this description, which

Fig. 440.



has been partially uncovered. In both examples the ordinary arrangement of the vases is clearly shown. The later resting-places of the Roman soldiery and of the poorer classes of Roman citizens, made of tiles, were of the same shape. Other tombs of larger dimensions are also found, sometimes carefully constructed of hewn stones, while others are formed of rough and massive stonework. The human remains and the vases are very commonly accompanied with weapons, ornaments, and other relics, of bronze, iron, and the precious metals. It is by no means uncommon to discover a large number of vases in a single tomb; thus Sir WILLIAM HAMILTON has recorded having seen a sepulchre in the archiepiscopal garden at Polignano, in which the archbishop had himself found more than sixty vases, including several of the largest size and the utmost beauty. When discovered, the vases are found to be arranged about the human remains, piled up in corners, and hung around the inside of the tomb upon hooks, or nails, of bronze or iron. Very many have received some degree of injury; others are in a complete state of preservation. Some few still retain the rivets with which, having been broken, they had been mended in ancient times. The oldest express mention of these vases in Greek authors is made by the poet PINDAR, who flourished five hundred and twenty-five years before CHRIST. Those deposited in the Athenian graves are distinctly alluded to by ARISTOPHANES. Painted vases are mentioned

by ATHENÆUS, SUETONIUS, STRABO, and the later scholiast of THEOCRITUS. To determine the age of the oldest existing specimens with anything approaching to exact accuracy, is not possible. Some seem to be coeval with the first dawn of Hellenic civilization, and many have been made at the same period with the earliest fictile works of the Etruscans. Between Olympiads eighty-four and ninety—before CHRIST four hundred and forty-four and four hundred and four—glazed vases of great excellence were produced. During the succeeding half century, the art attained its highest perfection. The close of another fifty years brought with it unquestionable evidences of an incipient decadence. ALEXANDER the Great introduced into Greece vases made of the precious metals, after which the finest varieties of fictile vases fell into disuse. Before the middle of the third century before CHRIST, PLUTARCH has represented metal vases to have been in common use at Sparta; and, consequently, it may be inferred that pottery of every kind was becoming comparatively rare. During the first century before CHRIST, vases of earthenware were entirely superseded by works in metal; and in the time of AUGUSTUS they were regarded both as rarities and as objects of antiquarian curiosity. The best and most accurate chronological classification of Greek vases appears to be as follows:—

Period I.—Archaic Greek vases, four hundred and fifty years before CHRIST.

Period II.—Fine Greek vases, from four hundred and fifty to four hundred years before CHRIST.

Period III.—Finest Greek vases, from four hundred to three hundred and seventy-five years before CHRIST.

Period IV.—Greek vases of the decadence, from three hundred and seventy-five to two hundred and twenty-five years before CHRIST.

Period V.—Debased Greek vases, after two hundred and twenty years before CHRIST.

A second classification, which has reference to the uses of the vases and their nomenclature, must be determined by their sizes and shapes, and in some degree also by their artistic character. Amongst the most important, and also the most characteristic of the varieties which may be considered to have been satisfactorily identified, the *amphora* is the best known. In their general character, the painted and glazed amphoræ resemble those in terra-cotta—Fig. 435—but at the same time they admit several important modifications of the prevalent type. The painted amphoræ generally were provided with flat circular feet, as in the example represented in Fig. 436. The forms and arrangement of these feet vary in different specimens; and other variations of design and treatment are apparent in the forms and decorations of the handles, and in the contour and proportions of the vases themselves. The style and execution of their decorative accessories necessarily depend upon the period to which they may be assigned. The amphoræ include in their numbers the most admired and the most admirable of the vases of the Greeks.

The *pithos* is a jar, with a wide open mouth, of large size.

The *stamnos*, a jar used to contain wine and oil, has two small handles, and still retains its name in Greece.

Amongst other uses, the *hyrche*, a large species of amphora, served to hold the tickets on occasions when lots were drawn at Athens. The *lagynos* is smaller, and has a long narrow neck. It was used at table by the Greeks, and is the vessel which the stork is represented in the fable to have set before the fox at dinner. The title *ascos* is applicable to several vases, which are more or less direct imitations of the *ascoi*, or wine-skins, commonly used in Greece.

The *cadus* appears to be a globular vessel for containing fluids.

Fig. 441.

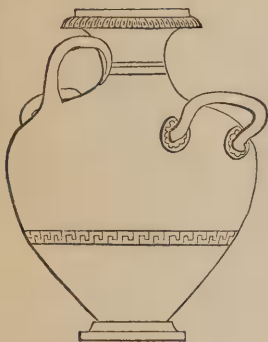
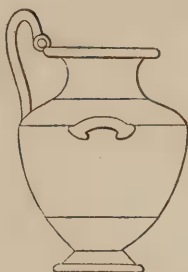


Fig. 442.

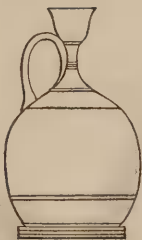


The *calpis*—Fig. 441—a water-vase, used also for unguents, and sometimes made to contain the lots of the judges, is principally found in the sepulchres of Southern Italy. It has three handles, like the *hydria*

Fig. 443.



Fig. 444.



—Fig. 442—which predominates at Vulci and other more Northern districts. The *hydria* is the older type, and it has been identified from the circumstance of the word HYΔΡΙΑ being inscribed over a vase of this shape in a vase-painting, representing *POLYXENA* going out from Troy to draw water from the fountain. In other painted scenes, *hydriæ* are represented on the heads of females who have been drawing water. These vases are generally black, and are ornamented with a frieze above the principal painting.

The *crossos*, a two-handled vase, was used in water-drawing.

The distinctive peculiarity of the *rhyton*—Fig. 438—consists in its form being such, that it could not be set down except when empty. It was made in the highest perfection in the time of *PTOLEMY PHILADELPHUS*, about three hundred years before *CHRIST*.

The *lecythus*—Fig. 443—or oil-cruet, found chiefly

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in Greece and in Southern Italy, commences with the early vases having black figures, and terminates with the

Fig. 445.



best vases with red figures and white grounds. Another well-known vase, of a jug-like shape, and having a spout and a single handle, is the *œnochoë*, which appears in the frieze of the Parthenon; the *olpe* is supposed to be a variety of this vase. Other varieties of it are the *prochoos*, the *aryballos*—Fig. 444—the *arystichos*, the *aryter*, and the *cotylos*. The *aryballos* is represented by Fig. 444, and the *cyathos* by Fig. 445.

The *crater*, a large open bowl with two handles, used as a wine-cooler, and found in Southern Italy, has various modifications, severally distinguished as the *holmos*, *oxybaphon*, *psycyter*, and *celebe*. A stand, having a hollow reeded foot, upon which the crater was commonly placed, was called the *hypocraterion*. Various other vases of bowl-like forms, and adapted to a diversity of uses, are severally distinguished as the *clytra*, the *thermanter*, the *holcion*, and others.

Many vases, in addition to the *rhyton*, were made expressly to serve as drinking cups or *scyphi*. Of these *HOMER* mentions several varieties of unknown forms. The most celebrated vase of this class is the Tazza-shaped *cylix*—Fig. 446—which takes rank amongst the most beautifully formed of the Greek fictile works. The *cantharos* and the *carchesion*, also, were popular drinking vases, and the *phiale*, a flat and saucer-shaped vase, was almost exclusively used in religious ceremonials. In addition to those already specified, a numerous series of other names for their different vases has been transmitted to modern times in the literature of the Greeks.

The potters of Greece, like their predecessors in Egypt, used the wheel, which is mentioned in *HOMER*. The processes of modelling and moulding were also in constant use by them. To one or other of these two processes the Greek potter would have recourse at every period of his art, in order to enable him to produce the handles and certain other parts of his vases, together with such of their constructive and decorative accessories as he might desire to execute in relief. The invention of moulding, when once introduced, appears to have become generally prevalent, and to have been employed for the production of many of the smaller plastic works, in addition to the details and accessories of vases. When completed on the wheel, and after the modelled or moulded additions had been

5 E

incorporated with the bodies of the vases, the ware was partially dried, either in the sun or in a furnace, at a low temperature, and then the painting took place. When the glaze had been laid on as well as the paint, the vases were placed in the furnace and carefully

baked. The furnaces themselves are often represented in gems, and upon the vases which they produced. They appear to have been of a very simple character, closely resembling the tall ovens of the Egyptians—Fig. 430.

Fig. 446.



Amongst the Greeks themselves the vases of Athens were those which enjoyed the highest reputation. They have been found in great numbers in Athenian sepulchres, and many of the existing specimens are unquestionably

works of the very highest excellence. Some of the most admirably executed of the Athenian vases—Fig. 447—are without any decorative figures or patterns, but are simply painted black, and they rely for their

Fig. 447.



effect upon their beauty of form and the careful delicacy of their finish. Other examples exhibit a diversity of enrichments produced by the painter's art. Of these the Athenian lecythus, with a representation of ELECTRA and her attendants meeting ORESTES at the tomb of AGAMEMNON, is a characteristic specimen—Fig. 448.

The figures which are represented upon this vase will not fail to excite attention.

The neighboring isles both imported their vases from Athens, and produced other ceramic works of the same class themselves. In the other parts of the mainland of Greece vases are frequently found. Next to

Athens, Corinth has been the most productive; but, notwithstanding the ancient celebrity of the vases

Fig. 448.



made in many of the Greek cities, a small number only of relics have been discovered on their sites. At Athens there were two pottery-quarters of the city, or *ceramici*—one within, and the other without the walls. Of the isles of Greece, Samos from the oldest times was the most renowned for its fictile wares. Samian pottery was always distinguished for its hardness, and for the fineness and the brilliancy of the red color of its paste. It maintained its reputation until the days of the Roman empire, when the island supplied services of its pottery to the imperial city. Melos and Ægina were also famous for the productions of their kilns. Passing eastward, the inquirer discovers remains of ancient pottery which convince him that, throughout the Greek settlements of the Lesser Asia,

the ceramic art had flourished from the days of the earliest civilization. Such inferences are in exact accordance with the historical records preserved in the writings of antiquity. Thus PLINY has specified the qualities of extreme thinness and lightness as being characteristic of the vases of Erythræ in Ionia; and he adds that two amphoræ, peculiarly remarkable for those much esteemed qualities, the rival productions of a distinguished Erythræan potter and one of his pupils, were consecrated in a temple of that city; and the same writer has specially recorded the celebrity enjoyed in his times by the potteries of Tralles and Pergamos. These statements are corroborated by other ancient authors.

Whatever success may have attended the operations of the Greek potters in the various provinces of the Lesser Asia, they sink into insignificance when brought into comparison with the remains of Greek ceramic works that have been brought to light in Italy. On Italian soil, in ancient times, the ceramic art found a congenial home; and the Greeks who settled there worked in happy harmony with the Etruscan occupants of the country. The finest vases of pure Greek design and workmanship, and by far the greatest number of Greek vases of every class, have been discovered in Italy. Throughout Etruria, vases that are decidedly Greek in their characteristics of style and treatment, are continually discovered in close association with others in which Etruscan types are prevalent. It is highly probable that not a few of the Italo-Greek vases were imported into Italy from the potteries either of Athens or of some of the Greek isles; but at the same time it may be considered to be beyond all question certain that vast quantities of this beautiful ware were produced in Italy itself, by the Greeks who had settled

and become established there. The same general system of coloring is observed to have prevailed in all the vases of Italy, whether they are to be considered of Greek or of Etruscan origin: thus, the figures in the early Greco-Italian vases are black; but during the best period of Greek art, from the epoch of PHEIDIAS and POLYGNOTUS, before CHRIST four hundred and sixty, to before CHRIST four hundred, the figures are red upon a black ground. A curious and also an eminently characteristic example of the vases of the best Greek period is the *hydria* in the British Museum, Fig. 449, upon which is represented the device adopted by

Fig. 449.



MEDEA to induce the daughters of PELEUS to put to death their aged father. The ram, which had been restored to youth by the enchantress, is in the act of leaping from the *olla* or cauldron; he faces MEDEA. JASON is on the opposite side, and the other figures of the composition are behind these two principal actors in the scene. The design is painted in red on a black ground; the outlines are drawn in black, and the minor workings are faintly traced in red, with accessories in white and crimson. Another fine *hydria* of the same style and period, in which horses and bigæ are introduced with figures, is represented in Fig. 450. It was found at Vulci, and is preserved in the Museum of Practical Geology. In height it measures twenty-two inches.

In every district of Central and Southern Italy the active influence of Greek art is indicated by the presence of fictile remains, frequently of great excellence and in large numbers. The character of the vases, however, differs very considerably in different localities, and with rare exceptions they indicate some degree of artistic decadence. Here, as farther north, the productions of Greek settlers or works imported from Greece may be considered to be intermixed with relics in which local influences are more distinctly evident. The vases also, in almost every instance, are to be assigned to some period not earlier than the fourth

century before our era, many of them being about two centuries later. It is remarkable that after the arms of Rome had conquered Southern Italy, about the second century before CHRIST, the Græco-Italian settlements relapsed into utter barbarism. A progressive

decadence in art may be observed in the vases, as they approach more nearly to that era. Their forms are less graceful, the subjects show a painful deterioration in moral feeling, and the execution of the whole is comparatively coarse and degenerate. The Capuan vases

FIG. 450.



are among the most interesting relics that Campania has yielded to modern research. Those found at Nola are equally remarkable, and they comprise examples of all the principal classes, with a few local types. Their distinguishing characteristics are their smaller size, their peculiar elegance of form, and the exquisite beauty of their glaze, which is frequently an intense black. The figure subjects that adorn these vases comprehend many well-known mythic scenes and personages, together with incidents from private life or local history, which it is difficult, if not impossible, to explain. In the execution of these subjects, the figures are generally left in red, by painting with a rich and lustrous black glaze upon a red body or ground. The details of the figures are also sketched in with the same black glaze, and a little white is occasionally introduced. Figs. 451 and 452 show the forms and painted decorations of two beautiful Campanian vases that are in the Museum of Geology. Fig. 452 was found at Nola. Fig. 453, from the same collection, is a no less excellent example of a Campanian ribbed vase, of about two hundred years before CHRIST. It was turned on the lathe; the body is red and the glaze black. The ornament on the neck is in engobe over the glaze, and in part incised through the glaze. Among the shapes particularly local at Nola is a species of *œnochoë*, modelled in the form of a

head generally, but not always, that of a female. Vases of Nolan fabric are found distributed through-

FIG. 451.



out Campania. The vases of Pæstum have pale red figures on a black ground, with a dull varnish. They

are of a late period, but singularly good as examples of the age to which they belong. Still further South, the region now called the *Basilicata* has pro-

Fig. 452.



duced an abundant store of vases, which illustrate in a significant manner the decadence of Greek art. Here

Fig. 453.



and there specimens are found of such rich and superior character, that they are undoubtedly importations from Greece itself, and several styles or gradations of style may be observed in the genuine Basilican vases; but the prevailing characteristics of these vases, in addition to the general inferiority of their shapes, are clumsy forms and indistinct representations of figures, crowded with details, and accompanied with most unsatisfactory attempts to render objects in perspective. In these vases the design is drawn in red on a black ground, in the same manner with the examples of a purer period; but the drawing is bad, and the inner markings of the figures are carelessly indicated, and white and red

patches are freely introduced into the accessories; the glaze also has a leaden hue. The subjects are generally Dionysiac and Erotic scenes, and they commonly are treated in a manner altogether inconsistent with that simplicity and dignity which are distinctive characteristics of the highest class of ceramic paintings. The vases found at Ruvo comprehend the finest works of their class that have been discovered in the Basilicata. The Museum of Geology supplies a characteristic specimen of a vase of Ruvo—Fig. 454. It is of an early period, about three hundred and fifty-seven years before CHRIST, and the execution is the same with

that employed in the production of the Campanian vases—Figs. 451 and 452. It is a singular circumstance that in Southern Italy the vases that are

Fig. 454.



discovered are far more frequently found broken into fragments, than in a condition that is even comparatively perfect. The ceramic works produced in Sicily, either by Greek settlers or under Greek influence, differ in no material points from the corresponding remains that are found in Italy; and the Greek vases that have at different times been brought to light along the African coast, with those more recently discovered in the Crimea, appear to have been importations from Athens, or from some other potteries of Greece.

ROMAN POTTERY.—Terra-cotta was used by the Romans from the earliest times of the republic, and also during the era of the kings, for the production of architectural details, accessories, and decorations, as well as for works of statuary. Capitals and bases of columns, corbels, the crests of cornices, the frames of windows and doors, spouts, bas-reliefs for friezes, and almost every variety of object that was employed in Roman architecture, were constantly executed in this material. The most ancient statues of the Romans, with the bas-reliefs and figure-decorations of their temples and other public edifices, were of terra-cotta; and they continued to be thus produced through the agency of the potter, until the extension of the Roman power into Greece disclosed to the conquerors other and still nobler means by which such works could be called into existence. It is worthy of special notice, however, that the introduction both of Greek sculpture, and of sculptors from Greece into Rome, did not supersede the demand for works of great importance executed in terra-cotta. Terra-cotta was also used by sculptors in marble and bronze for their models. A vast number of figures of diminutive size is found throughout the republic to have been made of the same material, and they extend until the middle period of the empire; they comprehend figures of every imaginable class, which were apparently used at the festival of the Sigillaria, or sometimes for other purposes. Having stated that it would be im-

possible to enumerate all the purposes to which the Romans applied terra-cotta, BIRCH observes that some of these are too remarkable to be passed over without special notice; and he proceeds to specify bee-hives, or amphoræ used for hiving bees, that were made by the Romans in terra-cotta, with cones that were heated and placed before other bee-hives in order to burn the butterflies and other insects which attacked the bees; money-boxes also; tesserae, or tickets of admission to the games; moulds from which spurious coins could be forged; toys of every kind; small altars for the sacrifices offered to the Lares; and cages in which dormice were fattened, in order to prepare them for the palates of Roman epicures.

Roman Terra-cotta Vases.—Like the Greeks, and also like the Egyptians before them, the Romans employed vessels of fictile manufacture for every possible purpose connected with their commerce, and with the ordinary requirements of daily life. Vases of terra-cotta were made by them in every variety of shape and size. Specimens of enormous dimensions and capacity were fabricated at all periods, and they were employed as well for storing up figs, honey, corn, oil, wine, and other commodities, as for their transport from place to place. The largest store or transport vases were called *dolia*, and sometimes *cadi*. Amphoræ, having bodies generally more globular than those of Greece, were in constant use for a variety of purposes amongst the Romans; and, like many other Roman fictile productions, they almost always have the name of the maker stamped upon them. The paste of these useful and much-used vessels is coarser than that employed by the Greeks; and it has been observed that until a late period vessels made of the same paste with the amphoræ were used for sepulchral purposes, sometimes as sarcophagi or urns for the reception of the ashes of the dead, and, in some instances, as cases in which more precious vases might be preserved. The vases used for sacrificial purposes, in like manner, were principally of terra-cotta; and so also were the cups and other vessels which, in the case of many classes of the Romans, sufficed for the purposes of the table. The names given by the Romans to their various vases are commonly of Greek origin. Some are Latin, and speak for themselves, and others, and these are not a few, are obscure as well in their distinctive signification as in their origin. As their general characteristic, the Roman potteries must be considered to have produced useful vases, and such as were well adapted to the requirements of life, but which can by no means be regarded as beautiful or fine, and therefore worthy of taking rank amongst works of art. The paste, except in the case of the coral red ware, is much coarser than that employed by the Greeks; but the processes of manufacture were the same, comprising the wheel and all the modifications of modelling, moulding, and stamping. The vessels of very large size, from the necessity of the case, were built upon framework. BROGNIART has classified the terra-cotta pottery of the Romans in the following four groups, distinguished by the color of the vessels:—1, Pale yellow paste, comprising the casks, jars, and amphoræ; 2, Dull red and reddish-brown,

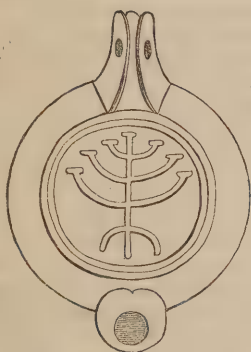
including the pottery of the first century; 3, Grey or ash-colored, which comprehends all Roman pottery of a date later than the first century; and 4, Black, under which division are grouped the Gallo-Roman wares, and those of the provincial potteries. This appears to be the most satisfactory of the many systems that have been proposed for the classification of Roman pottery. In adopting it it will be necessary to observe, that the wares of the different classes are now commonly found together, and they consequently were employed simultaneously by the Romans themselves.

Besides the larger vessels of the yellow ware, there are some subdivisions of this class in which the paste is fine in quality, and of either a rosy or a very white hue, and sometimes intermixed with grains of quartz. The vases formed of this paste are small, and of a superior order as ceramic works. The largest and most comprehensive class of Roman pottery is the second, which comprises nearly all the vessels used for domestic purposes. This red ware varies in color from a pale salmon hue to a deep coral, and in quality from a coarse and gritty compound to a fine compact paste. Grains of quartz and mica are occasionally found intermingled with this paste. This ware is generally red externally, and without glaze; but not unfrequently it is covered with an engobe of white pipe-clay, or more rarely with a black coating, susceptible of a good polish from friction. A subdivision of this ware, which has been distinguished as *false Samian*, has the red paste covered with a thin coating of still brighter red, formed from sulphate of iron. The greater number of the vessels that were made of the Roman grey ware were such as would be used in cooking, and consequently would be exposed to the heat of the fire. There is a distinct class of productions of this color, which closely resembles the modern stoneware of Staffordshire; it is heavy and sonorous when struck. The black ware, which was chiefly used for the requirements of the table, is distinguished by the fineness of its paste, and the skill with which the vessels were made; its ornamentation is rude both in style and in execution.

Roman Terra-cotta Lamps, which are found in considerable numbers throughout the regions that once were comprehended within the wide range of the Roman empire, form one of the most interesting products of the Roman potter's art. The greater number are of a red ware; but many are of a pale yellow or white hue, while others are black. The paste also varies considerably in quality, though it very rarely is as fine as that used in the production of their lamps by the Greeks. In form, these lamps are either circular, with a projecting nozzle and a handle, or elliptical or shoe-shaped. Some were placed on stands, others were designed to be suspended, and others again were not intended to require any external appendages. Many specimens have more than one nozzle, and examples are occasionally found in which various capricious shapes have been substituted for those which conform to the established types. Lamps are first mentioned by the Athenian PHERECRATES, who was contemporary with ALEXANDER the Great; but all those lamps that have been discovered in modern times were

evidently made during the imperial age of Rome. They were manufactured from moulds, and variously ornamented with groups of figures, devices, and patterns. Had the Romans of the empire been gifted with a historical taste, their lamps would have contributed in no slight degree to the illustration, both of their personal memoirs and of their national history; but the lampmakers of those times knew well the frivolous character of the purchasers for whom they worked, and therefore they were content to decorate their productions with figures of popular divinities, demi-gods, and heroes, and with representations of incidents, fables, and ornaments such as would be sure to be in harmony

Fig. 455



with the prevailing sentiments of the day. Among the most remarkable examples that have come down to us, are several lamps bearing the devices and monograms adopted by the early Christians, with which may be included one—Fig. 455—upon which is stamped in relief the golden candlestick of Israel, as it appears upon the arch of TITUS. After the Roman manner, in addition to their decorations, these lamps are generally inscribed with the names of the potters and potteries, or with the places where they were made, or with the

Fig. 456.



title of the class or style of the lamps themselves; while other inscriptions refer to the period of their production, or are of a votive character, or they are stamped with the word SAECVL, or SAECVLARIA—as Fig. 456—in reference to the games of the period.

Roman Red Lustrous Pottery.—This peculiar class of fictile productions, commonly known as *Samian* or *Aretine* ware from the celebrated potteries of Samos and Aretium, now Arezzo, in Tuscany, appears to have been in universal use wherever the Roman arms and the Roman name were known in the ancient world, numerous remains of it having been discovered in every

region in which the Roman people had settled after their conquests. The period of its manufacture is considered to extend from the first to the third century of this era; and it would appear to have been produced in large quantities, as well in Roman Gaul and Germany, as in Italy and at Samos. There is no evidence to show that the Samian was ever manufactured in this island, though its remains are sufficiently common, and especially at the more important Roman stations in Britain. It was apparently imported into this country, as it might have been into many other parts of the empire. The paste is of a rich sealing-wax red color, and well worked before it was wrought into vessels of various forms; BROGNIART, indeed, considers that it was worked in the most perfect manner, and with the aid of the greater part of the processes and means now employed in the most perfect manufacture. The vessels vary considerably in form, but are rarely of a large size. They are thin and delicate in their structure, and it may be inferred that they were considered valuable in ancient times from the fact of fragments being often discovered neatly riveted with lead. The red hue of the body or paste is derived from the sesquioxide of iron; and the brilliant glaze, which appears to have been formed of a silicate with an alkalino-earthly base, is colored red by the same means. Fragments of this ware have given the following analyses:—

	I.	II.	III.
Silica,	54.45	60.67	64.00
Alumina,	22.08	20.96	17.77
Sesquioxide of iron,	7.31	5.95	10.23
Lime,	9.76	6.77	4.86
Magnesia,	1.67	1.22	—
Water,	—	—	2.29
Potassa,	3.22	} alkalies in small quantities.	
Soda,	1.76		

The glaze has been found to consist of 64 silica, and 11.0 sesquioxide of iron. It is remarkable that this ware, wherever it may be discovered, is always exactly identical in its structure, forms, and style of ornamentation.

Across the centre of the bottoms of most Samian vessels are stamped the names of the potters, and they also appear upon the exterior surface of the embossed examples. The vessels themselves are either plain with mouldings, or they have delicate and fine patterns that have been appropriately designated *engine-turned*, or they are embossed with foliage and groups of figures. The scrolls, foliage, and other arabesques which appear on the Samian vessels very commonly, have a decidedly architectural character, and they rarely fail to demonstrate the sound taste of the artists employed in their production. A common form of Samian bowl, with characteristic arabesques moulded in relief, is shown in Fig. 457. The figure designs embrace an almost infinite series of curious and interesting representations of popular subjects which, like those introduced upon their terra-cotta lamps, are strikingly illustrative of the social and religious habits and customs of the Romans. Divinities and their emblems may be reckoned amongst these subjects, with priests and sacrificial ceremonies, bacchanalian processions

and dances, mythic and mythological scenes, fabulous and imaginary animals, other animals more true to nature, shows of gladiators, musicians, and others. The fragment in the British Museum, represented in Fig. 458, is in the highest degree characteristic of

Fig. 457.



Samian ornamentation; the figures are gladiators engaged in combat. Some few examples have the figures modelled in high relief, and affixed to the ware during the process of its production, instead of being moulded upon it. Moulds or materials used in pro-

Fig. 458.



ducing the embossed Samian have been occasionally discovered; they contain the designs impressed upon them in intaglio—as in the fragment—Fig. 459—found near Mayence—by means of a master-mould in relief. Specimens of such master-moulds have also been found;

Fig. 459.



and modelling tools, styles, punches, and other little instruments of ivory and bone, have lingered amidst the

remains of several ancient Samian potteries, as if for the express purpose of telling their tale to the inquiring explorers of modern times. This ware was evidently used much after the same manner that porcelain is at the present day. It is frequently mentioned by PLINY and other Roman writers, with whose words the existing relics are found to correspond with the most satisfactory precision.

Examples have been sometimes discovered in this country, and also in various other places, of glazed Roman pottery of a much paler red than the Samian, and altogether inferior to that celebrated ware. Other rare varieties are grey, yellow, brown, orange, or black; these wares sometimes have a lustrous glaze which shows the color of the paste, and in other examples the glaze has various hues of its own.

Roman Black Lustrous Pottery, made of any tenacious clay in the neighborhood of the manufacturer, varies in its color from a rich deep black to a slate or olive hue. The paste, in many instances, is red, grey, or even white; the black tint of the ware being due to the glaze, which is lustrous and has a metalloid aspect. Many vessels of this class are of small size and simple in form, as in Fig. 460; others are ornamented with incised lines and herring-bone patterns, or with clusters of small studs; and it is also common to find them having their sides depressed in compartments, after the manner shown in Fig. 461. In this example, found in London, the sides are depressed in seven compartments, and there is also a small pattern produced by tool-marks in bands.

Fig. 460.



Fig. 461.



Another mode of ornamentation exhibited in this ware consists of scroll-work, foliage, and hunting scenes, with other figures, executed in low relief upon the vessels after they had left the lathe, by means either of a deposit of semifluid clay, which could be modelled, or by an engobe of white pipeclay. Vessels of this class, though not so generally diffused as the Samian, are found in considerable numbers in all the countries that once were subject to the Roman rule. In this island great quantities have been discovered, which exhibit some varieties of character. The most characteristic examples are from the neighborhood of Castor in Northamptonshire, where Roman kilns for their production also yet remain; this class of Roman pottery has accordingly obtained the title of *Castor ware*. The fragment represented in Fig. 462 is from Castor; and the vase—Fig. 463—which is a most characteristic example, was found at Water Newton, also in Northamptonshire. So perfect are the remains of the Roman kilns, that the different processes employed for firing the wares have been

accurately distinguished; and it has been ascertained that in the case of the black ware, the fire, or rather the smoke of the furnace, was smothered upon the

Fig. 462



Fig. 463.



vessels when in the kiln, and it is supposed that the carbon was thus deposited on the heated surfaces of the vessels, giving them their black glaze. It must be added that occasionally vases have been found which are identical with the black Castor ware, with the sole exception that in color they are of different shades of yellow and yellowish-grey.

CELTIC, ANGLO-SAXON, AND TEUTONIC POTTERY.

—The sepulchral mounds erected over the graves of deceased chieftains of the early European races, have contributed many examples of the vases that were fabricated, both before and after the era of the Roman dominion, in countries beyond the limits of Italy and Greece. The fictile works of the rude and primitive races who inhabited Western and Northern Europe in ages anterior to the spread of the Roman power, are precisely what might have been expected—simple, and, indeed, barbarous in their composition, their forms, their ornamentation, and manufacture. Nor does the civilizing influence of the imperial sway appear to have long survived the decline and fall of the empire; since the pottery which may be assigned to the centuries that immediately succeeded to the era of Roman occupation, exhibit scarcely any higher qualities than those of the primitive period. It is probable, however, that the ceramic relics exhumed from Anglo-Saxon tumuli, and from other sepulchral mounds of the same age, may represent but imperfectly the various kinds of pottery then in use, and particularly such as were employed for domestic purposes. The arts of the Romans, indeed, seem to have passed away almost with the receding steps of the legions; and, on the other hand, it is certain that much yet remains to be accomplished, before the manufactures of the Celtic and Teutonic races can be considered to have been thoroughly investigated. Urns and vases of various sizes and forms, generally without handles, and as commonly inverted as placed erect, are found in Anglo-Saxon tumuli; and, with objects evidently of British or Saxon design, others are occasionally observed which are no less certainly imitations of Roman works. The rudeness of the greater number of the specimens of Anglo-Saxon pottery, is indeed as remarkable as the tendency which it so generally exhibits to assimilate rather to the British than to the Roman types. The paste both of the Celtic and Saxon pottery is coarse, and consists of the clay found on the spot,

and without much preparation, and it has undergone a baking of only a very imperfect kind. The vessels are of a dull blackish-brown hue. They are generally of an urn shape, tapering towards the base, and having wide mouths with bevelled and overlapping lips; and their style of ornament consists for the most part of simple cords or bands of punctured zigzag and herring-bone work, intermixed with dots and small projecting bosses. The two vases represented in Fig. 464, exemplify, in a highly characteristic manner, this class of early pottery. Contemporary fictile works, found at the North of the Tweed, closely resemble the relics of the same class that have been exhumed from barrows in South Britain. The urns and vases discovered in Ireland are also closely analogous to the British; but they are frequently finer in their texture and color, more complex in shape, and more elaborate in ornament. Their general resemblance to basket-work

Fig. 464.



also is more distinct and decided than in the British specimens. In France the Roman dominion has almost obliterated any traces of the primitive Gallo-Celtic potteries, so that a very small number of rude relics of an ante-Roman period has been discovered; and but little more is at present known of the operations of the Gallic potteries during the centuries which succeeded to the Roman sway.

The Teutonic pottery, which is found throughout Germany, bears a considerable resemblance to that of the Anglo-Saxons. The urns are formed of a friable paste composed of clay and sand, intermixed with particles of mica, and the compound varies in color in different localities. Like the Celtic pottery, many of the smaller vases have been modelled by the hand; but some of these, and the greater number of the larger urns, bear decided marks of having been turned upon the wheel. Handles are not uncommon in these vessels. They are ornamented with incised and punctured patterns, or with small bosses, and their decorative accessories are also frequently produced by painting in various colors. In addition to sepulchral urns, vessels have been found in abundance throughout the whole of Germany, of such forms and sizes as denote their original application to various domestic uses. Some few of the smaller works are apparently toys; and others of larger dimensions and still more singular aspect, resemble the hut-shaped cinerary

urns of the ancient Etruscan inhabitants of Alba Longa, and were actually used for sepulchral purposes.

MEDIEVAL POTTERY.—The manufacture of decorative pottery appears to have been unknown in Europe during that dark and stormy period which succeeded the fall of the Western Empire. Throughout these ages, however, there is every reason for believing that such simple fictile vessels as would be required for the ordinary domestic requirements of daily life, were produced by the different European nations. In process of time the potter's art reappeared in Spain, having been carried thither by the Mahomedans when they overthrew the Gothic monarchy in 711. But the influence of the Hispano-Moors did not extend beyond the region which had submitted to their arms, and, consequently, several centuries elapsed during which the ceramic productions of the rest of Europe knew no improvement. And when at last improvements began to be gradually introduced, earthen vessels still continued for a long space of time to be esteemed simply as articles of present utility, so that but few specimens have been preserved, and only casual notices of these objects have found their way into mediæval documents and records. It is known that the Arabs employed lead glaze in the ninth century, and that the Moors introduced their plumbiferous glaze into Spain early in the thirteenth century, about which time its use seems to have spread into other countries. Stanniferous glazes were also brought into Europe by the Hispano-Moors, and probably the use of both tin and lead in glazes or enamels became known in the West at about the same period, though the exact manner and time in which the knowledge of these glazes passed into the different European countries has yet to be determined.

Inlaid Tiles.—There is one class of the fictile productions of the middle ages which claims distinct and special notice. This class comprehends the various decorative tiles that were designed to form pavements, and in some instances to serve as surface-coverings of an ornamental character for walls. For England, in the thirteenth and three following centuries, paving-tiles were produced in great abundance, and in an almost infinite variety. The devices were obtained by impressing or incising the desired designs upon the slabs of dark colored clay, the intaglios being then filled in with a white composition; the surfaces were generally covered with a thick and lustrous glaze, but in some instances the terra-cotta was left without any such protection. The designs that have been observed upon these tiles comprehend geometrical and other patterns, miscellaneous devices, figures, architectural details, heraldry, and inscriptions, and they are invariably both curious and interesting. In some instances the designs are executed in low relief; and occasionally inlaid tiles have been observed that were produced for the purpose of monumental commemoration. A noble pavement of early tile-work has been preserved in the Chapter-house, Westminster; other examples of great excellence remain at Great Malvern, Gloucester, Worcester, and Ely Cathedrals, at St. Alban's Abbey, and in many other churches; but the very finest specimens are those which have very recently been discovered upon the site of Chertsey Abbey in Surrey.

Moulded terra, for architectural purposes, was also produced in great abundance and of excellent character in England, at the same period with the inlaid tiles.

SPANISH POTTERY.—Tiles of enamelled earthenware, called by the Spaniards *Azulejos*, were used for the pavement and the surface-decoration of their buildings by the Arabs wherever they extended their conquests. By the Spanish Moors these beautiful tiles were made in great abundance, and with those examples of them which yet remain, vases and other objects of decorative pottery may be associated. The Moors, indeed, appear to have continued their ceramic manufactures without intermission throughout their partial occupation of Spain, and until their final expulsion about the commencement of the seventeenth century. The colors introduced into the ornamentation of the Hispano-Moorish pottery are rich and gorgeous, abundantly intermixed with gold, yet always adjusted and blended together with judicious taste, and a thorough appreciation of harmony. The enamel is generally of a yellowish-white, over which an iridescent lustre plays with remarkable splendor. The designs and forms alike indicate their Oriental origin; the former comprise arabesques, scroll-work, flowers, and conventional foliage, with occasional birds and animals; and, in some examples, Spanish shields of arms and Arabic inscriptions. The patterns are infinitely diversified, and elaborate and intricate in the highest degree. Sometimes the Arabic legends appear on Gothic shields, and occasionally there may be seen instances of Christian devices and inscriptions. The tiles are formed of a pale clay, the surface being covered over with an opaque white enamel, upon which the elaborate designs are executed in colors. The celebrated fortress-palace of the Alhambra has supplied the most beautiful examples of the tiles—*azulejos*—of the Hispano-Moors, and also the most remarkable vase of their production that is known to be in existence. Other relics yet remain in different places where the Moors once were powerful; and the art of producing *azulejos*, learned by their ancestors from the Moors, is still practised by the Spaniards of the present day.

ITALIAN POTTERY.—Partly from the fictile productions of the Saracens or Moors, as the Arabs of Europe were called, and in part also from the ceramic manufactures of the Byzantine Greeks, Italy may be considered to have obtained the elementary principles of those processes which she cultivated with such distinguished success during the fifteenth and sixteenth centuries. As early as 527, the Saracens conquered Sicily, and adorned their great mosque at Palermo with colored and enamelled tiles, similar to those of the Alhambra. In this same ninth century the Saracens obtained a footing in Apulia. The island of Majorca somewhat later became a stronghold of the same invaders, and there they systematically carried on their characteristic ceramic manufactures with the utmost vigor. In the year 1115, the Saracen king of Majorca was defeated and slain by the Pisans, after a fierce and protracted struggle, when the Pisan galleys, amongst other spoils and booty, carried specimens of rich Moorish pottery in triumph to their native city. Fictile plates, known as *baccini*, are said to have been

incrusted in the walls of the churches of Pisa, as trophies commemorative of this event; and it is certain that the most ancient Pisan churches, as well as those of other parts of Italy, still retain examples of these *baccini*, which are apparently of Moorish origin. It will be remembered that the Moors themselves employed their enamelled tiles for the decoration of the walls of their edifices, and accordingly a similar treatment of the spoils of the conquered Majorcans would naturally suggest itself to the victorious Pisans; and thus the usage might prevail in Italy of incrusting the walls of churches with *baccini*-plates, discs, or pateræ of fictile ware. In addition to the spoils of the Majorcans, and the works of the Italo-Moors in Apulia, and of their brethren in Sicily, other fictile productions would appear at an early period in Italy in consequence of the gradual recovery of Spain from the Moorish invaders. The conquered Hispano-Moors would frequently settle in Italy, carrying with them their potters' art. So also, without doubt, the never absolutely lost art of the ancient potters would travel to the congenial soil of Italy from Byzantium, as soon as there would appear even a prospect of its receiving a cordial welcome. Indeed, in whatever degree the early mediæval potters of Italy may have been indebted to the Moors, and excited by their admiration for the brilliant prismatic coloring introduced into their fictile works by that remarkable people, the revival of the ceramic art in Italy must be considered to have also received a powerful impulse from the operations of the Byzantine Greeks.

In the thirteenth century Italian pottery claims to have attained to a distinctive character. The course of the succeeding century witnessed a progressive advance. Under the Malatestas, lords of Pesaro, the manufacture assumed a more decorative and artistic aspect, and the peculiar characteristics of the works of the two next centuries may be considered to have been determined. A new process at this period was developed, upon which the subsequent ceramic operations of Italy were based. The red, or other comparatively coarse and dark-colored clay which formed the paste or actual body of the pottery was first fixed, or partly baked, and then, by immersion, it was covered with a thin coating or engobe of a composition formed of oxides of lead and tin, and of a very white earth procured from the territory of Siena; after this the ware was again placed in the kiln to receive its final firing. As the enamel was required to be more hard and white, the proportion of the tin was increased. The overlaying of an opaque white surface upon a colored body of a totally different texture formed a process altogether new, which may be regarded as the basis of the celebrated *Majolica* ware of Italy.

Born about the year 1400, and having his life prolonged until 1481, LUCA DELLA ROBBIA commenced his artistic career under LEONARDO, a goldsmith of Florence, of deservedly high reputation. He soon relinquished the profession of a goldsmith, and devoted himself, in the first instance, to sculpture in stone, and afterwards to modelling in clay. After many experiments, he arrived at the conclusion that an almost endless durability might be imparted to his figures in clay, by

overlaying them with a thick glaze of tin combined with other mineral substances. About the year 1438, LUCA succeeded in discovering an opaque white, highly lustrous stanniferous enamel, which he was the first Italian to apply to terra-cotta. His earliest works are in white on a blue ground; but he subsequently introduced green, maroon-color, yellow, and violet. He appears, however, to have used these colors very sparingly, and to have retained his preference for white and blue. The works of LUCA DELLA ROBBIA, distinguished invariably by their simplicity and purity of style, consist of Madonnas and Scripture subjects, with architectural ornaments and glazed tiles. LUCA was succeeded by his nephew, ANDREA DELLA ROBBIA, with the survivor of whose four sons the production of the Della-Robbia ware may be said to have passed away.

The remarkable class of ceramic productions known as *Majolica* is supposed to have derived its name from Majorca, where the Hispano-Moors had long practised the art of applying a peculiar lustrous enamel to pottery. It may be divided into the productions of four periods:—1. From about 1450 to 1530. The works of this period are distinguished as *Mezza Majolica*. In the earlier examples ornamental devices of a moresque character may commonly be seen, associated with busts and various Italian and mythological figures, and brief explanatory inscriptions. The figures represented upon the *Mezza Majolica* have their outlines traced in blue or black on a white ground, with faintly-tinted draperies: there are no shades or half tints, and the flesh is not colored: the drawing, though tolerably correct, is hard and harsh, and the figures have a flat and lifeless appearance. The whole is covered with a film of metallic glaze or *madre-perla*, that produces a richly-glowing iridescent lustre of a splendor that has never been surpassed. 2. The second period comprehends the ten years included within 1530 and 1540. At this era, instead of arabesque and foliage patterns, with busts and armorial bearings, the *Majolica* artists began to introduce groups of figures into their compositions; they made great improvements also in the art of coloring, and employed half-tints and full-colored draperies. 3. The third period of *Majolica*, in which the art was in its greatest perfection, extends from 1540 to 1560. 4. The fourth period, which extends throughout the decline of the art, may be considered to close about 1610, when true *Majolica* gradually ceased to exist; a species of imitative *Majolica*, however, continued to be made at Venice, Naples, Siena, and Savona, until the middle of the eighteenth century. After the year 1560 the decline of the true *Majolica* was rapid, having been in a great measure occasioned by the introduction of oriental porcelain into Italy. In addition to dishes, plates, and bowls of various sizes, the manufacturers produced statuettes, bas-reliefs, vases, candlesticks, inkstands, water-coolers, and cisterns also, and various other objects in *Majolica*. Artists of the highest celebrity were engaged to furnish designs for the decoration of this ware, and these designs were executed—many of them in relief—by men who might also claim to take rank with artists of no mean order. The engravings of MARC ANTONIO and the

drawings of RAFFAELLE and of his disciples were largely used by the Italian ceramic painters, and hence the Majolica has sometimes been denominated *Raffaelle ware*. The idea, however, that Raffaele himself actually painted the Majolica is proved to be erroneous by the fact, that the finest specimens of the ware were not produced until twenty years after his death. In the sixteenth century classical, historical, and mythological subjects were introduced, and formed a strange medley with the paintings of Scripture subjects which still continued to be very prevalent. In the selection of these various subjects, the Majolica artists were in the habit of adopting those which might be considered peculiarly appropriate to their several works. Vessels to contain water, accordingly, were decorated with representations of such incidents as VENUS rising from the sea, or the catastrophe of PHARAOH. Fruit dishes were painted with vintage and other similar scenes. The actions of DAVID, SOLOMON, CÆSAR, or ALEXANDER, would be set forth on royal services; while those destined for ecclesiastical dignitaries would represent scenes in the lives of MOSES or SAINT PAUL. It was a custom amongst the Italians to interchange presents of specimens of Majolica, which were always painted with subjects appropriate to the occasion. Of these, one class in great favor, called *Amatorii*, consisted of plates and vases, which cavaliers presented to ladies they admired. Portraits of the ladies, accompanied with their names and some complimentary epithet, were generally painted upon *amatorii*. From its first appearance, the Majolica received the most liberal encouragement from the Italian sovereigns. When the lordship of Pesaro passed in 1450 from the house of MALATESTA to that of SFORZA, the new rulers at once granted special privileges to the manufactories of Majolica. At Urbino, Majolica flourished under Dukes FEDERIGO and GUIDOBALDO, who severally reigned from 1444 to 1482, and from 1482 to 1538. Both of these princes were invested with the order of the Garter of England, the former in 1474, and the latter in 1503. To GUIDOBALDO, his sister's son, FRANCESCO MARIA DELLA ROVERE succeeded, under which energetic prince the ceramic productions of his country made rapid and most important advances. His son and successor, GUIDOBALDO II., who reigned from 1538 till 1674, witnessed both the crowning perfection and the incipient decline of the art, with which his name will ever be associated. The early *Mezza Majolica* was chiefly made at Pesaro. An artist, who flourished there about 1480, and who employed peculiarly brilliant ruby and golden yellow pigments, was the most remarkable ceramist of the period; his productions, readily distinguished by their peculiarities of treatment, as well as by their singular excellence, are always resplendent with the *madre-perla* glaze. The wares of Gubbio are also celebrated for their iridescent lustre; and the metallic glaze having a ruby color is peculiar to the productions of that city, in common with those of Pesaro. The great artist of Gubbio was MAESTRO GIORGIA ANDREOLI, the brilliancy of whose metallic colors is unrivalled. He delighted in the use of the ruby lustre; and, in addition to golden and silver hues of the same iridescent character, he introduced

an intermediate tint, which has the peculiar glow of burnished copper. It has been observed that the ruby lustre of this artist is transparent, and that when he desired to render it very deep and rich, he first placed blue beneath it. His pieces date from 1519 to 1537. The Majolica of Urbino comprehends a considerable portion of the specimens that still exist, and it ranges from the concluding quarter of the fifteenth century till the decline of the style had been far advanced. These works are in great variety, and they exhibit all the peculiarities, and also all the most excellent qualities of this remarkable class of ceramic productions. The most celebrated artists who painted the Majolica of Urbino were FRANCESCO XANTO AVELLI, whose works are not dated later than 1540, and ORAZIO FONTANA, the date of whose pieces is from 1540 to about 1560. The manufactories of Urbino also benefited by the services of several other artists of deservedly high reputation. Castel-Durante and Faenza are the other places most celebrated for their Majolica, which yet remain to be specified. But little is known respecting the artists who painted at these cities, but their productions may be grouped with the best Majolica of Urbino. Besides its Majolica, Faenza produced bas-reliefs, after the manner of LUCA DELLA ROBBIA; and this city, with Florence, was the first to adopt the beautiful white tin glaze, when the secret of its production had become known some years after the death of LUCA. The term *Fayence*, now generally applied to all enamelled earthenware, and particularly to that of Italy, is supposed to have been derived from Faenza, in commemoration of the early use at that city, in its ceramic works, of the white Della-Robbian glaze. In several cities of the papal states, Majolica was made during the best periods of the art; and subsequently, at the close of the sixteenth century and throughout the century following, and even later still, the same manufacture was actively carried on in several parts of Italy. The artistic character of the Majolica ware rarely fails to produce a powerful impression upon all who may have opportunities for observing it; at the same time, it is no less evident, that both the forms of the greater number of the pieces of this ware, and the nature of their decorations, are such as to render them objects, not of utility, but simply of decoration. In this respect the Majolica differs essentially from the finest vases of the Greeks, in which a useful application of the vessel always predominated over its artistic adornments. The Italian ceramic artists, on the contrary, treated their Majolica as a vehicle for the display of their paintings; and they, accordingly, aimed rather at the production of pictures upon clay, than at the decoration of the various useful productions of fictile art manufacture. It must be added, that Majolica was produced in the sixteenth century both in Germany and France. HIRSCHVÖGEL, an artist of Nuremberg, when travelling in Italy, visited Urbino in 1503; and, having there learned the art of making this ware, he established a manufactory in his native city on his return: his works are ornamented in relief. At Nevers in France also, a manufacture of Majolica was established by Duke LOUIS GONZAGA, about the year 1570, attempts having been already made to produce

the Italian ware at that city by CATHERINE de Medicis. That princess, herself a daughter of a Duke of Urbino, very naturally sought to introduce into France the characteristic production of her native country. It is remarkable that CATHERINE styled the Majolica *Fayence*. MARRYAT states, that it is difficult to distinguish the early works, produced under Duke LOUIS GONZAGA at Nevers, from the true Italian Majolica; and, indeed, it is probable, that the two classes of this ware may be almost identical.

FRENCH POTTERY.—In addition to the Majolica of Nevers, manufactories for the production of enamelled pottery existed at an early period in several cities of France. The ware of Beauvais was honorably distinguished as early as the twelfth century, and it continued to enjoy an increasing reputation during the four succeeding centuries. In the sixteenth and seventeenth centuries Avignon had ceramic works of some importance; and there were also other establishments of the same order in various parts of the South of France. Rouen possessed a manufactory founded by FRANCIS I., which in the seventeenth century was much celebrated. At the same period the productions of Nevers and of St. Cloud were held in high esteem. They were all enamelled, and they exhibit many qualities that still command admiration; but they were altogether deficient in that one quality—originality both in form and decoration—which in so eminent a degree distinguished the works that next claim attention. These are the *Fayence* of BERNARD PALISSY, who was born about 1500 at La Chapelle Biron, in Perigord. Of the humblest origin, this ardent, enterprising, resolute, and persevering man, whose history forms a genuine romance, rose to become an artist, an author, and a philosopher of the highest order. About the year 1550 PALISSY discovered the enamels which enabled him to execute the remarkable ceramic works that are identified with his name. He had labored through a memorable probation of fifteen years before success crowned his experiments. Thenceforward his career as an artist was one sustained triumph. He composed rustic pieces, or dishes, and other objects, ornamented with fishes, shells, plants, insects, and reptiles, all executed in high relief, and perfectly true to nature in both form and color. He modelled exclusively from the fish of the Seine, from the fossil shells of the Paris basin, and from other natural objects found in the same localities. His enamels are hard and brilliant, and his hues rich and vivid; but he did not discover the pure white of the early Majolica. He employed a tin glaze, upon which his colored enamels were laid. PALISSY made many large works for decorating fountains, *et cetera*, besides a vast series of smaller productions of every kind to which pottery is applicable. In the year 1589 this venerable and eminent artist fell a victim to the Huguenot persecution, and after his death his art speedily disappeared. His two brothers, or more probably his nephews, continued for some time to produce works somewhat in the manner of BERNARD PALISSY; but they were able to do no more than imitate at a distance the productions of their great relative.

The French *Fayence* of HENRY II., of the seven-

teenth century, is a class of ceramic works which comprises but a small number of pieces, and which flourished but for a short period. No particulars are known respecting either the artists who produced this *Fayence*, or the part of France in which they lived and worked. It is supposed, however, that the manufacture may have been carried on at Thouars in Touraine, and that the *Fayence* was the production of a single artist—probably an Italian, who had been in the first instance educated by some goldsmith of Florence. The period of this *Fayence* is determined by the presence of the insignia of FRANCIS I. upon the earlier specimens; while upon the later and more perfect works there appear the arms of HENRY II., with his device—the three crescents, or his initial H, interlaced with the two Ds of DIANA de Poitiers, Duchesse de Valentinois. The paste is a hard, fine, and very white pipe-clay, which did not require to be covered, like the Majolica, with any superficial coating. Upon this, when it had been modelled to the desired form, the decorative enrichments were incised, or perhaps in some instances impressed, the incisions or impressions being subsequently filled in with different coloring substances of yellow, brown, and carnation hues. The designs were drawn and executed with the utmost delicacy; and small detached figures, with various objects, designed after the *renaissance* feeling of the period, and boldly modelled in full relief, completed the ornamentation. Over the whole was laid a thin, transparent glaze of a pale yellow. The examples of this peculiar pottery may be compared to the *niellos* of the preceding century, with accessories of *repoussé* and chased metal work; and they contain some of the most delicate productions of fictile manufacture that are in existence.

GERMAN POTTERY.—Long before the introduction of the manufactory of Majolica into Nuremberg at the commencement of the sixteenth century, many parts of Germany had attained to a high degree of excellence in the practice of the potter's art. Throughout the Northern regions, the manufacture of fictile works was not limited to the production of portable vessels, but the use of moulded and glazed terra-cotta was extended to almost every variety of architectural work. Glazed tiles, also, of great size were produced in the German potteries, and particularly in those of Nuremberg. The German wares partake of the characteristics of Italian pottery in union with the artistic attributes of a Gothic race. The wares of a late period are generally of very elaborate workmanship. They are commonly ornamented with representations of the various animals of the country, and not unfrequently the different pieces are found to have been modelled in the forms of deer, bears, *et cetera*. Upon the Upper Rhine many potteries existed, which, in the beginning of the eighteenth century were converted into porcelain establishments. A fine enamelled ware was also made at Cologne, and colored enamelled wares were produced in Lower Saxony. Manufactories of a species of Majolica are said to have been established in various towns of Hungary, Transylvania, and Austria Proper.

DUTCH AND FLEMISH POTTERY.—Delft and the adjacent towns of Holland, were celebrated at an early

period for their fictile wares. These productions were imported into England as early as the reign of HENRY IV.; and, with other Dutch pottery, tiles remarkable for the beauty of both their color and their glaze were brought in great numbers into this country. Paving-tiles of green, yellow, and white, were imported from Flanders in the time of HENRY VIII. for Hampton Court, and for Christ Church, Oxford. Lord BACON introduced others of a similar character at his mansion of Gorhambury, near St. Albans. About the year 1625 these tiles became fashionable, and their use was very general in England. As the sixteenth century drew towards its close, the ceramic productions of Delft acquired a European celebrity, and the success which attended the manufacture of them may be pronounced unexampled. The objects themselves were for the most part closely copied, both in form and color, from the old porcelain of Japan, with which the Dutch were familiar long before it was known to the rest of Europe. The clay found in the vicinity of Maestricht was mixed with marl or sand; and this was covered with a beautiful glaze having a blue tinge, which presented a smooth and even surface, and received paintings, chiefly in blue, in imitation of the Oriental, without impairing the distinctness of the colors. One curious branch of the Delft manufacture consisted of dinner services, of which the dishes and covers were made in the forms, and painted to resemble animals, birds, and vegetables, such as are usually served at table. The pseudo-Japan Delft ware flourished until the commencement of the eighteenth century, when it began to decline. The superiority of the wares of WEDGWOOD caused the Delft to be superseded, even in Holland, by pottery of English production.

Stone-Ware—Grès Cérame—is a densely-baked earthenware, formed of clay mixed with sand, and glazed with salt. It exhibits, when broken, a close grey texture; it is somewhat vitreous, resists the action of fire, and is impermeable to liquids, even such as are of the most penetrating and corrosive nature. The stoneware of the Low Countries may be divided into common and fine. Both are commonly ornamented with subjects in relief, and colored; but the fine stoneware is distinguished by a more elaborate ornamentation as well as by the superior quality of its paste. The common stoneware appears to have been in general use towards the close of the sixteenth century. The specimens of it which are usually found in England consist of stone flasks, having a grotesque bearded mask on the neck, and some device on the body of the vessel. They are known as *greybeards* or *Bellarmines*, the latter name having been given to them in the reign of JAMES I., in derision of Cardinal BELLARMIN, and as an implied compliment to the king. The earliest examples of this ware are of a white-yellowish color, without any glaze, and delicately ornamented with Scriptural or allegorical subjects, produced in relief from copper moulds. This manufacture was indebted in a great measure for its early success to the attention bestowed upon the production of it by JACQUELINE, Countess of Hainault and Holland, the repudiated wife of HUMPHREY, Duke of Gloucester, after her abdication and

retirement in 1433. The later wares have a brown or reddish color, in place of the earlier yellow tint. The stoneware jugs of the same period have various ornaments in relief, including figures, armorial bearings, personal devices, with foliage and patterns, and also with dates and occasional brief inscriptions. Their enamel is hard, and of a rich brilliancy. The Flemish stoneware, or *Grès Flamand*, is peculiarly striking in appearance from its beautiful blue color—commonly used in combination with grey tints—its quaint forms, and rich ornaments. The manufacture of *Grès Flamand* extended from 1540 to 1620, when it gave way before the introduction of oriental porcelain.

ENGLISH POTTERY.—The few specimens of early pottery that have been found in England, and which may be considered to have been of home manufacture, are such as lead to the conclusion that before the seventeenth century this country was chiefly supplied with fictile productions from foreign establishments. In some few instances foreign workmen appear to have settled in England, and thus their art became naturalized with them. Vessels, most of them tall and slender jugs, have been discovered in excavations in London, which may be assigned to the fourteenth and fifteenth centuries, and were probably made in this country. Occasionally, also, other relics have been brought to light, the most curious being some terracotta models for stamping his wares, which had been used by a potter of the time of EDWARD III., and which were found, with numerous fragments, near the remains of a kiln at Lincoln. The glaze used was obtained from lead. Amongst the productions of the seventeenth century, an English Delft may be considered to have occupied a prominent position; dishes, plates, mugs, wine-pots, and other objects were made in considerable numbers at Lambeth, Fulham, Liverpool, and in Staffordshire, the process having been in the first instance introduced at those places by Dutch potters who had settled there. The wine-pots are globular in form, with narrow necks and handles; their color is white; and they are inscribed in blue with the words, *sack, claret, whit*, usually accompanied by dates ranging from 1642 to 1659. A stoneware, identical in character with that of Flanders, was also produced in England in the reign of ELIZABETH, who made many efforts to establish potteries amongst her subjects; but little of importance, however, was accomplished until the close of the seventeenth century.

THE STAFFORDSHIRE POTTERIES, which now produce the great mass of the earthenware manufactured in this country, from their great local advantages have been intimately associated, from a remote period, with the art that has given to them their name. This district contains twelve lordships and three parishes, and now constitutes the borough of Stoke-upon-Trent. There the Romano-British ceramists plied their wheels and threw their clay. There the Saxon *tile-wrights* practised their useful calling, and transmitted to the Norman potters a hereditary craft. English potters now flourish in the same localities, and, in memory of long-past times, they still have amongst them a family named TELLWRIGHT—formerly written TYLRIGHT—who for several centuries have been settled in Burslem,

and are in all probability descended from a remote ancestry who exercised what our Saxon forefathers—before the Normans had introduced the word *potta*—designated the *tile-wrights'* occupation. In the year 1686, Dr. ROBERT PLOT, in his Natural History of Staffordshire, first directed public attention to the potteries of that county. He mentions Burslem as being the seat of the most important pottery of the district, and he also speaks of the manufacture of tobacco-pipes at Newcastle-under-Lyne. He gives a minutely exact description of four varieties of white and red clays, all of them found within half a mile of Burslem, the best being dug up nearest the coal, which were of close texture and would work well on the wheel; and three other clays of looser and more friable natures, called *slips*, which were used for painting the wares. One considerable branch of the Burslem pottery manufactures at that time consisted of butter-pots—coarse cylindrical jars to contain butter for sale. An act of parliament passed in 1661, provided that these butter-pots should not exceed six pounds in weight, and should contain at least fourteen pounds of butter. Tygs or tiggs, drinking-cups, commonly having two or three handles, were made at Burslem, in addition to the butter-pots, both before and during the reign of ELIZABETH, and specimens of them are the earliest examples of Staffordshire pottery that are known to be in existence. The tyg was a kind of loving cup, and had its handles so arranged that two or more persons drinking out of it, and each holding a separate handle, might bring their lips to different parts of the rim. Ornamented dishes appear to have been made at Burslem as early as 1650. Until 1680, a lead glazing was employed; glazing by means of salt was accidentally discovered in that year, and first used by a potter named PALMER. About 1605, white and brown stonewares were made by THOMAS MILES of Skelton. These wares, when salt-glazed, were called *crouch-ware* by the Burslem manufacturers, who first produced them in 1690. The vapor arising from the salt-glazing is described as being so considerable, from about eight to twelve o'clock on Saturday mornings in the town of Burslem, as to produce a dense white cloud, sometimes so thick as to cause persons to run against each other in the street. At that period—1700—Burslem contained twenty-two ovens, each having eight mouths at equal distances. In 1852 it was estimated that upwards of sixty thousand persons were regularly employed in the hundred and thirty-three fictile establishments then in active operation in the Staffordshire potteries.

The first attempts that were made to imitate some Japan ware by the Staffordshire potters were not successful; but in 1690, two brothers named ELSERS from Nuremberg, discovered a bed of fine compact red clay, which enabled them to produce with complete success a fictitious Japan ware. The discovery of the use of calcined and pounded flint as an ingredient in pottery, attributed to the younger ASTBURY in 1720, led to great and highly important improvements in the Staffordshire wares. The new material was used in combination with pipeclay and sand, and colored with oxide of copper and manganese. The agate and tortoiseshell wares, some of the specimens being moulded

in relief and enriched with gilding, were thus produced. About this time moulds of plaster of Paris were introduced from France into England by RALPH DANIEL of Cobridge, and generally adopted by the English potters. The wares produced from these moulds were distinguished only by their different shades of color, and were known as drab, or cream-colored, and white. Printed and painted wares also soon followed the plain varieties. The forms and patterns of this pottery were generally obtained from the silver plate of the period. Such was the condition of the English pottery manufacture in the most important district in the country, when another PALISSY arose in England in the person of JOSIAH WEDGWOOD.

In common with several members of his family, THOMAS WEDGWOOD had carried on the manufacture of pottery for some years at Burslem, at the time of the birth of this son JOSIAH—the youngest of thirteen—in 1730. Very scanty was the education which the young JOSIAH was enabled to acquire, and very early in life he found it necessary to work as a thrower in his elder brother's pottery. His weak health compelled him to relinquish the more laborious occupations of his art, and to follow the natural inclination of his ingenious and enterprising mind. He made various ornamental and useful articles in clay, mixed with metallic oxides, and thus obtained imitations of jaspers, agates, and other variegated stones. In 1759 he succeeded in fabricating a white stoneware, and subsequently a cream-colored ware, by which he gained a high celebrity. This renowned ware was composed of the whitest clays of Devon and Dorset, mixed with ground flint, and covered with a brilliant vitreous glaze. It was capable of enduring sudden and violent changes of temperature, and was not affected by acids. Some specimens having been presented to Queen CHARLOTTE, WEDGWOOD was appointed the royal potter, and his cream-colored pottery he was desired thenceforth to designate *Queen's-ware*. His success having now become established, WEDGWOOD applied himself with the most devoted assiduity to the introduction of various improvements in the composition, glaze, and color of his productions. He consulted the writings of the best authors who had treated of chemistry; he worked assiduously at his own experiments; and he sought the aid and co-operation of the ablest workmen and the most accomplished artists. Having completed his most interesting discoveries, in 1763 WEDGWOOD opened a metropolitan establishment in St. James' Square, in connection with his friend BENTLEY, a descendant of the celebrated critic. Having obtained the loan of valuable specimens of antique sculpture, cameos, intaglios, seals, and other objects, WEDGWOOD produced the most admirable copies of them in his new wares. Amongst the most remarkable of his reproductions, are the fifty copies which he made in his peculiar pottery of the Barberini, now the Portland, vase. The Wedgwood Portland vases are examples of the *Jasper pottery* of this great artist. This remarkable class of fictile works was produced from a white body of extraordinary delicacy and beauty, which, unlike any other ceramic composition known either in ancient or modern times, possesses the property of receiving through its whole substance, from

the admixture of metallic oxides, the same colors that those oxides communicate to glass or enamel in fusion. The effect of this property was such as enabled WEDGWOOD to produce, in bas-relief, any figures or objects that he might desire, of the purest white upon colored grounds. The blue jasper of his grounds he obtained by adding to the mixture of his vitrescent materials oxide of cobalt, the quantity being increased as a greater depth of color was desired. In the case of the green jasper, the admixture was made with the protoxide of chrome. So great was the extent to which the manufacture of imitative gems was carried by this process, that the catalogue of *Antique Ornaments, et cetera*, published by WEDGWOOD in 1777, enumerates and describes seventeen hundred and thirty-five cameos, and three hundred and sixty-six intaglios, which had been reproduced by him in fac-simile from ancient works. Another important discovery made by WEDGWOOD, was that of painting on vases and other objects without the glossy appearance of ordinary paintings on earthenwares—an art practised by the ancient Etruscans, but which appears to have been lost since the days of PLINY. It is worthy of especial record that, in addition to his vast series of objects of an exclusively decorative character, WEDGWOOD also produced many articles of domestic use and requirement, all of them designed in the same true artistic spirit, modelled with the same care, and adorned with the same admirable bassi relievi, as his more elaborate and costly works. The fame of WEDGWOOD was so great that his works at Burslem, and subsequently at Etruria, a village erected by him, and to which he removed in 1771, became a point of attraction to visitors from all parts of Europe; while his own talent and energy, coupled with the sound judgment which led him to secure the co-operation of such an artist as FLAXMAN, not only obtained for him extensive patronage and an ample fortune, but also greatly promoted the commercial interests, and exalted the reputation of his country. He died in his sixty-fifth year at Etruria, January 3, 1795. During his lifetime, WEDGWOOD sold his ware at a price which brought it within the means of general consumption, both at home and abroad; and so highly were his works prized on the continent of Europe, that, notwithstanding duties that were intended to prohibit the admission of British earthenware, not less than five-sixths of the entire quantity which he made were exported. His cameos and other works are still held in high honor abroad, and at home Wedgwood-ware of every description now finds ready purchasers at prices which significantly indicate its present reputation. It is most satisfactory to be able to add, that the influence of JOSIAH WEDGWOOD has acted most beneficially in promoting the permanent improvement of British pottery, and also that the wares which still issue from Etruria are not unworthy of their association with his name and his memory.

In the seventeenth and eighteenth centuries manufactories of pottery existed, and flourished with varying success, at Lambeth, Fulham, Liverpool and its neighborhood, Leeds, York, Bristol, Nottingham, Jackfield in Shropshire, and Lowestoff in Suffolk. The potteries of Lambeth and Fulham produced a species of delft

and a stoneware, with some excellent decorative tiles. At Lambeth the manufacture of stoneware is still carried on to a great extent; the materials are pipeclay from Dorsetshire, pulverized Staffordshire flint, and sand; a salt glaze is used, which renders the ware perfectly impermeable to water, and even to acids. The Liverpool manufactories produced many fictile works of considerable interest and importance. They are first mentioned in the year 1674. A century later, SADLER and GREEN introduced the art of printing upon pottery; and they succeeded so completely in keeping their process secret that, until the time of his death, WEDGWOOD was in the habit of sending his Queen's-ware to Liverpool to be decorated by the new style of ornamentation, after which it was returned to Burslem and Etruria. In 1752 RICHARD CHAFFERS made a fine white earthenware at Liverpool; but finding WEDGWOOD a formidable rival, he directed his attention exclusively to the production of porcelain. After many disappointments, he succeeded in discovering accidentally the requisite materials, and he produced a chinaware of great excellence. About 1760 the manufactory of PENNINGTON at Liverpool became celebrated for punch-bowls and vases of delft. PENNINGTON was also noted for his wonderfully successful imitations of Oriental porcelain. He eventually broke up his Liverpool establishment, and retired to Worcester.

At the present day the potteries of Staffordshire and of other parts of England occupy a most important position amongst the national industries. Every imaginable object that may be produced from clay is now made by English ceramists, and the most elaborate and the simplest works are executed with equal facility and the same success. The early fictile productions of the country, *inlaid tiles* and *moulded architectural terra-cotta*, have been revived, and are now produced with admirable skill. His inlaid tiles were the productions which in a pre-eminent degree established the fame of HERBERT MINTON, a man whose name will ever be honorably remembered as one of the worthiest of ceramic art manufacturers. Messrs. MAW are more particularly distinguished for their tiles having geometrical designs, after the manner of the ancient tessellated pavements; and PULHAM of Broxbourne, in Hertfordshire, may be specified as taking the lead amongst the most successful producers of moulded terra-cotta.

MEXICAN AND SOUTH AMERICAN POTTERY.—Examples of several varieties of ancient pottery have been discovered in Mexico, and described by STEPHENS in his *Incidents of Travel*. They have been obtained from the ancient tombs of the country, and are remarkable for their singularly grotesque forms rather than for any other distinctive peculiarities; the fictile works of Mexico, however, at the time of the invasion by the Spaniards, are spoken of by the conquerors in terms of great admiration. The early pottery of Peru, Chili, and Columbia has a peculiar character which very decidedly distinguishes it from any European, and also from all Oriental works of the same class. It approximates to the Mexican, having the same uncouth and rude forms, and a similar grotesqueness pervading its ornamentation; and yet in connection with such indi-

cations of a rude condition of manufacture, many of these works exhibit in their carved or impressed decorations, patterns identical with such well-known classic forms as the Greek honeysuckle, the frette, and the Vitruvian-scroll. In his History of Brazil, alluding to the excellence of the South American potters, SOUTHEY states that the Tupinambas were in many respects an improved race. The women were skilful potters, they dried their vessels in the sun, then inverted them, and covered them with dry bark to which they set fire, and thus baked them sufficiently. There were some who buried their dead in jars large enough to receive them erect. The Tupinambas, by means of some white liquid, glazed the inside of their vessels so well that it was said the potters in France could not do it better, but the outside was generally finished with less care. Fig. 465 represents a chief of the Coroados

Fig. 465.



Indians in his funeral jar, decked with his war ornaments and his arms, sitting on his heels in the usual posture of the savage in repose, and having some animal at his feet. Such sepulchral deposits are found at the foot of the large trees of the forests.

It is far from improbable that future researches may bring to light many varieties of pottery, some of them perhaps the simple and rude productions of aboriginal races, in regions which now can scarcely be said to have supplied any contributions to the history of fictile manufactures; and possibly, also, the sepulchres of long-departed generations may yet contain an abundant store of precious examples of ceramic art, scarcely less interesting than the most esteemed of those that are so well known, and which, at the same time, may prove to be distinguished by characteristic qualities peculiarly their own.

EUROPEAN PORCELAIN.—Although vases and other pieces of Chinese porcelain had found their way into Europe before the Portuguese doubled the Cape of Good Hope in 1497, it was not until after that event that this porcelain became well known to the various European nations. Having introduced comparative large quantities of Chinese porcelain into Europe about the year 1520, the Portuguese were succeeded in a great part of their East Indian traffic by the Dutch. The earliest known mention of China in England is in 1586. In 1600 the English East India Company was founded,

and having at length formed an establishment at Gambor in the Persian Gulf, it was enabled to introduce Chinese porcelain directly from that port into England, and hence it became known as Gamborware. In 1631 China was commonly imported into this country.

A familiarity with the porcelain that was brought into Europe from China, naturally induced a strong desire in the minds of European chemists and manufacturers, to produce a ware that was at once so beautiful and of such signal utility. Two centuries, however, had passed away before the most energetic efforts could attain to more than a habit of systematic copying of Chinese forms and patterns, upon the ordinary fictile wares of European production. The translucence that characterised and distinguished the porcelain of the East remained undiscovered until the commencement of the eighteenth century, when BÖTTCHER first succeeded in producing, at Meissen, the true porcelain known as *Dresden China*.

The two chief components of porcelain are entitled *Kaolin* and *pe-tun-tse*. The Kaolin—its name being considered to be derived from Kaon-ling, or Lofty-ridge, the name of a range of hills near the imperial Chinese porcelain works of King-te-chin—is an infusible substance, consisting of alumina or clay, or, in some cases of decomposed felspar; and the pe-tun-tse, or white paste, which is fusible, and produces the translucent quality of the ware, is composed of felspar or petrosilex reduced to powder. The two classes or varieties of porcelain, severally distinguished as *hard paste* and *soft paste*, contain the two principal ingredients in different proportions; the hard contains a greater quantity of alumina and less of silica; in the soft the proportion of silica is increased. The former acquires a greater, and the latter a less density. The latter, also, is soft in two senses; first, as being less able to resist a very high temperature; and, secondly, since the paste, where unprotected by the glaze, is easily scratched by an iron instrument. It must be added, that besides the naturally soft paste—*tendre naturelle*—there is a porcelain formed from a paste that is artificially soft—*tendre artificielle*.

BÖTTCHER was an apothecary's assistant of Berlin, who fled into Saxony to avoid the persecution which threatened him in consequence of his reputation as an alchemist. In 1709 he produced a true white porcelain of sufficient merit to induce the elector, AUGUSTUS II., to establish a manufactory. In the year following, BÖTTCHER was appointed director, and in 1715 he succeeded in making fine porcelain of great excellence. BÖTTCHER used the kaolin of Aue, in the Erzgebirge, and the most profound secrecy was rigidly enforced with respect to the entire process of the manufacture. Notwithstanding every precaution, however, certain workmen escaped from Meissen; and, the secret having thus become in some degree divulged, other porcelain manufacturers arose, one by one, in various parts of Germany, and particularly at *Höchst*, *Fürstenberg*, *Baden*, *Kronenburg*, *Nymphenburg*, and *Fromtrental*. In the year 1720 and 1751, the great establishments of Vienna and Berlin were severally founded, and they speedily obtained for their works the very highest

reputation. The porcelain of Berlin, indeed, rivals that of Dresden.

Meanwhile, in 1713, REAUMUR commenced a series of experiments, based upon the transmission of Chinese kaolin and pe-tun-tse to Paris by D'ENTRECOLLES, which paved the way for the successful use of those substances in the Sèvres manufactory, after they had eventually been discovered in France. Before this discovery, the researches of REAUMUR led to the production of an artificial porcelain from a soft paste—*pâte tendre*—the composition of which was both complicated and costly. Manufactories were established at *Chantilly* and *Vincennes* in 1735 and 1745; and in 1754 the manufacture was transferred, under a special royal sanction, to Sèvres. True kaolin was accidentally discovered in 1768, at *St. Yriex*, near Limoges; and having been ascertained by MACQNER to be both abundant and of good quality, it was introduced at Sèvres, where, in 1769, the production of hard porcelain was regularly established. The two varieties of porcelain, however, continued to be made conjointly at Sèvres until 1804, since which year the hard or true porcelain only has been produced. It is very remarkable that the quarries of *St. Yriex* produce not only the kaolin, but also the pure white felspar or pe-tun-tse which is indispensable in the production of porcelain.

Some degree of uncertainty hangs over the date of the first English porcelain manufactories at *Bow* and *Chelsea*, nor is it distinctly known what were the clays employed in the earlier works at *Derby* and *Worcester*. The natural kaolin of Borey Tracey, Devon, is said to have been worked in 1730; but the kaolin of Cornwall, which caused such great and important improvements in the porcelain manufactures of England, was not discovered by COOKWORTHY until about 1755. Kaolin, or *China-clay*, is now chiefly prepared from the granitic rocks of both Devon and Cornwall; and, as in the instance of *St. Yriex*, pe-tun-tse, called also *China-stone*, is obtained from the same Cornish rocks which also furnish the kaolin. Bone is an ingredient in common use in the composition of English porcelain.

In addition to the porcelain manufactories of Germany, France, and England, there are establishments for the production of this ware at St. Petersburg and Moscow, at Amsterdam and the Hague, at Copenhagen, at Zurich and Nyon in Switzerland, and in several cities and towns of Italy, Spain, and Portugal.

GERMAN PORCELAIN.—*Dresden* is remarkable for the beautiful forms, and the uncombined richness and delicacy of the painted and gilded decorations. Figures of every kind have been made in it at all times, and they are held in very high esteem. The Dresden candelabras have never been equalled by any others. The clock-cases and snuff-boxes, with the porcelain flowers, lace, and the honey-comb, and May-flower vases, are all of great beauty, and exemplify the singular taste and skill of the artists who produced them. The value of this ware is determined by the fashion of the piece and the execution of the paintings, which are generally copies of the works of the best Flemish and Dutch masters. The Dresden porcelain with the royal mark—two words crossed having a dot below them, A.D. 1778—is the most valuable.

Berlin porcelain, which closely resembles that of Dresden, is almost equal to it in form and painting. Berlin is now celebrated for the manufacture of a *lithophares*, or translucent pictures, executed in white porcelain. The porcelain of *Vienna* is thicker than that of Dresden, and its glazing has a grey line. It is distinguished by the excellence of its raised and gilded work, and for the application, in relief, of solid platina and gold. It is now exported in large quantities to Turkey, Russia, and Italy. The *Höchst* porcelain, which was produced in no great quantities from 1740 till 1794, partakes of the beauty and excellence of the Dresden manufacture. In varying degrees, also, the same character may be assigned to all the porcelain produced in other parts of Germany.

FRENCH PORCELAIN.—In France the porcelain manufactures have always enjoyed the highest patronage, and every encouragement has been given to promote their success. The results have fully realized the most aspiring hopes of their friends and admirers. The early soft porcelain of Sèvres is remarkable for its creamy and pearly softness of color, the beauty of its painting, and the depth of its glaze. After repeated efforts the Sèvres artists, who have ever reckoned among their number men of the most distinguished ability, succeeded in producing upon the hard porcelain the most exquisite landscapes, with flowers, and various figures disposed in graceful medallions. Portraits and miniatures were subsequently introduced. The jewelled cups must be specified, as occupying a place of honor in the productions of Sèvres. In form this porcelain is decidedly inferior to the Dresden, but in beauty of painting, richness of gilding, and depth of color, it has never been surpassed. The peculiar ground-colors of the Sèvres porcelain, that so justly enjoy a pre-eminent popularity, are distinguished as *bleu-de-roi*, a rich, deep blue; *bleu-turquoise*, a pale blue, the tint of the jewel; yellow, or *jonquille*, a full, glowing green, or *vert-pré*; and the lovely rose-color, called after Madame Dubarry, *rose-Dubarry*. In connection with the royal porcelain manufactory at Sèvres there is a *Ceramic Museum* of the utmost value and interest, the establishment of which was due to the exertions of the learned and accomplished director of the manufactory, the late M. BRONGNIART. Twenty-one other porcelain manufactories in France, besides that at Sèvres, are noticed by MARRYAT.

ENGLISH PORCELAIN.—About the middle of the eighteenth century the porcelain works of *Chelsea* attained to considerable importance, and under the patronage of GEORGE II., and of the Duke of CUMBERLAND, they produced services, and various pieces and objects of the very highest excellence. The early Chelsea-ware aimed at a close imitation of the Chinese, but subsequently the forms and decorations in favor in France were adopted, and retained in use until the close of the works about 1765. About the same period with the Chelsea, *Bow-china* was made at Stratford-le-Bow, and was generally distinguished by its embossed and quaint devices. When the Bow works were given up, about 1750, a porcelain manufactory was established at *Derby*, which, on the decline of the Chelsea-ware, became celebrated. It is very trans-

lucent, and of fine quality. This porcelain has long ceased to be produced; which is also the case with the beautiful ware, the first true porcelain of hard paste made in England, at *Plymouth*, by COOKWORTHY, and with the *Bristol*-ware, of still superior character, which succeeded it.

In 1751 the manufacture of porcelain was introduced by Dr. WALL, at *Worcester*, and, from the first, the works produced at that city have commanded decided admiration, and secured extensive patronage. The earliest efforts were directed to the imitation of the porcelain of China and Japan. About 1756 the important process of *transfer printing* was discovered and adopted at Worcester. In 1786 GEORGE III. paid a visit to Worcester, when he granted the patent which gave to that city the first *Royal Porcelain Works* in England. At this period, and until the present century had seen its first quarter pass away, the artists of the Worcester establishment appear to have been influenced by an irresistible desire to imitate the most attractive works of other ceramists, and they accordingly studied with equal attention the best productions of Dresden, Berlin, and Sèvres, as well as those of the East. More recently the Worcester porcelain, which has always been celebrated for its beautiful translucency, and the rich variety of its colored and gilded decorations, has gradually assumed a decided and definite character, and it stands in the front rank of the fictile manufactures of England. The present productions of the Worcester works comprise the most exquisite works of ceramic art, together with every variety of useful object—the spirited proprietors are Messrs. KERR and BINNES. Nearly contemporaneous with the works at Worcester are those that still flourish on the right bank of the Severn, at *Coalport* and *Colebrook Dale*, and other places in the same neighborhood in Shropshire, and produce vast quantities of excellent porcelain. The porcelain wares of *Nantgarrow* and *Swansea*, also of about the same date, were amongst the first that succeeded in England in attaining to the highest qualities of the manufacture; and besides these, attempts, attended with various degrees of success, were made in other parts of England, for producing the universally-admired porcelain for which Europe was indebted to the East. At the present day porcelain manufactories, side by side with those for the production of the humbler classes of fictile works in terracotta, are carried on in many parts of England, but Staffordshire and the city of Worcester still continue to be the scenes of the most important operations. Amongst the most distinguished of the Staffordshire manufacturers are the firms of COPELAND, MINTON, and RIDGWAY; and with them the names of ROSE and of BATES must be associated as ceramic manufacturers of the first class.

STATUARY PORCELAIN AND PARIAN.—Under these titles are comprehended some of the most beautiful and most popular productions of modern ceramic art. These delicate compounds were introduced about 1842 by COPELAND, MINTON, and KERR, for the execution of statuettes and other decorative works of a high order; and they have been constantly improved, until they now have attained to the utmost perfection. Delicate and

refined in the highest degree, the Parian or statuary porcelain is eminently sculpturesque in its aspect and tone of color, and at the same time it excites no suspicion of fragility or evanescence. Works thus executed are true works of art, and the comparative facility with which they may be produced renders them easy of general access.

CERAMIC ENAMELS.—The processes for the application of enamels to metals, so famous in the middle ages, have been revived by modern ceramists, and by them used for the decoration of certain classes of their own works. These works are executed on porcelain in the style of the champléré metallic enamels of Limoges, but without their thread-like lines of gold; they exhibit the same beautiful tints with the enamels of the thirteenth and fourteenth centuries, and are uniformly distinguished by an exquisite delicacy of touch and general treatment, associated with admirable energy and decision of expression.

Turning from this historical account of the ceramic art to the modern practice of manufacturing the various kinds of pottery wares, the first thing to be considered is the nature of the *clays* and other substances used in the art.

PROPERTIES OF CLAY.—Clay consists of a hydrated silicate of alumina in combination more or less with other substances derived from the felspathic rocks, which by their disintegration and decomposition have formed the clay; the silicates of potassa and soda, which form constituents of the felspar, having been dissolved out by water during the decay of the rocks. The chemical formula of the more important varieties of clay, according to BROGNIART and others, may be represented by $2 \text{Al}_2\text{O}_3$, 3SiO_2 , 4HO , which appears to be the composition of the fire-clay of the Staffordshire coal measures. In nature, however, the greater number of clays is intermingled with substances foreign to them in their original localities, fragments of undecomposed rock, carbonate of lime, magnesia, and the oxides of iron, certain proportions of potash, and variable amounts of silica in the hydrated condition, all of which modify the character of the clay and its applications, according as one or other of these ingredients predominates.

Pure clay is soft, more or less unctuous to the touch, white and opaque, and when breathed upon emits a characteristic odor; it may be converted by water into a doughy, tenacious, plastic paste, insoluble in water. The most prominent physical properties of clay are its plasticity and behavior when exposed to heat; when slowly dried and exposed to a high temperature, it shrinks considerably, and splits into masses extremely hard, and does not undergo fusion in the furnace; the stronger the heat to which it is exposed, the more dense, sonorous, and hard the clay becomes, although still porous enough to absorb water with avidity. It is, however, a remarkable fact, that while an increase of temperature brings the pores of the clay continually closer together, and the burnt clay increases in density and in hardness, this is not the case with the mass itself—a fact which has been proved by weighing porcelain clay after it has been dried or burnt. Thus, porcelain clay which had been exposed successively to

different temperatures was found to vary in specific weight as follows:—

Temperature of	212°.	334°.	639°.	Cherry red heat.	Lively red heat.	White Heat.	
						Low.	Intense
The cubic inch weighed in powder in grammes	38·58	39·52	40·61	42·17	41·24	39·05	38·74

by which it will be seen that the density of the mass itself attains its maximum at an incipient red heat, and is reduced at a white heat to the same state which it had acquired at 212°. In the commencement the clay loses water as much as 8½ per cent.; after having been dried at 334°, this weight then remains unalterable. But other changes occur at a red heat; the particles of clay are augmented in volume and possess less density; at the same time, however, the interstitial spaces are diminished, and they approach more closely together, giving an increase of density to the whole mass of burnt clay, which is practically observed by a diminution of surface, and technically called the *shrinking* of the clay. It can easily be conceived that this shrinking will be very materially modified and affected by the admixture and proportion of foreign matters possessing other properties—substances which may either be constituted of undecomposed detritus of the rocks which form the basis of the clay, or of others which do not yield clay by decomposition.

Pure clay does not fuse in the most powerful blast-furnaces; it dissolves with difficulty in borax, producing a transparent glass; with carbonate of soda it forms a green glass; if ignited with solution of cobalt, it assumes a blue color. Clay is insoluble either by nitric acid or dilute hydrochloric acid; but boiled with diluted sulphuric acid until the acid begins to evaporate, the alumina is dissolved out, together with a small quantity of silica. By boiling in a solution of carbonate of soda, the quartz, sand, felspar, *et cetera*, frequently mixed with the clay, may be separated. The presence of clay in any soil may be readily distinguished by the absorbent quality which it exhibits; when applied to the tongue or lips in a dry state, it adheres to them strongly, absorbing the saliva from their surface. It is this absorbent property in clay which causes it to retain ammonia in the soil. The ingredients which most affect the character of clay are sand, iron, lime, and magnesia, and its plasticity diminishes in proportion to the amount of any one of these sub-

stances which it contains, as they are not plastic. Sand exercises the most marked effect in this manner; lime somewhat less, and oxide of iron very little. Clay containing sand is said to be *poor*, in contradistinction to *fat* clay.

When clay containing lime or iron is subjected to the action of heat, the silica, alumina, lime, and iron form together a mixture similar to that employed in the manufacture of bottle-glass, melting in the fire with more or less ease, according as it contains much or little of the latter two ingredients. Magnesia exerts less influence upon the character of clay; and the greater the amount of quartz and silica that enter into the composition of the clay, the more difficult it will be of fusion. Clays which contain an excess of iron or lime can be corrected by a large quantity of these ingredients. The fixed or *fireproof* clays are thus distinguished from the *fusible* ones. Those containing iron are either red, yellow, or blue, after firing, according to the quantity of the metallic oxide they contain, and the degree of heat to which they have been subjected. Many kinds of clay are permeated by an organic substance which gives them a blue, bluish-grey, or black color, arising from the presence of coloring matters which are of no practical importance, as the clay when exposed to the influence of fire becomes white.

It is upon the property which clay possesses of being converted by heat into a firm compact mass, no longer influenced by the action of water, that its employment in the preparation of bricks and vessels of various kinds depends; and with a view to this object the different varieties of clay have been classified into *fireproof*, *fusible*, *calcareous*, and *ferruginous*—the calcareous being those which effervesce considerably with acids from containing a large proportion of earthy carbonates, particularly lime, while the ochry or ferruginous clays contain much oxide of iron, and possess a red-brown color.

FIREPROOF CLAYS.—*Kaolin* or *Porcelain earth* is one of the most important materials in the production of porcelain. It is an earthy, pure white, greyish, or milk-white substance, easily pulverized. It occurs in granitic soils rich in felspar, but containing little mica or porphyry. The chief localities of this substance are Sedlitz, near Meissen; Morl, near Halle; Oberzell and Diendorff, near Passau; Saint Yriex, near Limoges, Department Nièvre; Saint Austel in Cornwall; China and Japan. Kaolin burns perfectly white. The subjoined analyses exhibit its composition:—

	Kaolin from					St. Yriex. Berthier.
	Aue. Kuhn.	Passau. Fuchs.	Halle. Bley.	St. Yriex. Berthier.	St. Yriex. Berthier.	
Silica,	47·09	43·65	39·62	55·80	47·09	55·80
Alumina,	36·41	35·93	45·00	26·00	36·41	26·00
Potassa,	1·56	—	—	8·20	1·56	8·20
Magnesia,	2·94	—	—	0·50	2·94	0·50
Lime,	—	0·88	0·07	—	—	—
Oxide of iron,	—	1·00	—	1·80	—	1·80
Oxide of manganese,	—	—	0·19	—	—	—
Water,	12·00	18·50	10·00	7·20	12·00	7·20
Loss,	—	0·04	1·80	0·50	—	0·50
	100·00	100·00	100·00	100·00	100·00	100·00

Granite or *Cornish-stone* is a material also much used in the English potteries, and is brought from Cornwall, where the granite hills are intersected by extensive deposits of this stone. It consists chiefly of quartz and felspar, mica not being entirely absent. This rock—pegmatite—after exposure to the decomposing action of the weather for some time, is one of the chief sources, especially in Cornwall, of the porcelain earth. In Cornish stone, which is brought with the porcelain earth into commerce, the decomposition of the felspar has only proceeded so far as to render the stone easily pulverizable. It consists of kaolin, undecomposed felspar, and quartz.

Dr. LYON PLAYFAIR has made the following analyses of two specimens of kaolin from Bluebarrow, and from Saint Stephens, Cornwall:—

	Bluebarrow.		Saint Stephens.
Silica,	45.52	....	46.38
Alumina, with trace of oxide of iron,	40.76	....	38.60
Lime,	2.17	....	3.47
Potassa, with trace of soda,	1.90	....	1.77
Magnesia, phosphoric acid, and sulphuric acid,	traces	....	traces
Water, with a small quantity of organic matter,	9.61	....	9.08

The China Clay Works at Saint Stephens, Cornwall, are composed of extensive tracts of felspathic rock in a high state of decomposition, twenty feet thick, standing on a declivity. Trenches are formed around spaces of the rock, and strong currents of water directed into them, which carry off the decomposed portion, united with small micaceous particles. These streams are directed into large pits, termed *mica pits*, where the particles are deposited. The pits are fitted with boards, which are raised from time to time as required, and as the mica rises in the pit, the finer particles of clay being held in suspension flow over the boards, and are conveyed by channels into other and deeper reservoirs or tanks of very large dimensions. When these large reservoirs are filled, the washing process is stopped, and the fine clay is allowed to settle, and is removed in the state of slip or thin paste to more shallow drying tanks, surrounding the general reservoir. The latter are about eighteen inches deep, and in these the slip is allowed to remain until it becomes a stiff paste. Cutting tools are then passed through crosswise, and the superfluous water runs off. The mass is afterwards cut into squares, which are placed to dry on a space appropriated for the purpose, and previously sanded to prevent the squares of clay being mixed with extraneous matter. The squares are arranged in the most convenient manner for drying, and sand is

sifted over them. When in a sufficiently hard state, women are employed with sharp triangular scrapers, to remove all the sand with care, and the squares are then ready for shipment. The scrapings are collected, and again passed through the washing process, so that little or no loss of materials can arise.

The clays vary much in quality, some being much more aluminous than others, and, although not so white, yet possessing most valuable qualities, and making very sound wares. Beneath the argillaceous strata lie the Cornish stone, which is harder in texture, and can be quarried in masses ready for shipment.

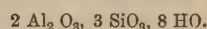
The clays are generally known by certain marks impressed upon them by the clay merchants, and which serve as a guide to the potters to recognize the several qualities, and adapt them to the uses of their manufacture.

Granite or Cornish-stone clay, previously dried at 212°, was found to consist of—

	1.	2.	3.
Silica,	46.32	46.29	35.65
Alumina,	39.74	40.09	32.50
Protoxide of iron, .....	.27	.27	1.65
Lime, .....	.36	.50	traces
Magnesia, .....	.44	—	—
Water and some alkali,	12.67	12.67	30.05
Loss,	0.20	0.18	0.15
	100.00	100.00	100.00

Specimen, No. 3, was analyzed by RICHARDSON in its unprepared state.

Another substance, nearly allied to kaolin, and which occurs in large quantities at Houscha, near Bayonne, and is often used in the manufacture of porcelain, has been found by BERTHIER to be halloylite, mixed with a product of the decomposition of pegmatite; it forms a connected, tolerably soft, and easily pulverized mass, is of a dull white color and opaque, affording no dough with water, and consequently not plastic. BERTHIER found it, on analysis, to be represented by the formula—



Pipe-clay is of different colors, very tough, exceedingly plastic, and becomes white, or sometimes yellow in the fire, from the presence of a small quantity of iron. It is used in the manufacture of stoneware, clay pipes, earthenware, *et cetera*, and occurs in very considerable quantities. The most generally known localities are on the Lower Rhine; at Cologne and Coblenz, near Halle; in Devonshire and at Stourbridge in England; and at Dreux and Forges-les-Eaux in France. The following analyses show that these clays contain but little iron and foreign earths:—

	Grossalmerode. Forchhammer.	Strasbourg. Berthier.	Stourbridge. Berthier.	Stourbridge. Editor.	Forges-les-Eaux. Berthier.	Coteau de Prairie, N. America, Catlin.
Silica,	15.906	66.70	63.70	62.99	52.00	48.20
Alumina,	11.170	18.20	20.70	20.04	27.00	28.20
Lime,	3.504	—	—	0.30	—	2.60
Magnesia,	—	0.60	—	0.94	—	6.00
Potassa,	0.786	—	—	—	—	—
Water,	4.119	12.00	10.00	10.70	19.00	—
Oxide of iron,	—	1.60	4.50	trace	2.00	5.00
Oxide of manganese,	—	—	—	—	—	0.60
Residue,	64.030	—	—	—	—	—
Loss, &c.,	0.485	0.90	1.10	5.03	—	10.00
	100.00	100.00	100.00	100.00	100.00	100.00

These analyses, however, give no clue to the nature of the aluminous compound. The proportion of silica in combination with the alumina and the proportion left free not being stated, while the amount of residue not capable of decomposition by the aid of sulphuric acid is only given in one instance, hence the great differences in the relative proportion of the alumina to the silica, which, observing the same order, is as follows:

3:1, 4:1, 3:1, 2:1, 1:1, and 2:1.

In England pipe-clay occurs as a second layer below the sandy clay which is used in making tobacco pipes. This clay, owing to its possessing the property of contracting more than sandy pipe-clay, is not employed in the manufacture of earthenware; its component parts are,—

	Centesimally.
Silica,.....	53·66
Alumina,.....	32·00
Protoxide of iron,.....	1·35
Lime,.....	0·40
Magnesia,.....	trace
Water,.....	12·08
Loss,.....	0·51
	100·00

Pipe-clay also burns white in the fire, and, before the oxyhydrogen blowpipe it melts to a transparent, almost colorless glass.

Potter's clay.—Among the *fusible clays* may be classed *Potter's clay*, generally used for the production of the commoner kinds of clay-ware. It is distinguished from pipe-clay by the presence of a very sensible quantity of iron and some lime, is more easily disseminated through water, and has the same amount of plasticity as pipe-clay. The presence of lime causes it to effervesce slightly with acids. In color it is generally red, or brown-red, sometimes part-colored from the intermixture of various layers; is less homogeneous than pipe-clay; contains a considerable amount of organic remains, fragments of stone and iron pyrites; varies exceedingly according to the locality in which it is found, being sometimes fat, at others poor. The presence of the oxide of iron causes it always to assume a red or yellow hue after burning, and according to the quantities of this ingredient and of lime which it contains, it fuses more or less easily into a dark, vitreous mass or slag. The analysis of potter's clay, from different localities, gives the following results:—

By	Potter's clay from	Silica.	Alumina.	Iron.	Lime,
Aubert,	Provins—D. Seine et Marne—	57	37	4	1·7
Berthier,	Livernon—D. Lot—	61	30	7·6	2·4
Laureat,	Helsingborg,	60	24	7·5	0·5

The relation of the silica to the alumina in these specimens is, therefore, as 5: 3, 2: 1, and 5: 2.

The common potter's clays in England are found in layers or strata lying over each other, each stratum possessing some distinctive property which fits it for a peculiar purpose. That which is called the sandy stiff, or ball-clay, is the upper layer, and from the considerable quantity of silica it contains is used for making salt-glazed ware. On analysis this clay, dried at 212°, will be found to yield:—

Silica,.....	66·68
Alumina,.....	26·08
Protoxide of iron,.....	1·26
Lime,.....	·84
Magnesia,.....	trace
Water,.....	5·14

100·00

Its specific gravity,..... 2·558

Blue Clay, also one of the fusible clays, is considered the best layer of clay in the whole series. In color it is greyish, but burns perfectly white, approaching China-clay in character. When exsiccated at a temperature of 212°, its analysis, according to Mr. HIGGINBOTHAM, gives the following composition:—

Silica,.....	46·38
Alumina,.....	38·04
Protoxide of iron,.....	1·04
Lime,.....	1·20
Magnesia,.....	trace
Water,.....	13·44

100·00

This clay is also called Dorsetshire and Poole clay, Poole being the port of shipment. It is obtained chiefly from the neighborhood of Wareham, and large quantities are shipped annually for Staffordshire and other parts of the United Kingdom.

These mines of clay are very large, extending upwards of seven miles from the port of shipment. The method of getting the clay varies according to the locality, and great trouble and expense are incurred in removing the superincumbent strata of soil, sand, and bituminous matter, which vary from sixty to eighty feet in thickness, the clay lying beneath a fine bed of sand. The heading of the clay is mixed with sand, and formerly was thrown aside as worthless; but of late years this has been extensively used for fire and fancy bricks, and for other ornamental and useful purposes. The bed of clay, once fairly laid open, is worked by cutting out cubical blocks weighing thirty to forty pounds each, with spades adapted to the work; and to facilitate the operation, currents of water are directed into small dams, into which the workmen constantly dip their spades: inspectors are engaged to examine the quality of the clay as it is taken from the beds, and to reject such as is not considered sufficiently good for shipment. The beds vary from three to six feet in thickness, and the latter is considered a profitable depth. The land from which the clay is procured is taken at a nominally low rental, but in consequence of the expense of removal of surface soil, the rental virtually is large. Returns of the quantities of clay raised are made from time to time, according to the terms of the lease. Railways are now in immediate connection with the mines direct to the port of shipment, and the clay is conveyed thence to Runcorn, where the cargoes are discharged, and forwarded by flats or small boats to the various manufactories throughout the district of the Staffordshire potteries.

The export of Poole clay, according to the Poole Custom House returns, reached in 1850, 54,877 tons; in 1851, 69,286 tons; and in 1859, about 102,000 tons. Many other clays of less value are obtained from the Poole bed.

The *Red* or *Brown Clay*, found in great quantities in

the vicinity of Glasgow, is a surface clay, the deep brown color of which results from the presence of a large quantity of sesquioxide of iron. It is in great demand for common black ware, flower-pots, and red bricks, articles which do not require to be exposed to any very high temperature which would fuse them. This clay, by analysis, yields—

Silica,.....	49.44
Alumina,.....	34.26
Protoxide of iron,.....	7.74
Lime,.....	1.48
Water,.....	1.94
Magnesia,.....	5.14
	100.00

An artificial yellow clay is obtained by a mixture together of sandy clay and red clay.

Fire-clay.—Another variety of clay, termed *Marl* or *Fire-clay*, is very abundant, occurring both on the surface and at various depths underground. From the porosity of its substance, it is well adapted to resist high temperatures, and its principal use in the potteries is for making seggars, or vessels for protecting the ware from the flames during firing. Fire-bricks, crucibles, and melting-pots for glass-works are made from this clay. Analysed, it gives the following composition:—

Silica,.....	66.16
Alumina,.....	22.54
Protoxide of iron,.....	5.31
Lime,.....	1.42
Magnesia,.....	trace
Water,.....	3.14
Loss,.....	1.43
	100.00

Fuller's-earth, a porous silicate of alumina, is a

Locality.	Silica.	Alumina.	Oxide of iron.	Carbonate of lime.	Carbonate of magnesia.	Alkali.	Analysts.
Abydos,.....	52.00	16.17	6.15	13.97	trace	trace	Salvetat.
Bonnefonds,.....	40.00	13.21	2.04	34.12	0.15	—	„
Belleville,.....	46.03	17.28	5.70	27.64	—	—	Buisson.
Chambray,.....	49.50	29.00	3.00	18.00	0.50	trace	Laurent.
Savone,.....	37.00	11.00	6.50	55.00	—	—	Buisson.
Viroflay,.....	39.00	18.00	1.00	40.00	trace	—	Lecog.
Villom,.....	30.00	20.00	2.00	46.00	—	—	„

A small portion of the lime in the marl is generally in combination with silica.

Loam is the commonest and least pure variety of clay belonging to the more recent alluvial formations; it is less uniform than any of the foregoing varieties—sand, gravel, stones, wood, roots, and all kinds of vegetal remains being mixed up with it in large proportions. The presence of hydrated oxide of iron gives it a yellow, spotted, and veiny color. Lime is also present, but in less quantity than in the marls. It is soft and easily reduced to powder, absorbs water with avidity, and forms with it a soft paste, which is much less plastic and fat than that obtained from pipe or potter's clay. As it occurs almost everywhere, it is the universal material for making bricks.

Ferruginous Clays, amongst which may be classed redde, bole, and ochre. The former two derive their red color from the presence of oxide of iron, the latter its yellow tinge from the hydrate of the same oxide. These varieties are used as pigments, but not for the same purposes as the other clays. From the large

fusible clay, distinguished from potter's-clay by its slight degree of plasticity. It is easily formed into a soft paste with water, and has a strong adhesion to oily matters, upon which depends the cleansing action of this clay upon woollen stuffs. The best clay for fulling cloth should be neither tenacious nor sandy; as in the first case it would not be easily diffused through water, and in the second it would abrade the cloth too much. The principal localities where it is found are in Bedfordshire, Berkshire, Hampshire, and near Nutfield, Ryegate, in Surrey.

CALCAREOUS CLAYS.—*The Marls*, a term which applies to all those deposits containing clay and carbonate of lime, the latter in considerable quantity. These mixtures being mechanical, and comprising all the intermediate formations between the limestone and the clays, are, from the variable quantities of the ingredient, multifarious in character. Those in which lime preponderates are named *Calcareous Marls*; those in which alumina is most abundant, *Aluminous Marls*. In general the marls afford the most fruitful soil for the purposes of agriculture. Aluminous marls are used in the manufacture of several kinds of pottery. They effervesce with acids. They are chiefly found in extensive stratified layers, consisting of a massive, but soft and pulverable substance, presenting an uneven, conchoidal fracture, easily permeable by water, and possessing but little plasticity; in color of a grey passing into brown. Aluminous marl is rarely of a uniform texture throughout, enclosing hard calcareous or silicious nodules; falls easily to pieces by exposure to the air, and is reckoned amongst the most widely diffused varieties of clay. The proportion of its constituents will be seen from the following analyses:—

amount of iron they contain they are sometimes classed with the ores of that metal.

Flint, quartz, silica, or silicic acid— SiO_2 —is found as an amorphous, black or brown colored mass, and occurs with chalk in roundish or irregularly shaped nodules, weighing from a few ounces to several pounds; it contains moisture, an organic substance, and occasionally iron. Whatever its original hue may be, it always burns white, and acts the part of a bleaching material, neutralizing imperceptibly the yellow or greyish color of the clay. In preparation for use, the flints are calcined in upright furnaces, constructed similarly to ordinary lime-kilns. The flint is thus rendered white and disintegrated, splits in all directions, and is sufficiently brittle and soft to admit of being crushed in the stamping mill, and ground under water in the block mill. A description of these processes will be given further on, under *Earthenware*.

CLASSIFICATION.—The production of earthenware from the different kinds of clays is effected by producing the proper form with the aid of the plasticity of

the clay, and afterwards modifying the formed vessels by heat in such a manner that they become no longer soft or flexible, but of a rigid stony consistence, permanently retaining their form, and able to resist the mechanical violence necessarily inflicted upon them by daily use. The quality of such vessels must necessarily vary according to the nature of the clay, the ingredients incorporated with it, the processes of purification, and the degree of heat of the furnace. Such differences are partly recognized by the color, texture, fracture, hardness, solidity, transparency, and chemical constitution of the ware, and partly by the sound produced by tapping. Many clay wares, *bricks and tiles*, have the appearance of being composed of various clays imperfectly mixed together, and containing foreign substances, as stones, *et cetera*. Other kinds again appear of a more homogeneous consistency, but resemble the former in the porous nature of the mass, which is soft, easily scratched, of an earthy fracture, little sonorous, and perfectly opaque. All ordinary pottery and earthenware, both ancient and modern, belong to this class.

There are other wares, again, such as *stoneware*, in which the mass combines a dense structure with considerable hardness, has lost its porosity and the properties connected with it, by the action of the intense heat of the kiln; produces a clear, sharp, ringing sound when struck; is somewhat translucent, with a fracture indicating an incipient fusion.

Porcelain exhibits the same properties—a fusible substance or *flux* being mixed with the clay.

Burnt clay-wares of a porous nature, and even non-porous vessels, to correct the roughness of surface, are generally covered with a vitreous coating or *glaze*, which, when it contains lead, is fusible and soft; when containing no lead, is refractory and hard. This glaze, according to the nature and requirements of the vessel, being laid on in thinner or thicker coats.

It is upon these and similar considerations that the classification of clay-wares is based.

CLASS 1.—Mass uniformly fluxed, dense, cannot be scratched with the knife, finely granular, *translucent*, very sonorous, white, and uniform.

PORCELAIN.—*Tender Porcelain*.—Mass easily fusible.

English.—Flux, bone-ashes—glaze containing lead and borax.

French.—A vitreous mass, containing no clay, with a lead glaze of harder consistence.

Real Porcelain.—Mass difficult of fusion; flux, a refractory glass, composed of silicate of alumina and potassa; glaze of a similar nature, often containing lime.

CLASS 2.—Mass dense, cannot be scratched with the knife, sonorous, finely granular, uniform, exhibiting incipient fusion, scarcely translucent—or only on the edges—white or colored.

STONEWARE.—*Common Stoneware*.—Mass of a reddish grey or bluish color, generally without glaze, a salt glaze only.

Ironstone Ware.—Mass generally white when it contains a flux, and has a lead glaze; artificially colored, also, without glaze.

CLASS 3.—Mass earthy, porous, pretty hard, opaque, texture open, little sonorous.

EARTHENWARE.—*Fine Earthenware*.—Mass white,

hard and sonorous; glaze of crystal, soft, containing lead.

Delft Ware.—Mass finely granular, uniform, more or less tinged yellow; glaze, a soft white or colored enamel.

CLASS 4.—Mass earthy, very porous, opaque, soft, homogeneous texture, always colored.

Ordinary Pottery.—Partly glazed and partly unglazed; the glaze may contain lead or not, but is always easy of fusion, and transparent.

Lustre Ware.—Mass earthy, porous, opaque, very soft; texture not uniform; glaze metallic and not transparent.

CLASS 5.—Mass more or less not uniform, always colored, very soft, porous, and open, little sonorous, and opaque.

Bricks, Tiles, Ornaments.—Sometimes glazed; mass fusible at a high temperature.

Fireproof Stones, Crucibles.—Mass difficult of fusion, or infusible; not glazed.

PORCELAIN.—*Tender Porcelain*.—This appellation has reference not so much to the hardness of the clay, as it has to the feeble resistance offered by this class of wares to the high temperature of the kiln, and the softness of the glaze, compared with true porcelain. It may be classed under two heads:—Natural, or the tender porcelain of England, in which kaolin or China-clay is the basis; and artificial, or the tender porcelain of France, in which the mass is a mixture of different substances, consisting mainly of silica, with alkaline and earthy salts.

English Tender Porcelain.—So named because the manufacture is exclusively confined to this country, local reasons being unfavorable to the production of true porcelain. The chief of these is the want of a cheap material for the construction of the seggars able to stand the firing, the present loss of seggars in Staffordshire being estimated at from eight to ten per cent. at each firing.

The crude materials which enter into the composition of ironstone China are *plastic clay*, *kaolin* or *China-clay*, and *granite* or *Cornish-stone*, with *chalk flints*, and occasionally *steatite* or *soap stone*, which contains magnesia, 44; silica, 44; alumina, 2; iron, 7.3; oxide of manganese, 1.5; oxide of chromium, 1.2, with traces of lime and chlorine—the action of which is said to diminish the contraction of the wares in the furnace. The bones, which are obtained either from native cattle or by importation, may previously have been employed for the extraction of gelatin or glue, or, for the production of ammoniacal salts by dry distillation, or may be used in the form of animal charcoal; but before they are applicable to the present purpose, they must be thoroughly calcined by being heated to redness with free access of air, so as to destroy all their organic constituents and leave only the mineral ash, phosphate of lime, carbonate of lime, and a little magnesia, in the form of a perfectly white substance. The phosphoric acid diffuses itself at a high temperature through all the materials, uniting them into a translucent enamel, which, being less apt to shrink and lose its form than the hard China body, may be baked in larger kilns, and with less risk of loss

to the manufacturer. All these ingredients are ground, suspended in water, and evaporated into the form of paste in the manner to be afterwards described under *True Porcelain* and *Earthenware*. A frit is then prepared, of which the mass is made up with other substances, as follows :—

FRIT.	
Bone,	100
Sand,	90
Pearlash,	7
MASS.	
Burnt bone,	600
Kaolin,	300
Cornish-stone,	360
Frit,	40

or the mass is not fritted in part, but, as in the case of table-ware, mixed all at once, in the following proportions :—

Bone,	450
Cornish-stone,	200
China-clay,	160
Plastic blue clay,	45

Other mixtures for English China-ware may be given as follows :—

I.	
Bone,	46
China-clay,	23
Cornish-stone,	31

II.	
Bone,	36
Cornish-stone,	21
Cornish-clay,	21
Flint,	12

III.	
China-clay,	600
Felspar,	335
Bone,	840

IV.	
Bone,	320
China-clay,	225
Cornish-stone,	230

The bone and flint are sometimes fritted to produce the highest degree of vitrescence, and then mixed up with other ingredients. A little Dorset clay is frequently added for large pieces, as dishes, *et cetera*, to give more ductility in working and greater stability in the fire. In all cases the ware, from the large proportion of clay in the mass and its extreme plasticity, requires to be fired twice. The first firing lasts longest, being of from forty-eight to fifty hours' duration; and the temperature is gradually raised during the whole time, the heat of the kiln, ranging, according to the composition of the ware, from 100° to 110° Wedgwood's pyrometer. It is somewhat singular that this instrument is never used in the potteries, the proper temperature being regulated by small trial pieces of the same material as the goods to be fired. The average quantity of coal consumed at a firing is from ten to twelve tons. When the trial pieces show that the heat is sufficiently raised, the firing is discontinued, the fire and ashpit doors closed, and the whole left to cool during twenty-four or thirty hours. The glaze is then applied to the ware, and the articles undergo a second firing, but neither at so high a temperature nor of so long duration; and in this consists the essential difference between English and foreign

manufacture; abroad the greatest heat being applied to the glazed vessels, and not to the biscuit ware.

GLAZES.—The porosity of ordinary porcelain seems early to have suggested the use of a glaze, or thin glass covering, for the purpose of rendering it impervious to fluids. The composition of such glazes requires to be such, that when they are exposed to the necessary heat, they shall unite with the body or paste; and that in cooling they may not split, crack, or craze, from occupying less volume in their fired state, and their consequent inability to completely cover or envelope the body of the ware underneath. Those most commonly used are flint, quartz, sand, felspar, gypsum or sulphate of lime, carbonate of lime, borax, boracic acid, chloride of sodium, potassa, soda, and oxide of lead. Some glazes are first formed into *frits*, imperfectly vitrified bodies so termed, and afterwards pounded for use.

Colored glazes are made with the addition of nearly pure oxides of manganese, copper, iron, chromium, cobalt, *et cetera*; *opaque glazes* or enamels, by the addition of oxide of tin, or phosphate of lime; for which see *Porcelain True* and *Earthenware*. Some of the ordinary lead glazes for soft porcelain are given below :—

Cornish China-stone,	100
Calcined flint,	60
Carbonate of lime,	25
Cornish kaolin,	10
Soda,	10
Borax,	60
Carbonate of lead,	30

These ingredients are all fritted together with the addition of twenty per cent. carbonate of lead and ten per cent. flint :—

Cornish China-stone,	34
Chalk,	17
Ground flint,	15
Borax,	34
100	

which substances, when fritted and ground together, are mixed with ten per cent. of Cornish-stone and twenty-one per cent. of carbonate of lead. The lead is sometimes omitted from the mixture, and the requisite fluidity of the glaze maintained by an additional quantity of borax :—

Cornish China-stone,	25
Soda,	6
Borax,	3
Nitre,	1

fritted together in gloss oven, and the mixture used in the following proportion :—

Frit,	26
China-stone,	26
White lead,	31
Flint,	7
Carbonate of lime,	7
Oxide of tin,	3

the whiteness being increased by the addition of a little oxide of cobalt. Another glaze for tender porcelain is given below :—

Felspar,	38
Lynnsand,	24
Carbonate of lime,	11
Borax,	27

fritted together and mixed as follows :—

Frit,	60
Cornish-stone,	20
White lead,	20

—see *Earthenware and Porcelain*. But the almost entire absence of clay, depriving the mass of plasticity, rendered the operation one of great difficulty and expense, the cohesion between the particles being extremely slight. This defect was partly overcome by the admixture of one-eighth part of soap and glue, or gum tragacanth, which imparted so much tenacity to the composition as enabled the mass either to be formed in gypsum moulds, or turned upon the potter's lathe. The operation of firing was one likewise of considerable risk, from the vitreous nature of the mixture; the prominent portions of the ware being often either fused or so softened by the heat as to lose their shape. Such defects could only be remedied by suitable supports, at a great expenditure both of time and trouble. The first firing, which was of longer duration than in the case of real porcelain, extended over a period of from sixty-five to a hundred hours; the glaze was afterwards applied to the vessels, and fired for a further period of thirty hours. The colors employed in the decoration of this species of porcelain required careful and particular treatment and preparation. In firing, the dishes and wares, instead of being placed in the kiln in a horizontal position, were suspended on pegs in a vertical direction to avoid fracture, which otherwise would have occurred. The point of suspension—a small hole—will be readily discernible on the under side of all Sèvres porcelain, and indicates a remarkable feature in the process of the manufacture.

Foreign Porcelain or China is the finest and most valuable description of ware, distinguished from other wares by the composition of the paste from which it is formed, giving a body of a fine, hard, translucent texture. Great care is exercised in the selection of the materials to give a colorless mass after firing. Two essentially

different constituents enter into its formation, one an infusible, plastic, white clay, called *kaolin*, or China-clay; the other a fusible, non-plastic material, the so-called *flux*, composed of felspar, with the addition of quartz, chalk, and gypsum, which, softening and becoming vitrified in the heat of the porcelain kiln, forms a kind of cement, binding the clay firmly together, and producing a dense, impenetrable, translucent mass, of a uniform texture throughout, and impervious to liquids. The transparency of porcelain arises, therefore, from the clay body becoming saturated with a mass of glassy flux. Under the microscope the two ingredients can be clearly distinguished from each other, the milky mass appearing as a transparent ground, mixed with an opaque substance, composed of minute globules, arranged in a lineal direction, one on the other, as articulated threads or little rods, which are interwoven and cross each other in all directions; the want of absolute transparency in the mass being due to the reflection and refraction of light from the surfaces of these crystals.

The *Glaze*, equally characteristic with the mass, is composed of *felspar*, sometimes mixed with a little gypsum, but with an entire absence of lead or tin ; it is consequently, of the same nature as the flux, and can be brought into the most intimate union with the flux and the mass, securing another essential characteristic of porcelain—the non-separation or peeling of the glaze from the vessel by any outward shock or sudden changes in temperature. The expansive and contractile powers of the glaze being assimilated to that of the body, it is not affected by high temperature, and its surface is less liable to the crazing so often discernible upon other kinds of clay wares. The absence of lead causes the glaze to be very hard, and to resist scratching. The mass for porcelain vessels is composed as follows:—

FINE OR HARD PORCELAIN—COMPOSITION OF THE MASS.
IN BERLIN.

IN DRESDEN.		IN VIENNA.	
For Domestic Uses, Plates, Dishes, &c. <i>et cetera</i> .	For Ornamental Purposes.		
Kaolin from Morl, .....76	Kaolin from Morl, .....25	Kaolin from Auerbach, .....72	
Felspar, .....24	Kaolin from Beidersee, .....50	Felspar, .....12	
	Felspar, .....15	Quartz, .....12	
	Pure sand, .....10	Gypsum, .....4	
IN SEVRES, NEAR PARIS.	IN ST. PETERSBURG.	IN COPENHAGEN.	
For Vessels.	For Tableware.		
Kaolin from St. Yriex, .....48	Kaolin from Risansky, .....50	Kaolin from Bornholm, .....40	
Sand, separated from above, containing felspar, .....48	Felspar, Finland, .....25	Quartz from Arendal, .....33	
Chalk, .....4	Quartz, .....25	Felspar, .....27	
IN MEISSEN, SAXONY—COMMONLY CALLED DRESDEN PORCELAIN.		IN NYMPHENBURG, NEAR MUNICH.	
For Domestic Purposes	For Ornamental Purposes.	For Low Temperatures.	For High Temperatures.
Kaolin from Aue, .....18	Kaolin from Seilitz, .....37	Kaolin from Passau, .....62·5	65
" " Sosa, .....18	Quartz, .....37	Quartz, .....19	21
" " Seilitz, 36	Lime from Pirna, .....17½	Sand separated by water from kaolin, .....6	4
Felspar, .....26	Broken porcelain, .....8½	Gypsum, .....5	5
Broken biscuit por- celain, .....2		Broken porcelain, .....7·5	5

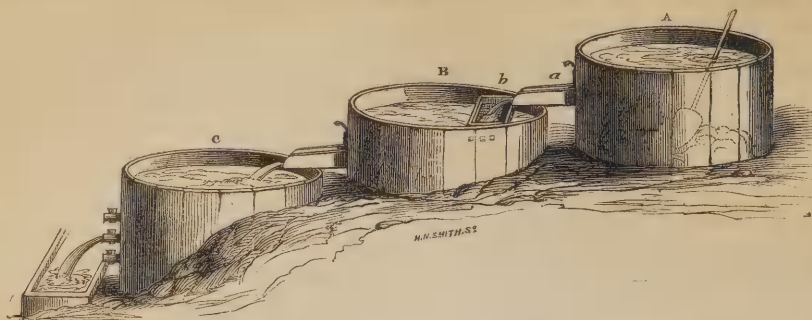
The following analyses of foreign porcelain are given, as having been recently made :—

	Berlin.	Chinese.	
		Superior.	Inferior.
Silica,	72·96	71·04	68·96
Alumina and protoxide of iron,	24·78	22·46	29·24
Lime,	1·04	3·82	1·60
Alkali,	1·22	2·68	—
	100·00	100·00	99·80
Specific gravity,	2·419	2·314	23·14

Preparation of the Material.—Crude kaolin is not sufficiently pure for the purpose of manufacture, being a mixture of real kaolin with undecomposed felspar and particles of quartz, both of which must be separated or finely ground and mixed, to form a uniform substance throughout. This process of washing and suspending in water, which precedes the grinding, is generally undertaken at the porcelain works, though in some cases it is partially effected at the pits.

The decanting or elutriating apparatus consists of three tubs or basins, A, B, C, placed one above the other—Fig. 466—the kaolin being put into the first basin. A, two men thoroughly mix the mass up with water

Fig. 466.



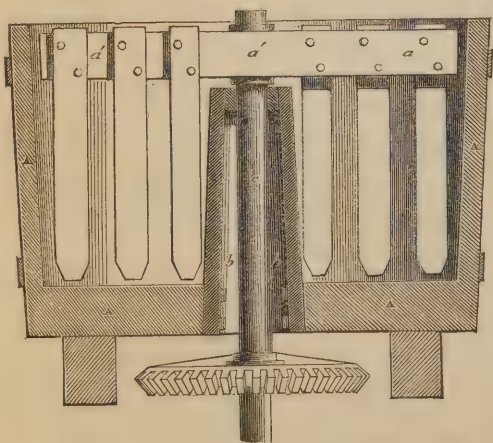
by stirring it with wooden spades or blungers. When every part has been thoroughly elutriated, the mixture is allowed to run off by the removal of a plug along the channel, *a*, situated a few inches above the bottom, into the vat, B, the stones and coarser particles remaining behind, while those carried forward are arrested by the sieve, *b*, leaving only the decanted liquid containing fine sandy particles mixed with real kaolin. After a further stirring, and remaining for a short time at rest, the sand subsides completely to the bottom, the liquid carrying with it only the argillaceous kaolin into the lowest vessel, where it is allowed to deposit completely before the water is drawn off from the finely-divided clay. Sometimes, as at Sèvres, there are six of these filters, at each of which two men are employed, the small particles of wood, straw, and other light bodies, which of themselves would not fall to the bottom, but float, being separated from the mixture or *slip*—a term in pottery technically applied to any preparation of clay in a state of suspension in water—in its passage from

particular kind of sand and crude kaolin. Sometimes machinery is employed instead of manual labor, for the stirring or kneading up of the mass with water. A vat, A—Fig. 467—is furnished with revolving arms, *a' a' a'*, armed with wooden oars or blungers, which, in their revolution through the mass, effect the requisite kneading and mixing, before the liquid is withdrawn into the subsiding vats. The shaft, *c*, carrying the arms, is inclosed in a second hollow shaft, *b*, to protect the mixture from dust and oil.

Chalk from Bougival is a constant addition to the porcelain paste. The chalk contains about ninety-five per cent. carbonate of lime. Its analysis is as follows—

Carbonate of lime,	95.50
Carbonate of magnesia,	0.80
Silica,	0.80
Water,	1.20
Iron, manganese, and alumina,	1.70
	100.00

Fig. 467.



one to another, by passing through hair sieves. This process of decantation supplies a sufficient amount of felspar and quartz in the state of sand, the strong and argillaceous varieties giving each their

Limestones of equal purity may be substituted for the chalk. At Nymphenburg, as in Meissen, fragments of old porcelain are also added, the mixture of which, when allowed to exceed a certain proportion, injures the plasticity of the paste. For the production of the best class of porcelain much depends upon the careful selection of the kaolin and material, the cost of manufacture being the same. With inferior clay the porcelain loses its whiteness, its sonorous ring, and much of its value. Kaolin, to be regarded as of the first quality and suitable for the finest manufacture, should possess a body of a beautiful white color resembling pure milk, entirely free from all foreign substances, however minute, capable of producing stain or blemish in the subsequent processes of manufacture; also the porcelain body formed from it should be easily worked without fear of cracking, neither too fusible nor too argillaceous; for although it may be possible to correct these faults by appropriate mixture, the mass never turns out so satisfactory. Great care must likewise be bestowed upon the uniform incorporation of the ingredients, so that everything of a coarse and massive nature, as felspar, chalk, gypsum, broken porcelain, *et cetera*, be reduced to the finest state of division, and the rejection of all particles of iron, mica, *et cetera*, which sometimes occur, and the

presence of which might impair the whiteness of the china. Mills are, therefore, employed for this purpose. A vertical section of one is given in Fig. 468. Two millstones, *a* and *b*, are inclosed in a

a b, the bearings of which are secured in solid masonry or framework. *c* is a shaft passing through a boss head, *c*, in the axle, *a b*, and carrying with it a strong framework, *E E*, bedded with stone, upon which the

Fig. 468.

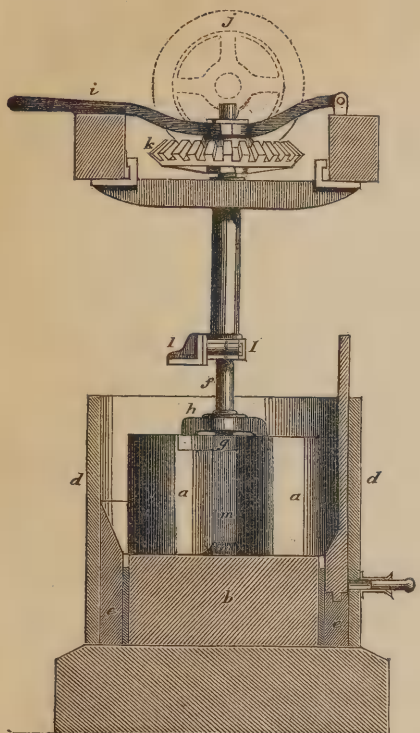
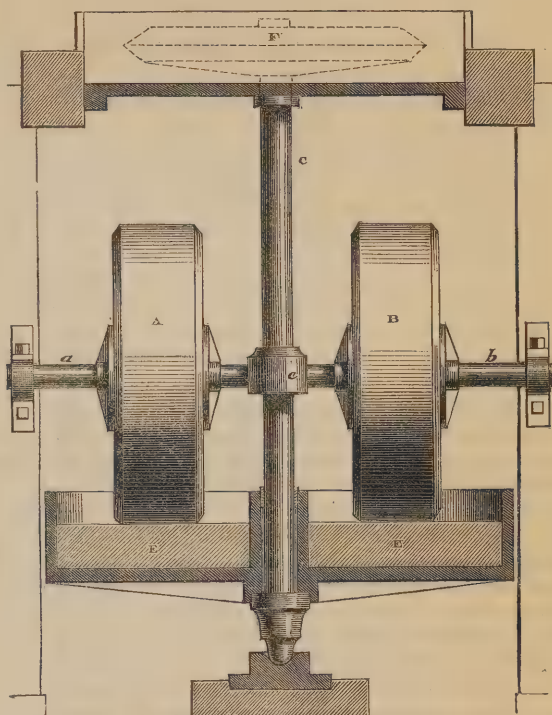


Fig. 469.



cylindrical case or framework, *d*, bound together by hoops, the lower one, *b*, being fixed into position by the wedging, *e*, while the upper one, *a*, revolves by motion communicated to it through the shaft, *f*. This shaft is keyed to the stone by means of a metal casting, *g*, let into its upper surface, which receives the coupling arm, *h*, attached to the lower extremity of the shaft, where it is depressed by the lever, *i*. *j* and *k* are two bevil wheels to which motion is given either by steam or water power, the axle of the horizontal wheel, *k*, being hollow and supported by bearings, *l l*. The shaft, *f*, in direct communication with the millstone, passes through this hollow casing, the rotatory motion of which is imparted to it by the spurs of the lever, *i*, when lowered, coupling with those of the arms of the revolving wheel, *k*. In order to guide the material better in a downward direction, the upper stone, *a*, is not perfectly round, but hewn flat on two sides, with two grooves, *m m*, cut opposite to each other. If the pieces of stone are of larger dimensions than these spaces, they will, of necessity, be excluded from the spot where the tituration is effected. They are, therefore, previously taken to the crushing machine, and brought to a uniform size. Fig. 469 represents a

mill-stones revolve and crush the material thrown in. The revolution of this mass is effected by the spur-wheel, *F*, driven by steam or other power. The materials in every case having been ground, and the clay separated from its coarser particles by elutriation in the manner described under *Kaolin*, are in a state of very fine powder, and mixed together in various proportions according to the manufacture. This is effected by mixing the several ingredients, felspar, kaolin, *et cetera*, by measure in a liquid state, the proportion of weight of solid matter contained in a cubic foot of each separate specimen of *slip* having been previously ascertained, and none of the material being allowed to settle down, but each forming a thickish uniform semiliquid mass.

This method of mixing, although more accurate than that of weighing, does not always give the exact proportion required, in consequence of the changeable nature of the kaolin, which contains sometimes more or less silica and alumina, and these, with the variation in the quantities of potash and lime, materially affect the qualities of the paste. The best proportions of the mass have been determined from a mean of several analyses of the best porcelain manufactured at Sèvres between the years 1770-1836; and are found, according to the results of experience, to be as follows:—

Silica,.....	58.0	Lime,.....	4.5
Alumina,.....	34.0	Potassa,.....	3.0

It is, therefore, only necessary to make an analysis of each of the crude materials that are to be mixed together, to ascertain the quantity of silica, alumina, lime, and potassa each contains, in order to obtain the data for calculating how much of each by weight, and consequently by measure in their semifluid state, will be required to obtain the proper mean quantity as nearly as possible in the mass.

It is worthy of remark, however, that artificial proportions are never so satisfactory in their results as the same when occurring in the natural condition of the kaolin.

Every importation of kaolin being chemically a different mixture, the proportions used of it will vary each time; but the mass must always contain the same quantity of elementary constituents, as the following mixtures of 1839 and 1843 will demonstrate :—

Mixture of 1839.		Contains				Mixture of 1843.		Contains			
Composed of		Silica.	Alumina.	Lime.	Potash.	Composed of		Silica.	Alumina.	Lime.	Potash.
73 Decanted kaolin,		38.69	30.66	0.73	1.75	48 Kaolin,.....		30	16.90	0.05	0.96
24 Felspathic sand,		19.27	3.40	—	1.27	48 Felspathic sand,....		28.30	17.04	0.53	2.01
3 Lime.....		—	—	3.77	—	4 Lime,.....		—	—	4.00	—
		57.96	34.06	4.5	3.02			58.03	33.94	4.58	2.97

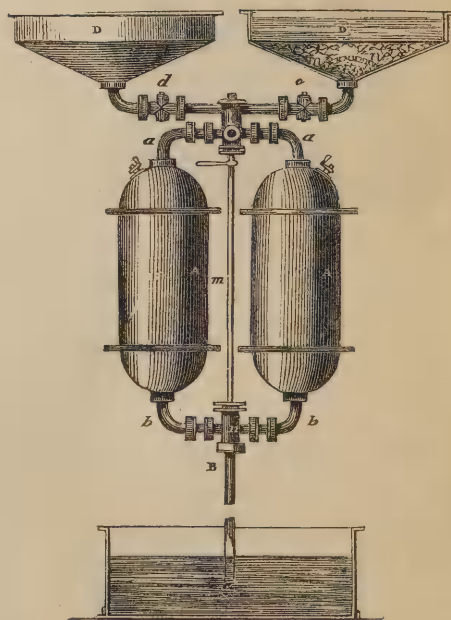
It is not to be understood that the practice at Sèvres is applicable to all other localities, or that every species of porcelain, possessing the same elementary composition, should exhibit the same properties; for even supposing the composition in one hundred parts to be identical, very much depends upon the nature of the proximate ingredients in the mixture.

The incorporation of the *mass* is effected in large cisterns or tanks under constant stirring, the paste being afterwards so far freed from water as to form a kneadable, dough-like mass. As this cannot be effected by subsidence, in consequence of the heavier felspar particles falling by gravity to the bottom and causing a disintegration of the mass, recourse is had sometimes to ebullition and evaporation, by which constant currents are kept up in the liquid, and any separation of parts is prevented. This process, however, is not well adapted to porcelain mixture, as it impairs its plasticity, and causes it to become, in technical language, *short*. Other methods are, therefore, substituted—one of which consists in drawing off the paste or slip into long shallow troughs, having their bottoms composed of gypsum, the porosity of which absorbs the moisture from the paste. In this process the gypsum beds require to be repeatedly dried by a gentle heat or by the action of air. Latterly, however, the application of gypsum, as a drying agent, has been superseded by direct pressure, either applied mechanically or by means of the atmosphere. In the former case the mixtures are inclosed in sacks of a strong and closely woven texture, the threads being carefully freed from filaments so as not to attach themselves to the paste, and which previous to use have been well soaked in hot linseed oil, giving them more durability and permeability to water. A number of these bags being placed between two boards, pressure is economically applied by means of a long lever loaded upon the long arm, and having the shorter arm placed against one of the boards, so that in this way the pressure may be maintained as long as desirable. A press of this description will prepare for use about thirteen hundred pounds of paste in three hours; and the process, though not more economical, has the

advantage of communicating greater plasticity to the mass.

Another more refined and successful plan, invented by M. L. TALABOT, consists in applying atmospheric pressure under vacuum to extract the water from the mass. Two vessels, or chambers, A A—Fig. 470—are

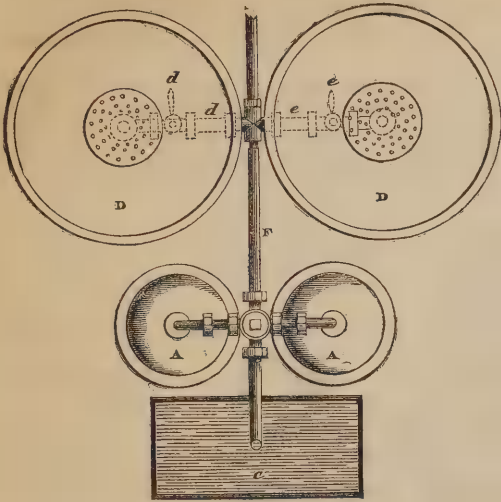
Fig. 470.



placed in connection with a pipe, B, of about thirty-six feet in length, by the tubes, a a, b b, furnished with stopcocks. The extremity of the pipe, B, is immersed in a reservoir of water, c. If one of the chambers, A, be filled with water by the pipe, F—Fig. 471—the stopcock being opened so as to communicate with the reservoir by the pipe, B, a vertical column of water will be formed of from forty to fifty feet in height, but the atmospheric pressure being only equivalent

to a column of about thirty-four feet, the vessel, A, will discharge its contents, by means of the pipe, into the reservoir, c, and form a vacuum above. The filtering vessels, D, D, placed above and communicating

Fig. 471.

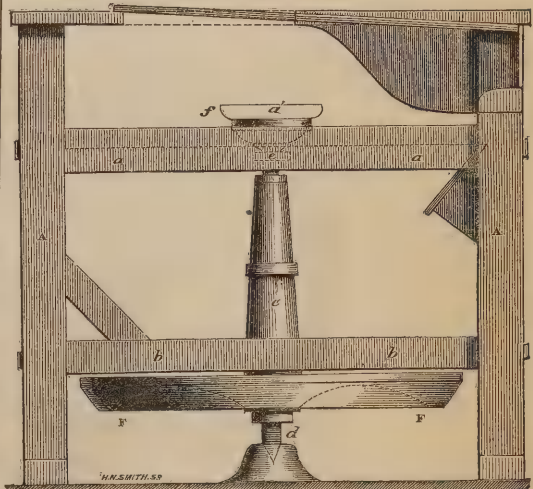


with the reservoirs, A, A, by pipes and stopcocks, *d* and *e*, are of a conical form; iron gratings are placed within over the orifices of the pipes, and a bed of pebbles is made to fill up the conical portion, over which a cloth of a thick spongy felt is placed—permeable to water, but not to the solid particles of the slip—and firmly secured to the edges of the filter; upon this another cloth of hemp receives the slip. Upon depressing the rod, *m*, which works through the two air valves, *nn*, a direct communication is opened above and below between the reservoir and one of the vacuum vessels, and the atmospheric pressure not being counterbalanced below, exerts its whole action upon the surface of the slip, forcing the water through the filtering cloth into the vacuum. In the course of forty or forty-five minutes a layer of slip of six inches deep, containing rather more than fifty per cent. of water, is reduced to a thickness of two and a quarter inches, and converted into a paste of remarkable plasticity, containing only one-fifth of water. In whatever manner this drying of the paste is effected, it is always obtained of equal consistency, the paste from the sacks or pressing apparatus being firmer on the outside than in the interior. This defect is obviated by a process called *slapping*, the clay, generally preserved in the form of lumps or balls, being forcibly thrown repeatedly against a hard stone or slab of gypsum, rendering it perfectly homogeneous throughout. Sometimes treading under foot, or laceration between metallic plates with a stamper, is substituted for the slapping process.

The felspar and lime in the paste, not being plastic ingredients, and always amounting to one-fourth or more of the whole, considerably interfere with its

plasticity, rendering it very much below that of pure clay. The forming and moulding process is consequently one of great expense and difficulty, so much so, that while a workman employed with assistants in preparing plates from the more plastic earthenware, can produce six hundred in ten working hours, not more than sixty or eighty plates of porcelain can be moulded in the same time. Every precaution and endeavor is, therefore, used to increase its plasticity—such as mixing it with fragments from the moulding operation, continued treading and kneading, and, what is found to be of greater utility, the storing it away in moist layers, in order to engender a peculiar species of decay. The superior value of clay that has been kept a considerable time is well known, and it is never desirable to work paste that has not been stored away in a moist state at least for a year. During this process of *aging*, a curious phenomenon occurs: a fetid smell of rotten eggs is evolved from the mass or lump, the interior portion becoming of a darker color passing from grey to black. This black color is produced by the highly carbonaceous product of the decomposition of organic matter, which, by a constant absorption of oxygen, reducing the gypsum and other sulphates that may be present to the state of sulphides, gives rise to the production of sulphide of hydrogen on the outer portions; and wherever the air has access to the blackened part, the black matter disappears, the oxygen being converted under these circumstances into carbonic acid. It is more difficult to assign a reason for the greater plasticity of the mass that has passed through this process, though it may be probable that the gas, in struggling to escape, more completely pul-

Fig. 472.



verizes the clay, and reduces the whole into a homogeneous mass. So fully aware are manufacturers of the efficacy of this fermentation, that attempts are sometimes made to induce it by the addition of honey, sirup, *et cetera*, to the mixture.

Forming or Moulding of Porcelain.—Porcelain

bodies being more susceptible of inequality of pressure in the process of turning and moulding than earthenwares, require a corresponding greater amount of care. The goods are formed either upon the *potter's lathe* or *throwing wheel*, in *moulds* or by *casting*. The art of *throwing* by the potter's wheel is the most ancient, as well as, from the skill it requires on the part of the workman, the most interesting. The form in which it is now employed in the porcelain manufacture is shown—Fig. 472.—The disc, *a*, consisting of the head, the axle, and the wheel, is placed in the middle of a table, *Δ Δ*, supported by massive framework, and bound together by cross-bars, *a a*, *b b*. The axle, *c*, is made of iron, one end, *d*, rotating on a piece of quartz cemented to

the floor by plaster of Paris; while the other, passing through the brass ring, *e*, screwed to the table, carries the massive block of gypsum, *f*, upon which the operation of forming or throwing is performed. To the lower portion of the axle a wide heavy horizontal wheel, *F F*, is attached, which, from its great weight, mostly accumulated in the circumference, works as a balance wheel, rendering the motion in the upper part, *f*, uniform and continuous—a matter of essential importance.

The *thrower* or workman engaged in the formation of the plastic clay seats himself upon the stool, *a*—Fig. 473—supporting himself with his feet against the board *b*, so as to obtain a sufficiently stable position to

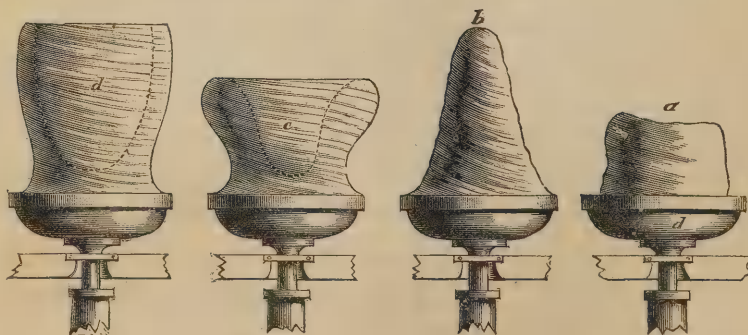
Fig. 473



enable him to rotate the wheel, *c*, with one foot. The mass of dough, as received from the *slapper*, is cut up into portions by means of a brass wire, each portion being weighed by an assistant called the *baller*, accord-

ing to the size and value of the article. The thrower receives one of these masses, and dashes it down upon the centre of the revolving block of gypsum, *d*. The thrower now presses both hands against the mass,

Fig. 474.



which being kept in constant rotation gradually acquires a round form, *a*—Fig. 474—his hands being maintained in a smooth state by dipping them into a vessel containing a quantity of water and paste held in suspension. If it were not for this precaution the

paste would adhere to the skin, and the smoothness of its surface be destroyed. The next operation consists in rendering the piece as homogeneous as possible, by raising it into the tall conical mass *b*—Fig. 474—for the purpose of squeezing out the air. The workman

then forces both his thumbs downwards into the centre of the mass, producing a cavity, which is enlarged as he removes his thumbs one from the other, *c*—Fig. 474—producing a bell shape. The sides of the half-finished vessel are then closely pressed in a slightly upward direction between hands and thumbs, and being lessened in thickness increase correspondingly in height, *d*—Fig. 474—according to the nature of the required vessel. It is in this manner that all vessels of a circular form in horizontal section, *e*—Fig. 473—are produced.

When the mouth of the piece is too narrow to admit the insertion of the hand, as is often the case with a jug, it is either made in two halves, afterwards cemented together, or shaped out by means of a wet sponge attached to the end of a crooked stick. In order to insure uniformity in the sizes of the piece, a gauge is used, consisting of a small rule, *a*—Fig. 475—sliding up and down a rod, *b*, and fixed to any required height by the marker, *c*, the whole being attached to the stand, *d*.

In this process of forming by the hand upon the lathe, the inequalities of the skin produce serrated spiral lines upon the surface of the ware, destroying its neatness and cleanliness. This circumstance, in conjunction with that of the plasticity of the mass not being sufficient to admit of its being worked by hand to that degree of tenuity required by commerce, renders a further operation necessary to bring it to the proper dimensions and perfection of form—the crude shape only being obtained upon the wheel, as will be further understood by reference to Fig. 473. Here the workman is represented as in the act of throwing, working with his hands and feet at the same time, and having a skin or apron, *f*, by his side to receive the fragments of slip thrown off in the operation, while the other operator, *g*, is engaged in roughly finishing the piece by means of the iron gauge in his hand. All vessels of an oval or angular shape which cannot be formed by turning, receive their shape by pressure in gypsum moulds, upon the inside of which the prominent parts of the piece are sunk, and *vice versa*.

This manipulation requires that the mass to be formed be of sufficient tractability to be easily introduced into the cavities of the mould by kneading, and that, when pressed, it be of sufficient tenacity as not to bend or yield upon removal. It must, therefore, acquire consistency, and dry in the mould—a condition which renders it absolutely necessary that the moulds be constructed of substances of a porous nature, otherwise the pieces would adhere and lose their shape upon removal. The moulds are, therefore, generally formed of gypsum—plaster of Paris—and sometimes of burned clay, and are of every variety of size and pattern, a complete set of patterns being required for every new design, and for every size of the same pattern. Moulds for plates, dishes, and other shallow articles, consist of only one piece, while for jugs, vases, and more elaborate forms, several pieces or moulds are employed.

The mode of making the moulds for plates and dishes, and the subsequent operation of moulding, are as follows:—Upon a model, *a*—Fig. 476—composed of either metal or gypsum, and turned in relief to

Fig. 475.

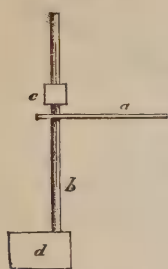


Fig. 476.



Fig. 477.

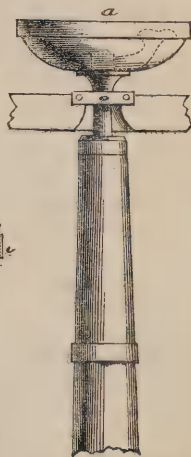
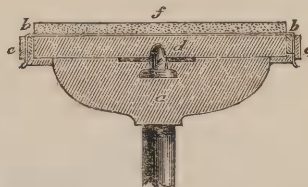
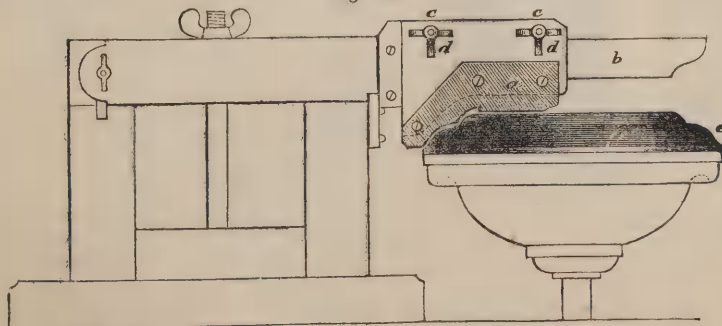


Fig. 478.



correspond with the exact contour of the inner surface of the plate or dish to be formed a hollow gypsum cast, *b*, is taken. This serves as the matrix, from which, when saturated with oil, innumerable other moulds, *c*, may be taken for use. As gypsum expands in setting about 0.01 of its linear

Fig. 479.



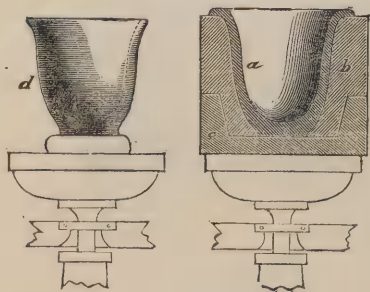
dimension, the original matrix must be made so much smaller. The mould being attached to the revolving

table, *a*—Fig. 477—receives upon its surface the sheet of thin dough, prepared as follows:—The assistant hav-

ing, by means of a wire, separated a piece of dough from the mass, hands it to the thrower, who places it upon the head of the throwing machine, *a*—Fig. 478—over which a piece of wet leather, *b b*, has been previously stretched, after the fashion of a drum, by means of the ring, *c*, the gypsum slab, *d*, fitting on to the socket, *e*. By the revolution of the head, the lump of paste is spread over the surface, and converted into the plate, *f*, which is brought to a uniform thickness by a gauge. It is now removed by means of the leather to the plaster mould, *c*, fixed upon another wheel, and pressed on to it during rotation by a sponge dipped and moistened in *slip*. In this manner the interior form is given to the plate, the outer surface, *e*, being finished off by the profile, *a*—Fig. 479—pressed upon it during its revolution. This profile, formed of a thin piece of brass plate, is mounted upon a carrier or slide, *b*, the adjustment being arranged by screws, *c c*, passing through the holes, *d d*. The excess of paste that extends beyond the proper outline is turned off, and the plate left in a finished state. The maker's name being impressed, the mould, with the plate upon it, is then conveyed to the drying chamber and placed upon a shelf, where it remains till sufficiently hardened to bear removal. In the meantime the operation at the lathe proceeds with other moulds.

In the process of drying, the gradual evaporation of the water contained in the paste brings the solid particles closer together in proportion as the moisture disappears. A consequent shrinking or diminution of volume takes place in the mass, the proper proportions remaining unchanged when the shrinking and desiccation have been uniform throughout; but, if this be not properly effected, distortion is the result. For this reason the pieces after they leave the lathe cannot be dried in a stove or current of air, or even by exposing them to the sun; for by such means they are desiccated only upon the outside, while the interior still contains a sufficient quantity of moisture to cause them to split with a kind of explosion in the furnace. They are, therefore, carefully stowed away in the shade upon wooden shelves, until no more moisture can be evaporated from them.

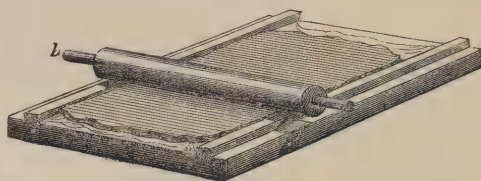
Fig. 480.



Sometimes the inner surface only of the ware is formed by the hand, the paste, *a*—Fig. 480—being pressed against the mould, *b c*, during its rotation, forming the vessel, *d*; the sheets of paste considerably thicker

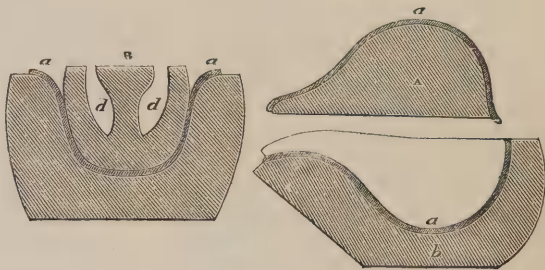
than the sides of the future vessel being prepared by rolling on a moistened gypsum slab, *a*, under a wooden roller, *b*—Fig. 481. When, from the elegance or complication of form, the admission of the hand into the mould is impossible, it has been stated that double

Fig. 481.



moulds are used. These are shown in Fig. 482, the paste, *a*, being first laid upon the solid form, *A*, and turned over into the mould, *b*, the interior mould being

Fig. 482



furnished with cavities, *d d*, for more easy removal. Fig. 483 represents the operation of moulding and finishing the additional pieces, such as the spout, handle, *et cetera*. The thin sheet of paste, *a*, prepared by rolling at *A*, is carried to the moulder, *B*, who, pressing with a damp sponge, makes the paste adhere to the mould, *b*. The latter is placed upon a circular plaster frame, *c*, mounted upon the iron axis, *d*, which can be revolved at pleasure by the hand of the workman. A further stage is shown at *c*, while the workman, *D*, is moulding a handle, *e*, for the sugar basin, *f*, removing the roughness, and filling up all cavities left by the moulding.

The porcelain paste, from the nature of its ingredients, is exceedingly susceptible to injuries from the least inequality of pressure in the moulding, injuries which are only made apparent at a period of the manufacture when it is too late to rectify them. The principal cause of these is the difference in shrinking during the drying and firing of the parts which have been subjected to different degrees of pressure. These defects are not so apparent when slight pressure only is applied, and may be easily avoided in the ordinary process of moulding; but when the pressure is increased and applied more unequally, they become so marked and unsightly as to render the article useless. Moulding presses are, therefore, only used for objects of small dimensions, in which perceptible differences in the consistency of the mass cannot occur; for larger vessels they are almost

entirely discarded in the manufacture of porcelain. Even when the greatest care is taken in manufacturing

the plate upon the mould, faults will occur; the bottom of the piece, instead of presenting an even surface,

Fig. 483.



will often fall away, as represented in Fig. 484, at *d*—a defect very fatal to the beauty of the subsequent processes of decorating and gilding—and the diameter and thickness will be variable at different places. Some

Fig. 484.

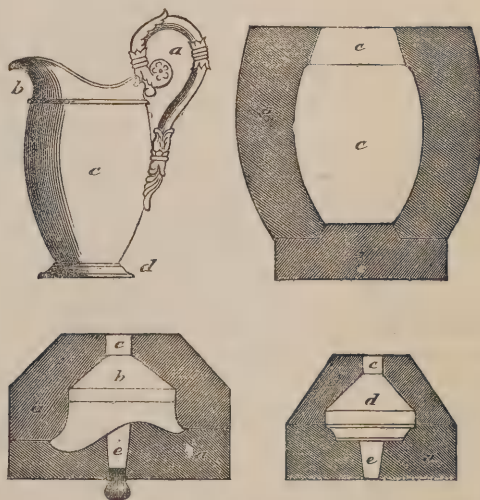


of these faults may be traced to the inequality of dampness in the surface of the mould, but generally to the unequal consistency of the mass used. To prevent loss also in the drying process, it is very necessary that all air be removed from the surface of the paste, as the presence of any particles of air, however minute, is sufficient to cause the splitting of the piece. If the plaster composing the mould also be not perfectly homogeneous and equally dense in all its parts, the absorption of moisture will be very irregular, causing a corresponding inequality in the separation of the paste from its surface.

When a dry gypsum mould is dipped in water, a certain absorption by capillary attraction takes place, the pores becoming filled; and should it happen that the water in which it was dipped held in suspension any particle of clay or other muddy substance, a kind of filtration occurs, the clay being left upon the surface of the gypsum, where it conglomerates and sets, the thickness of this deposit depending upon the duration of the operation, the massiveness and absorbing powers of the mould, the nature of the substance, and dilution of the paste. A very plastic material and pure clay soon form an impenetrable crust, which prevents further increase in thickness; but the flux in the porcelain paste, preventing the particles from

coming into too close proximity, admits of absorption taking place through the deposits already formed. For the purposes of casting, the slip is stirred up into a thick but perfectly liquid state, and passed through sieves, that all granular particles and bubbles of air may be separated, the number and nature of the moulds depending upon the form and elaboration of the article required. Thus in the case of the jug—Fig. 484A

Fig. 484A.



—the foot, *d*, body, *c*, neck, *b*, and handle, *a*, are each cast in a separate mould, the prominence of the parts requiring these distinct operations. The neck, *b*, is moulded in an inverted position, *a a* being the sides of the mould, *c* the aperture through which the slip is introduced, and *e* that through which it is withdrawn.

The same manipulation is applied to the moulds for the other portions, which, being closed below, are completely filled with the semifluid slip, and allowed to remain for two or three minutes before the water is rapidly drawn off, leaving a residuum of from one to two lines in thickness round the sides of the mould. The casting for the body, *c*, of the jug proceeds in exactly the same manner, but the mould is emptied by inversion. The various pieces having been removed from the moulds, and cleaned from superfluous paste, are put together and joined while in a moist state, the connection being so perfect that no indication of it is perceptible. The handle is put on afterwards—see *Earthenware*.

In the moulding of a teapot, five moulds are again required—two for the formation of the exterior form, and three for the interior manipulation, the parts being afterwards united together in such a manner as to produce the interior development of the spout and double casing of the sides necessary for strength and utility. The pieces must remain in the moulds, however, for a considerable time before they acquire proper consistency; the operation of moulding, therefore, requires much time and numerous moulds. Many articles likewise, even without appendages, such as a vase with a narrow neck, cannot be cast in one circular piece, which could not be extracted from the mould even by inversion. Such articles can only be made by casting in two halves, to be afterwards joined together.

In casting, the pieces are never perfect or free from blemish, as they leave the moulder, but require often tedious finishing processes, such as *turning*, *retouching*, *ornamenting*, and the adaptation of the separately moulded pieces to each other.

Turning.—Many articles are made much thicker upon the throwing-wheel than they appear when finished, the superabundant mass being turned off in a lathe to give the requisite beauty and uniformity of *contour*. This turning is precisely similar to that practised in the earthenware manufacture—which see—the clay being in such a state as to throw off a connected shaving without either crumbling or adhering to the tool. In this operation the piece is fastened to the gypsum slab of the throwing-lathe, by moistening the bottom, or fixed on to the lathe in a horizontal position by means of an ordinary chuck, as the case may require, ordinary sharp flat knives being used as tools in place of the chisel. One of the chief points in the finishing operation consists in the removal of the edges or seams caused by the penetration of the slip into the joints of the moulds. It is necessary that the seams should be carefully pared away with a knife, as, if removed by pressure only, they appear again after burning.

The casual cracks and indentations have at this stage of the manufacture to be carefully filled up, and all engraved or carved work which requires cutting away with the knife, to be performed. Frequently an ornamental appearance is imparted to the ware in this state by impression upon its surface with the *roulette* or stamp, in the use of which turpentine is applied to prevent adhesion to the paste, the fatty oils

not producing the necessary effect. It has already been stated that such parts as handles, feet, *et cetera*, are formed or moulded separately, and fixed upon the porcelain before firing, but smooth handles of uniform dimensions are often formed by pressure through an aperture of corresponding shape and diameter—see *Earthenware*—while those of more elaborate pretensions are produced by moulding in gypsum moulds. The union of all such parts with the body is effected by sticking them together under very gentle pressure, the two opposing surfaces having been previously roughened and covered with slip. All changes which affect unequally the mass of the vessel and the ornamental parts tend to cause cracks during the drying, and to separate the latter. It is therefore essential that the body and the ornamentation of the vessel be equally dry, and that the surfaces be prepared either by turning or casting in the same manner; also, that all excess of slip, from the increase of moisture it contains, be avoided. The same precautions apply to the joining together of pieces moulded in separate forms, the surfaces of which should be retouched with a sponge or wet cloth.

Firing.—In the operation of firing the true porcelain with the glaze—see *Glaze*—is rendered dense, vitreous, sonorous, and translucent, the glaze being of that nature that it melts at the temperature necessary for the perfect firing of the mass. The waste heat from this process is employed to produce the ware in the state of *biscuit*, or, in other words, for the firing previous to glazing.

On account of the chemical composition of the substance and the refractory nature of the glaze, the greatest possible amount of artificial heat that can be produced is required. This intense heat is the more necessary, as from the white color of the material, the transparency of the glaze, and its softness at high temperatures, it cannot be exposed to the direct action of the flame. Porcelain, like many other kinds of clay wares, is always, therefore, inclosed during firing within clay vessels or *seggars*—see *Earthenware*. This high temperature of the furnace must, for the successful firing of the pieces, be maintained as steady and uniform as possible, otherwise various misfortunes, such as splitting, bending, and fusing, will ensue. To effect this, with the large quantity of materials and the considerable number of seggars fired at once, requires a peculiar arrangement of furnace; as the porcelain goods cannot be brought into direct contact with the fuel, without impeding the draught, and causing a want of regularity in the distribution of the heat throughout the mass. All pottery requires, therefore, to be baked in a reverberatory furnace, in which the fire being kindled upon a separate grate does not come into contact with it. In short, potters' kilns are all reverberatory furnaces, which possess the advantage of surrounding the seggars more completely with flame, and of imparting a more uniform heat than would be practicable were they placed in direct communication with the fuel.

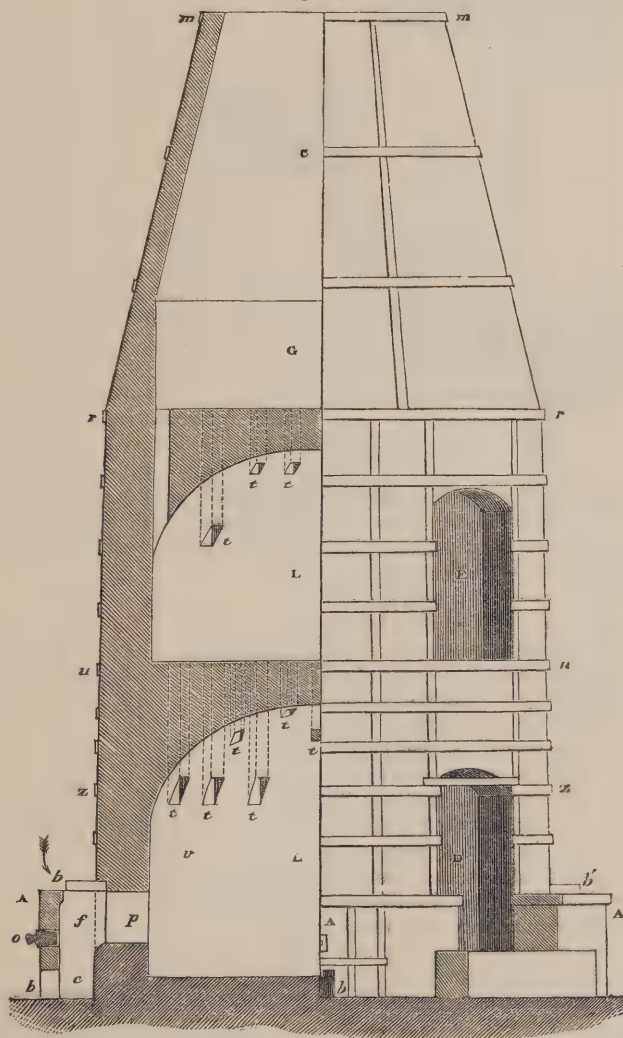
Furnaces.—The porcelain furnace is very similar to the glass furnace, with the exception that the source of heat is dispersed over several grates situated at the

circumference of the base instead of being united into one central fire. It consists, therefore, of a round chamber, on the floor of which the seggars containing the ware are arranged and piled in columns or *bungs*, the flames ascending from a number of wide flues below and around, in connection with the same number of fire-places, so as to circulate between the columns of seggars, filling the whole space, and escaping through different apertures at the top of the chamber into a second room, where they are again employed for heating the *biscuit-ware*. The details of one of these porcelain kilns are shown in Fig. 484B, one-half of which is

in section and the other in elevation, the horizontal section—Fig. 484C—being partly on a line through the fire-bars, and partly through the upper chambers, showing the vent-holes for the circulation of the flame.

The kiln or oven is surrounded by four or five separate fire-grates, A, A, A, A, which first heat the space, L, where the *porcelain* is burnt; then the second chamber, L, where the *biscuit* is baked; and thirdly, the space, G, used either for a similar purpose, or for the firing of the *seggars*—the flames finally escaping through the chimney, c. In the construction of the hearth of the

Fig. 484B.



porcelain kiln, the draught is forced to take a direction contrary to that usual in other furnaces. The space, c, being filled with hot charcoal, wood in small billets is introduced through the aperture, b' b', so as completely to fill the space, f. The draught, therefore, in the first instance, assumes a downward direction through b, as indicated by the arrow, and reaching the burning wood between f and c, induces a long flame, which

escapes through the opening, p, into the chamber, L, where combustion is completed. The difference between this arrangement and that of an ordinary fire grate is this, that while in the one case the glowing fuel is brought into direct contact with the external air, and the flame has to pass through the freshly added fuel, in the porcelain furnace the combustion is kept up by air already heated by its passage through the upper

layers of fuel, and the combustion rendered more complete. The hearth of the furnace is composed of a bad conductor of heat, such as bricks; and the velocity of the draught being reduced on entering the wide cham-

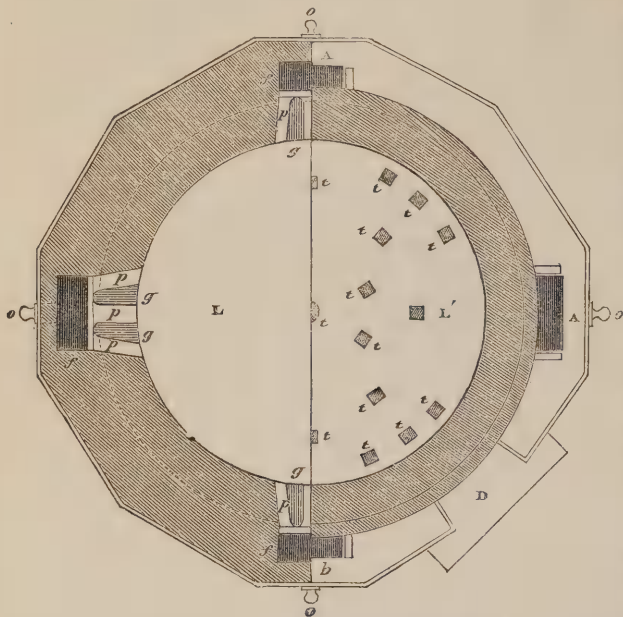
ber, *L*, greater time is allowed for the perfect combustion of the volatile products from the fuel. The small aperture, *o*, employed for the purpose of stirring the fire, is closed with a clay stopper, while the opening, *b*, at the foot of the hearth serves for the removal of ashes, *et cetera*. The regulation of the draught is effected by the lid, *b' b'*, the aperture or flue from which, before entering the furnace, is divided by tongues, *g g*, into the channels, *p p p*, for the better dispersion of the flame. *D* and *E* are doors for the insertion and withdrawal of the goods. In the arched covering of the space, *L*, twenty-five apertures or flues, *t, t*, are left to conduct and spread the flame as it enters the second chamber, *L*, the effect of a single opening in the centre being to draw the flame to one spot. Similar openings, *t, t*, but of half the number, conduct the flame from *L* into the upper chamber, *c*.

For the purpose of examining the progress of the firing, and for the introduction of small samples or *watches* into the seggar nearest the hole, small openings, *v*, are made in the walls of the chamber, *L*. These *watches* consist simply of pieces of biscuit covered with glaze, by the appearance of which, and the degree of fusion they undergo, an indication is given as to the state of the porcelain vessels. In order to prevent the access of air into the furnace through the opening, *v*, a tube—Fig. 484D

—is introduced from the outside, supplied with an iron damper, *z*, sliding in the frame, *h*, and closed in front by a plate of glass. These furnaces, averaging about twenty feet in diameter, and forty feet in height, are constructed internally of fire-stone, surrounded by an exterior casing of ordinary brick, the whole being bound together by iron stays or bands, *m, r, u, z*. To prevent their cracking or giving way by the great expansion caused by the heat, elastic hooks connect these girders together, and enable them to meet the strain. An improved modification of this furnace has recently been patented in France by M. VITAL ROUX of Noirlac, with a view to the employment of coal as fuel in the manufacture of true porcelain, without the necessity of reconstructing the entire kiln. It consists of the insertion of a grate at *g*—Fig. 484E—by which the air is allowed access to the fuel from below through the channel, *i*, as well as from above through *g*; the number of fire-places is increased to eight or ten, according to the dimensions of the kiln. It has been found to produce ware much more evenly fired throughout the kiln, while the lining of the furnace and the seggars are less attacked. In consequence also of the draught being greatly increased, and the ash of the coal containing only a very small proportion of alkali compared with that of wood, the clay does not

vitrify and destroy to such an extent. The saving in the expense by employing coal instead of wood, is calculated to average from sixteen pounds to sixteen pounds

Fig. 484C.



ten shillings for each firing. A vertical section of a porcelain kiln is represented in Fig. 484F; the interior arrangement and piling of the seggars, one upon another, being shown, together with the ordinary contents, such as plates, *a a*, vases and jugs, *b b b*, tubes, *c*, and a porcelain slab at *d*. The partitions which divide the

Fig. 484D.

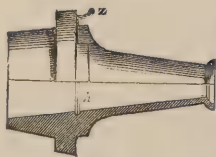


Fig. 484E: A vertical cross-section of a porcelain kiln. It shows a large arched interior space. At the base, there is a grate 'g' and a channel 'i' for air flow. The interior is filled with various items: plates 'a a', vases and jugs 'b b b', tubes 'c', and a porcelain slab 'd'. The structure is supported by a brick base and has a thick exterior casing.

Fig. 484E.

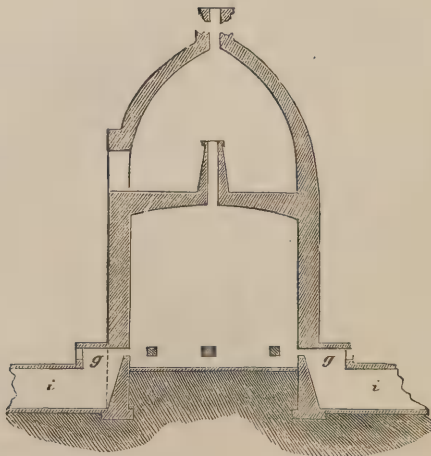
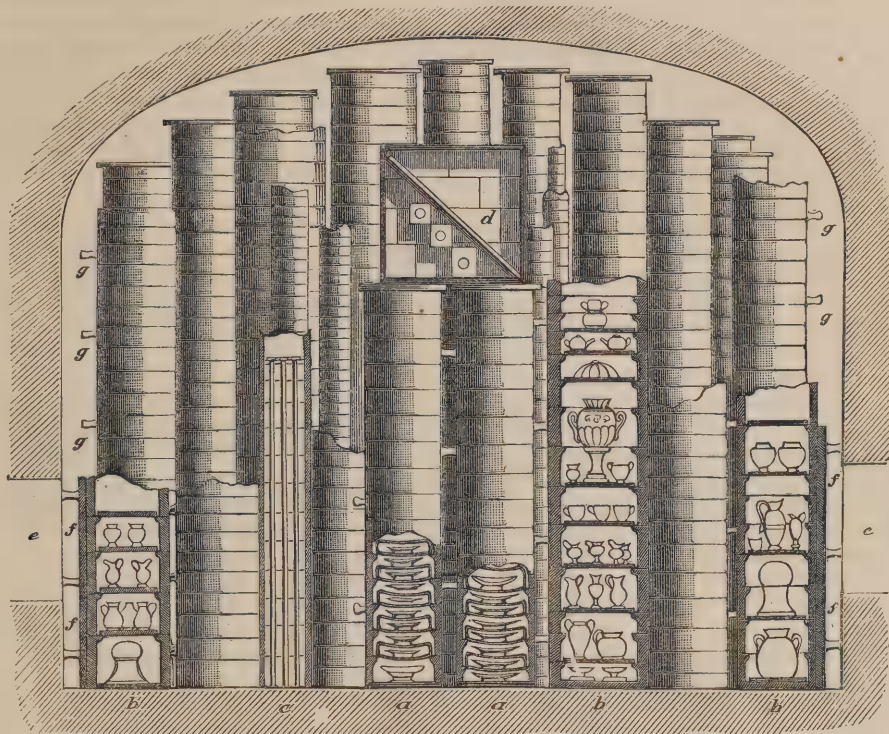


Fig. 484F: A vertical section of a porcelain kiln showing the interior arrangement and piling of seggars (one upon another) along with ordinary contents like plates, vases, jugs, tubes, and a porcelain slab. The diagram illustrates the internal structure and the placement of various items within the kiln.

flame on its entrance to the furnace are shown at *ee*, while *fff* are plates of refractory clay, called fire-guards, which prevent the flames and ashes from coming

into contact with the seggars. *ggg* are props for supporting the seggars. In Germany the furnaces are very similar in construction, but the apertures from one

Fig. 484F.



chamber into the other are only seven in number. They are wider, and furnished with short chimneys, which project it on the upper chamber, L.

The idea of supplying fires to both floors of the furnace, and obtaining the greatest amount of heat, in the hope that the expenditure of fuel in the upper floor would be proportionably less according to the amount of heat derived from the lower one, has been tried at Sèvres, but the results have by no means realized the expectations of the inventors.

Kilns for true porcelain are much more durable than glass furnaces, being free from the destructive action of the volatile alkalis; on an average they last three hundred firings, while in some places they have endured a much longer period. A dry foundation, exerting as little cooling influence as possible, is an important point in their construction.

Fuel.—In regard to choice of fuel, the porcelain manufacture is much more circumscribed than any other industry. It is only those kinds of fuels which burn with a flame that can be employed, and their comparative value depends upon the length and vigor of flame they afford in combustion. Another important requisite in connection with the fuel is, that it should discharge as little dust and ash into the kiln as possible, as this, penetrating between the joints of the seggars, produces black spots upon the surface of the ware. Amongst the varieties of wood in use, preference is given to the light kinds, as poplar, pine-

wood, *et cetera*, cleft into small billets; the effect of which is, that more wood is consumed at once, and a larger flame produced. The wood is not artificially dried, and retains from six to ten per. cent. of moisture. The use of peat has not been found satisfactory as regards the quality of the wares.

Firing.—After the chambers of the furnace have been charged with seggars, the apertures are all closed, and the process of *firing* commences. In this process there are two distinct stages—the first intended only to expel the moisture which may still remain in the vessels, and gradually raise them to a red heat, while the second completes the baking of the porcelain. At the commencement the firemen keep the upper aperture of the fire-hearth closed, the plate *b'*—Fig. 484B—being only removed for an instant as fresh fuel is thrown into the fire; the draught, therefore, enters through the ash-pit, *b*, in the same direction as in an ordinary furnace, producing a smoky, carbonized flame. In this operation the wood is thrown in irregularly in thick billets, crossing each other in various directions, until the furnace is found by examination through the test-holes, *v*, to have attained a cherry-red heat. This being the case, the space, *f*, is filled up to *b'*, with logs of from one to one and a half inches thick, laid parallel, and which are of the same length as the breadth of the hearth; the lower opening, *b*, is then closed. The draught being now reversed, the heat increases, and the smoke entirely disappears,

while the process of *baking* commences, and nothing visible escapes from the chimney but a stream of hot transparent gases. During this process, from the intense draught, the fuel is entirely consumed, all ash being carried away; as after the firing, ash which, from the quantity of wood consumed, should amount to over two hundredweight, does not yield, ash and charcoal together, a cubic foot. Any irregularity in the firing is immediately perceptible, the heat of the furnace diminishing directly on that side where the firing is badly attended to. When any one of the fires is out of order, the red-hot charcoal not being properly consumed, stops the progress of the flames, and causes them to beat back, a fault only remedied by the removal of the charcoal as rapidly as possible. A similar effect in the irregularity of the combustion of the fuel is caused by repairs upon the furnace. At Sèvres, for instance, when one half of a furnace had been newly constructed, it was found that the ware situated upon that side was thoroughly baked two or three hours before the other contents were fired, an old furnace always working more slowly than a new one, and requiring from five to six hours longer to complete the baking. In general the first process of firing occupies half as long as the baking, lasting from seven to eight hours, and the firing from eleven to thirteen. In some instances the two processes, as at Berlin, are nearly the same, the one taking from twelve to fifteen hours, and the firing from seventeen to eighteen. At Sèvres, again, the first is the longer process, occupying from fifteen to eighteen hours, while the baking only takes from ten to twelve hours. The temperature upon the upper floor of the furnace ranges from 30° to 60° of Wedgwood's pyrometer, while that of the lower chamber is from 130° to 160° Wedgwood, the heat of the base of the furnace being some 40° less. The *pyrometer* introduced by WEDGWOOD as a measure of high temperatures can only be employed as affording a useful approximation, and not the accuracy required for scientific purposes; the contraction of the clay under the action of intense heat being the principle upon which its measurements are made. This contraction is variable, even when the same kind of clays are placed side by side in the furnace, and a good pyrometer that shall indicate exactly intense degrees of heat is still a desideratum. As nearly as can be ascertained, the relative value of one degree of heat on the pyrometer, compared with that of the mercurial thermometer, is about 72° of Celsius, or 130° Fahrenheit, the zero of Wedgwood being about 580° Celsius, or 1076° Fahr., so that the greatest degree of heat in the baking will range from 19832° Fahr. to 21632° Fahr.

At Sèvres the average amount of fuel consumed as a mean over twelve operations in a double furnace, with two great fires, was found at first to be seventy-three cubic metres, which gradually diminished at the end of twelve months to fifty-two cubic metres; the mean quantity of porcelain baked during the period was seven hundred and eighty-four kilogrammes, and the seggars required for incasing it fourteen thousand kilogrammes, being in mass eighteen times that of the porcelain. In a kiln—represented at

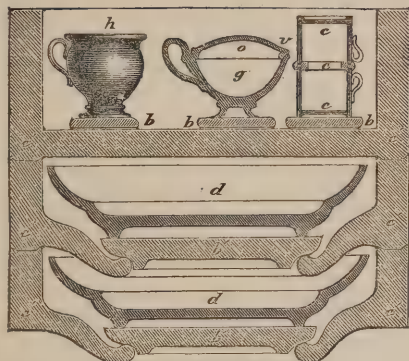
Fig. 484B—the cost of firing one kilogramme of porcelain may be taken as two francs—or one shilling and eightpence; while the cost of a cubic foot of space in the furnace will be one franc one centime—about tenpence. In Vienna, for every firing about seven klafters of wood are used, equal to sixteen and a half stacks, each of one hundred cubic feet, Hessian; in Berlin ten stacks, about seven hundred cubic feet, same measurement.

In consequence of the glaze of porcelain being a true glass, and entering into the mass, the process of annealing requires to be carried out; that is, the material must be cooled slowly in order to prevent it becoming brittle. This is rendered necessary from the circumstance that the particles of the glass, while in a fluid state, have a tendency to arrange themselves in a regular manner, and form crystals; whereas, by the process of cooling suddenly, they are forced to remain in the relative position towards each other which they assumed during the working; and this constrained state is greatest at the surface, where the cooling and contraction have been most rapid, the interior of the mass being less affected. These outer layers are consequently in a state of tension with reference to those in the interior, and a want of uniformity in the results, inducing a tendency to destroy the cohesion of the whole, which the slightest impulse from without will be sufficient to overcome. It is not necessary to employ any separate kiln for this annealing process, the kiln, with its contents, being simply bricked up after firing until it has become sufficiently cool to be emptied. A period of from five to eight days is allowed for the gradual reduction of temperature. In general the kiln is opened the evening before the porcelain is removed, the annealing process being thereby rendered more complete.

Seggars.—The composition of which the *seggars* are composed at Sèvres consists of forty parts plastic clay, sometimes decanted, and sixty parts of ground fragments of old seggars, or an equal quantity of a mixture, containing equal proportions of fragments and crushed quartz sand. At Meissen sixty parts of clay are used to forty parts cement; at Berlin 66·7 clay to 33·3 cement. At Sèvres it has been ascertained that the average duration of the seggars is fifteen firings or more; at Vienna from four to five; and at Berlin only from two to three; in which latter case, the loss occasioned by the seggars becoming useless amounts to nearly thirty dollars, or about four pounds ten shillings at each firing. At Meissen twenty per cent. of the seggars are lost at each firing. These differences result entirely from the local inequalities of the plastic clay, even when obtained from the same deposit, the loss becoming heavier, inasmuch as bad seggars cannot be piled so high in the kiln as good ones. The interior surfaces of the seggars are sometimes glazed, as they have been found to suck up the glaze from the porcelain, exerting a chemical attraction for it by facilitating the volatilization of the potassa, and absorbing it upon their inner surface. It is also of great importance to pay attention to the shrinking of the clay wares upon introducing them into the seggars, as when any obstruction prevents them from shrinking uniformly in their soft-

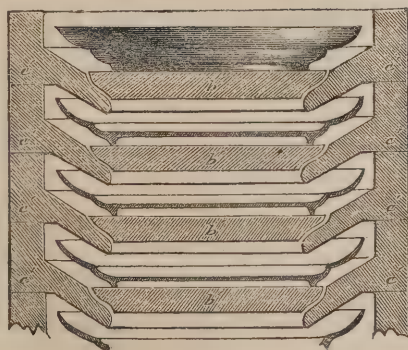
ened state they become warped and twisted, while the unevenness in the bottom of the seggars renders it necessary often to support the pieces by other means. The form, also, which is given to the seggars is a point of the utmost importance, since the quantity of goods that can be placed in the furnace at the same time depends upon it; and the amount of cost in the firing of each piece is lessened in proportion to the number of seggars that can be properly packed into the

Fig. 484g.



furnace for the same firing. All seggars are, therefore, made in the form of shallow cylinders, except when the particular form of the piece requires it otherwise, and the bottom being flat, each seggar forms the lid of the one placed underneath. Several vessels are placed in one seggar—Fig. 484g—and in order to insure the wares standing upon a perfectly smooth and even surface, small ground plates, *b b b*, are introduced, consisting of the same material as the seggars, and which can be easily taken away and repaired as required. In order to prevent the ware adhering to the plate, the glaze is removed from those parts of the piece

Fig. 484h.



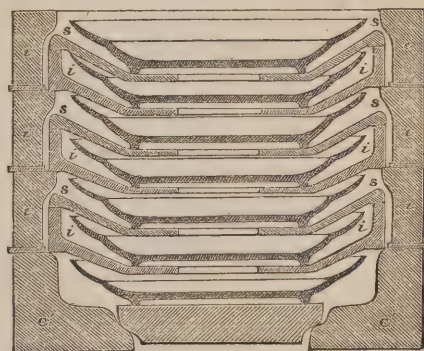
that come into contact with it, and as even those parts which are free from glaze are liable to soften and adhere, sand is interposed to prevent such occurring. Seggars which are intended to support hollow wares,

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such as plates, pans, saucers, *et cetera*, are constructed with a curved bottom, which, projecting downwards into the hollow of the vessel situated in the seggar beneath, economizes space; in this way from twenty-nine to thirty plates may be packed into a space which would otherwise have only contained twenty. The bottoms of the seggars are, with this view, constructed in a separate piece, *b b*—Figs. 484g, 484i—which has the advantage of enabling the seggar better to withstand the action of heat without fracture.

A form of seggar was introduced at Sèvres in the year 1839, by REGNIER, which has the advantage of economizing still more the space occupied in the disposition of the pieces, as well as of protecting them from the minute particles of ash carried during the firing through the kiln, and which, as already mentioned, affect the purity of the ware. The principle upon which this seggar is constructed is shown at Fig. 484h—the plate or ware being inclosed in a double casing, an inner and an outer one; and this arrangement requires the two parts to be slightly different in composition. The exterior casing is composed of forty parts of ordinary plastic clay decanted, and sixty parts cement; while the mixture for the interior seggar contains twenty parts ordinary plastic clay decanted, twenty parts of the best plastic clay, thirty parts cement, and thirty parts crushed quartz sand. The outer seggar, *t t*, con-

Fig. 484i.

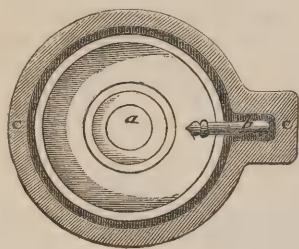


sists only of a hollow ring with a projecting ledge upon the interior of the upper edge to support the plates in their respective seggars, *i i* and *s s s*, which together form one closed vessel, the rim of the lower one, *i*, forming the sides. One plate being inclosed in each of these chambers, a second one is supported between each pair of seggars, the lowest chamber of the series being of necessity formed as at *c' c'*. In this manner from fifty-one to fifty-two plates can be fired in a space that was occupied by from twenty-nine to thirty, with the construction shown at *c c*, and by only twenty when the seggars had flat bottoms, as at *A A*. This economy of space, amounting to seventy-five per cent. in the height, is reduced to forty-five or even twenty-five per cent. with wares of a less flat outline; the cost of firing one hundred plates upon the new method being two pounds seventeen shillings against four pounds eight shillings as formerly, or fully thirty-six per cent. less. Some

5 K

wares, on account of their undulated and varied form are apt to become distorted in the firing, and, therefore, require supports to keep them straight. Thus the two mugs, *e e*—Fig. 491—placed one above the other, are separated by the ring, *c*, round which a groove is run at the top and bottom to receive the edge of each cup. The cup, *g*, is furnished with a lid, *o*, which does not belong to it, but is only employed for the purpose of retaining the edge in a perfectly true and circular form. The rim, *v*, of this lid is conical to enable it to rise in proportion as shrinkage takes place in the vessel. To enable vessels of larger size having handles to be fired, the seggar, *c c*—Fig. 484k—is formed with a prominent part for the support of the handle.

Fig. 484k.



When all the seggars are properly arranged and safely piled in the furnace, the joints being secured to protect the glaze from particles of falling dust, the firing is proceeded with, and here great care is necessary to insure that all the articles in the kiln receive the proper degree of heat—too much heat causing a partial fusion, and too little leaving them incompletely burnt. Although the mode of building the kilns insures a tolerably uniform distribution of heat throughout the mass, all parts are not equally hot, these immediately in front of the stoke-holes being much more intensely heated than such as are situated between them. At different heights also a different temperature is attained, the heat being less intense immediately at the bottom, while the greatest intensity is acquired about the middle, diminishing again as it proceeds towards the top.

The piling of the seggars in columns or bungs in the furnace requires great experience and caution on account of the very narrow base they rest upon compared with their height. By the contraction or expansion in the separate pieces an alteration in the centre of gravity will sometimes occur, affecting the stability of the structure so much as often to bring down the entire column, and even those in proximity to it, reducing the whole to a mass of fragments. Frequently a break down of this kind arises from the fracture of a lower seggar unequal to support the weight of the superincumbent mass. The lower seggars require, therefore, to be made stronger and the height of the column to be reduced as at Berlin, in proportion as the quality of the seggars deteriorates by repeated firing. Care must also be taken to place the more massive wares in the centre of the furnace where the heat is greatest, and the thinner and more easily

distorted articles in less heated parts. In order to protect the seggars immediately in front of the furnaces from the too intense heat, hollow semicylindrical screens of clay, *ff*, are employed—Fig. 499. The tendency of the columns of seggars to lean and tumble over is counteracted by the insertion of clay between each pair, and the stability of the mass is further insured by the support of broken pieces of seggars, a space of from two to four inches being left between the columns for the free circulation of the flame. In order to prevent the lowest seggars of the tiers from uniting with the floor of the furnace by fusion with the ash mechanically carried with the flame into the furnace, a layer of sand is interposed. Those seggars intended to receive the tests, and which have corresponding apertures in them are placed opposite to the small watch-holes of the furnace.

After firing the wares are removed from the seggars, and the sand which may have attached itself to the bottom, where they rested on the seggars, is ground off by a piece of sandstone or some soft artificial substance, used as a kind of file; while those articles which have been spoilt by bending are assorted and placed aside. This warpage of the ware is sometimes of considerable amount; at Vienna, for example, only three plates out of four come perfect and sound from the firing. Even in the so-called perfect ware there is always something to correct—such as dark points caused by the adherence of minute grains or splinters that have separated from the seggars; or a deficiency of glaze upon the parts which have been in contact with the supports, causing them to appear dull and rough, with a total absence of lustre, and which can never be kept so clean as the glazed portions. When this occurs at the bottom, it is of much less consequence than if on the edges. Such parts are re-glazed afterwards by means of a brush, and exposed a second time to the furnace—an operation of equal risk and expense with the first firing. Sometimes an easily fusible lead glaze is burnt upon these parts in a muffle, but this never acquires the degree of hardness which characterizes true porcelain. For these reasons the inequalities are now commonly removed by a grinding wheel, and the edges and such portions polished finally with tin-ashes, a plan which admits of greater scope in placing the vessels in the furnace and omitting to glaze them in different parts, and one also by which the best ground for gilding is obtained.

The qualities which distinguish porcelain from other wares are its pure milk-white color and entire absence of porosity, together with the very intimate union of the glaze with the mass, and its indestructibility when exposed to sudden changes of temperature. This entirely depends upon the liquefaction of the glaze occurring simultaneously with the complete firing of the ware, and both being nearly equally expansible by heat; the similarity of constitution in the flux and the glaze exerts the greatest influence in this last particular. The *shrinking* which porcelain undergoes, in common with all other wares, is the most important change that takes place, and one which varies with the least alteration in the quality of the body; but which may always be calculated from its remaining constant in mixtures

constituting the same body; the lineal contraction, or shortening in one direction, being on an average thirteen per cent., but sometimes falling as low as seven, and at others extending to seventeen per cent., while the contraction in volume amounts to thirty-nine per cent. on an average. A fourth of this contraction occurs during the first process of firing, and the remaining three-fourths during the subsequent baking of the mass. It may be accounted for in two ways—the evolution of all moisture, and the incipient fusion of the mass during firing. The amount of contraction will vary, therefore, according to the mode in which the mass was formed, the pressure it was subjected to, and the moisture it contains; the shrinkage being least in pressed objects, increasing in those formed in moulds, still greater when the formation of the ware has been on the

throwing wheel, and greatest of all in such as have been cast in moulds. These facts explain why those portions of the ware which have been subjected to less pressure, project after firing beyond such as have been more forcibly pressed. The density of porcelain, and consequently its specific gravity, increases as its volume is diminished; the specific gravity of the dry mass, after the first firing, being 2.305, which after baking is increased to 2.478. This applies to the mass as a whole, and includes the pores. The result is different, however, when its porosity is destroyed, and its specific gravity is taken in the state of fine powder; it is then found to diminish with the increase of temperature to which the mass has been exposed, and the amount of contraction it has undergone—see CLAY. This has been found by experiment as follows, in specimens of—

		Specific gravity.	
		G. Rosa.	Malaguti.
Once heated porcelain,.....	Adhering to the tongue,	2.613	2.619
After three hours' baking,	Adhering to the tongue,	2.589	2.440 half baked.
After four hours' baking,	Adhering to the tongue,	2.566	
After nine hours' baking,	No longer adhesive,	2.452	2.242 thoroughly baked.

It follows from these results that the cubic foot of really solid matter, weighing eighty-two pounds, becomes reduced to seventy pounds; and this is accounted for, first, from the fact that nearly all bodies are rendered specifically lighter by their transition from the crystalline to the melted vitreous state, as is the case with the felspar employed in the manufactory at Berlin, the specific gravity of which is 2.592, but is reduced after fusion to 2.384. The specific gravity of the kaolin is likewise diminished in this manner from 2.633 to 2.562. In the second place, the expansion may also arise from a partial chemical reaction of the

ingredients—a fact very probable from the specific gravity of the mass not corresponding with the mean specific gravity of the component parts. The separate particles of the porcelain become, therefore, permanently expanded during baking, but, at the same time, are brought into closer proximity with each other, and goods that have been once heated are not altered in weight by being thoroughly baked. The contraction of the mass composing the seggars is very much less, and often imperceptible.

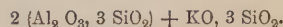
The following analyses of different specimens of porcelain may be given:—

Place of Manufacture	Silica.	Alumina	Potassa.	Protoxide of iron.	Magnesia.	Lime.	Analyst.
China vase,	70.5	20.7	6.0	0.08	0.01	0.05	—
China plate,	63.5	28.5	5.0	0.08	trace	0.06	—
Berlin,	66.6	28.0	3.4	0.70	0.6	0.3	Laurent.
Vienna, 1806,	61.5	31.6	2.2	0.80	1.4	1.8	"
Meissen,	57.7	36.0	5.2	0.80	traces	0.3	"
Paris,	58.0	34.5	3.0	—	—	4.5	Laurent and Malaguti.

THE GLAZE.—At Sèvres the glaze is composed of the pegmatite from St. Yriex, which is felspar, incorporated with a certain proportion of quartz. Although the proportions of these two constituents may vary considerably in small pieces, this ceases to be the case in the enormous mass prepared at the same time at Sèvres, as shown by the following table:—

Component parts of the glaze.	1826.	1839.	1839.	1841.	1842.
	Berthier.	A. Laurent.	Malaguti.	Marignac.	Salvetat.
Silica,	73.0	74.0	73.4	74.6	74.3
Alumina,	16.2	18.6	15.7	16.0	18.3
Potassa,	8.4	6.6	7.4	8.1	6.5
Lime,	—	0.4	1.9	1.2	0.4
Magnesia, ...	—	0.3	0.3	—	0.2
Loss by water,	0.6	—	1.3	—	0.3
Loss,	1.8	0.1	—	0.1	—
	100.0	100.0	100.0	100.0	100.0

The mean of these analyses corresponds with the formula—



In some places, as at Berlin, Nymphenburg, and Meissen, the glaze is composed of kaolin, gypsum, and broken porcelain, equivalent to a gloss containing alumina and lime, with no more potassa than the small quantity contained in the felspar of the kaolin and broken porcelain. In the beauty of the porcelain, everything depends upon the proper fusibility of the glaze, as when too difficult of fusion it does not become fluid enough to form a smooth and even surface, but appears wavy; while, should it be too easily fused, it becomes liquid before the paste is sufficiently baked, and when the latter is still so porous as to suck in the glaze, in consequence of which the ware afterwards presents a rough and dry appearance. As has been before stated, all the ingredients of the glaze require to be

finely pulverized, decanted, and mixed in the same manner as the paste composing the ware. The operation of putting on the glaze can only be accomplished in a rapid and uniform manner by dipping the pieces into a vessel containing the glaze in the form of slip suspended in water; and as, in this operation, the wares, if simply dried, would not only be liable to bend in handling, but would also absorb the water too slowly, they are previously fired to a certain extent, in which state they are called *biscuit*, in order to counteract this tendency—see *Firing*—and after having received this first firing, they absorb, when dipped into the mixture, a certain quantity of water, leaving the suspended glaze attached to the surface. The quantity and thickness of the coating will depend, therefore, very much upon the porosity and massiveness of the vessel immersed, the amount of glaze slip held in suspension, the length of time the vessel is kept in the liquid, and the dryness of the biscuit previous to dipping—circumstances all more or less tending to render the deposit of glaze unequal, and only guarded against by proper care in the preparation of the biscuit, and reduction of the slip to a proper consistency. In general, a very short immersion, varying from twenty to forty seconds, is sufficient; the more rapidly that the operation is performed, the more uniform will be the absorption of the liquid; and to insure this as far as possible, that portion of the ware which was first dipped into the glaze is always first removed. After the dipping process has taken place, the part of the piece held by the workman is coated with glaze by the aid of a brush, and the glaze is removed from those parts of the vessel which, coming in contact with the seegar in the operation of firing, might cause adherence by its fusion.

The process of dipping the *biscuit* wares into the glaze tub is shown at Fig. 484L. The operator, A, holding the plate with the right hand by the rim, plunges it into the liquid, his left hand receiving it at the opposite side upon emersion; the workman, B, dips it again vertically, holding it so as to allow the excess of glaze to run off; the assistant, C, removes the glaze from the bottom of the plate to prevent it adhering to the support on which it is placed for the purpose of firing. As the pieces are taken out of the trough they are placed upon the shelf, *g*, the sieve, *t*, being employed to separate the froth or other impurities floating upon the surface of the glaze. The *blunger*, *p*, is for the purpose of agitating the glaze and maintaining it at a proper degree of consistency; *b* is a vessel containing vinegar, used for mixing amongst the glaze from time to time; and *c* is a small cup containing glaze and a brush for retouching defective portions wherever the glaze is uneven or coated too thinly. It is obvious, that if

during the operation of glazing, the mixture is allowed to settle down, the coating of glaze in the dipping process will be unequal. The liquid is, therefore, stirred from time to time, and some substances mixed with it

Fig. 484L.



to prevent the slip from being deposited. Vinegar exerts a most remarkable effect in this particular; for instance, glaze in water at a temperature of 68° requires only four hours and twenty minutes to separate; in water, at a temperature of 140°, three hours; while in water containing three-seventh parts of vinegar it requires six hours; and in water with one twenty-second part of gum-arabic eight hours, under similar circumstances. When a thinner coating of glaze is required upon any particular part of the ware, that part is moistened previous to immersion, while places desired to be entirely free from glaze are coated with a mixture of wax and tallow. When necessary, a portion of the glaze may be removed by the application of the brush, or the whole by scraping with a knife.

Decoration of Porcelain—see also *Earthenware*. From the nature of the surface of porcelain being that of a true glass, it is the best adapted of all clay wares for the purposes of ornamentation with pigments and metallic lustres; the art being analogous in fact to glass-painting, with the difference that the coloring is solely adapted for reflection and not for effect by transmitted light. All the pigments, therefore, are colored glasses, which acquire their lustre and adhesion to the mass by fusion, and consist of a *flux*, with the addition of a *coloring* ingredient, generally a metallic oxide; such tints as will not withstand the agency of heat being, of course, excluded. Some of the metallic combinations in use for producing the various hues are given below:—

1. Yellow, Oxide of titanium.
2. Yellow, { Chromate of lead and chromate of baryta.
3. Yellow—different tints, Oxide of antimony.
4. Orange-yellow, black, Oxide of uranium.
5. Yellow tints—red, brown, violet, grey, sepia, black, } Oxide of iron.

6. *Violet, brown, black,*.....Oxide of manganese.
7. *Blue, grey, black,*.....Oxide of cobalt.
8. *Brown,*.....Protochromate of iron.
9. *Beautiful black,*.....Sesquioxide of iridium.
10. *As an addition to carmine*
 and purple,..... } Chloride of silver.
11. *Purple,*.....Purple of cassius.
12. *Red,*.....Suboxide of copper.
13. *Green,*.....Oxide of copper.
14. *Green,*.....Oxide of chromium.

Transparent and opaque colors or enamels are used with equal effect upon a white and almost opaque ground, such as porcelain. Transparent colors are rendered *opaque* by the addition of oxide of tin; and oxide of zinc is used for *enlivening* the different tints, a property peculiar to the oxide of that metal, and the effect of which is greatly enhanced by the fact that it imparts no color to the glaze; it also improves the sulphur-yellow colors of the oxide of antimony.

As the property of communicating any desired color to glass is confined within certain limits of temperature, beyond which the tint varies, or is altogether destroyed, a certain classification of the colors becomes necessary, according to the reaction of the temperature upon their constituents. They are, therefore, divided into such as have the power of withstanding the most intense heat of the firing kiln, and which can be burnt in with the glaze—termed *refractory colors*, and those which afford no color at such temperatures, on account of the volatilization, or only a very imperfect tint—designated *muffle colors*. The latter require to be applied to the wares after the process of glazing has been completed, and afterwards fixed in a small furnace called the *muffle*, shown at Fig. 484M—and at a temperature far below the fusing point of the glaze or body of the ware, otherwise they would run and penetrate into the glaze. *Muffle colors*, being painted upon the ware in *relief*, can be distinguished by touch from the decoration in *refractory colors*, and impair by their projections the lustre and smoothness of the surface, besides being more liable to suffer and wear away by friction. It is worthy of remark also that the firing of *refractory colors* causes no increase in expense, while the burning in the muffle is a constant source of additional expenditure. The refractory colors are—

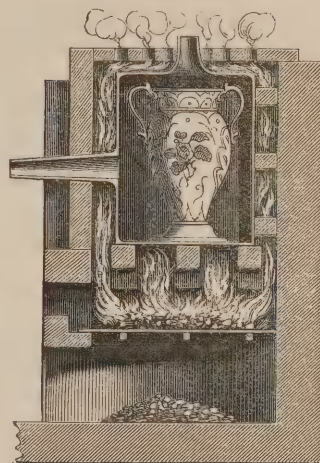
1. *Blue*, with cobalt.
2. *Green*, with chromium.
3. *Brown*, with oxide of iron, oxide of manganese, and perchromate of iron.
4. *Yellow*, with oxide of titanium.
5. *Black*, with oxide of uranium.

These pigments in the firing generally impart a very intense color, and can be used in very small quantities, which exert no liquefying action on the glaze, or on the mass of the ware. They may either be applied directly to the biscuit ware, or upon the glaze, the silicate of an alkali being used with them as a flux. *Muffle colors*

are incorporated with a great variety of fluxes, the most important of which are—sand or quartz, saltpetre, borax and boracic acid, felspar, potassa, soda, and minium or litharge.

Gilding is executed on porcelain in the usual manner, the gold being prepared in a pulverized form, and pre-

Fig. 484M.



cipitated from its solution in nitrohydrochloric acid by protosulphate of iron. The brown powder thus obtained is washed, dried, mixed with about one-tenth of oxide of bismuth, and rubbed up with thickened oil of turpentine. This gold mixture is then applied with the brush and fired in the usual manner, when the oxide of bismuth forms a flux with the surface of the glaze, and the gold becomes firmly attached. It has a dull yellow appearance upon leaving the *muffle*, and requires to be burnished with an agate to restore its metallic lustre. *Platinum Black*, or *Platinum Sponge*, is applied in precisely the same manner as the metallic gold. A preparation of gold, held in complete solution by oil of turpentine, is used for gilding at Meissen. It is not so durable, however, as that obtained by the ordinary process.

As a certain amount of heat is necessary in the muffle for the successful firing of the more fusible colors and gilded ware, pyrometrical tests are applied to ascertain the necessary temperature. A very convenient test is afforded by the variation of color through which the gold purple passes when submitted to a gradually increased temperature, six gradations being marked by the porcelain painters, corresponding to the six most important changes in temperature. Thus a piece of porcelain painted with the prepared purple of cassius, and exposed to the muffle, gradually becomes—

		Degrees of Fahr.
Of a dirty-brown red color,.....	corresponding to gilding upon colored grounds,.....	1148°
Brick-red,.....		
Brick-red, passing into rose, and red on the edges and thinner parts,.....	" retouching,.....	1474°
Rose-color, passing into purple,.....	" easily fusible colors,.....	1652°
Rose-color, passing into violet,.....	" gilding upon glaze,.....	1688°
Rose-color, passing into deep violet,.....	" gilding upon plate edges,.....	1742°
Violet has become lighter,.....	" more difficultly fusible colors,.....	
Rose-color has disappeared, and the violet become very pale,.....	" dull gilding,.....	1832°

The *watches* introduced into the muffle for the purpose of ascertaining the temperature, are covered both with gold and color, in order to ascertain the degree of heat at which the gold becomes attached without altering the tints of the hues. Painted porcelain generally requires retouching and passing through the muffle two or three times, the results of the first firing always being more or less imperfect. The principle of the muffle pyrometer used at Sèvres depends upon the expansion of a silver rod, which, melting at 2282° — 1000° Celsius—does not register quite up to that temperature. At this manufactory, also, an ingenious method of removing faults in the painting is adopted previously to retouching them. A brush, dipped into liquid hydrofluoric acid, is traced over the parts, which are afterwards washed with water; the etched part appearing perfectly white, and only slightly corroded, is in a very favorable condition for receiving the fresh pigments.

The semitransparent nature of porcelain has been made subservient, within the last few years, to the production of elegant imitations of paintings, and termed *lithophanous* pictures or transparencies, from *λίθος*, stone, and *φαίνω*, I shine through. The porcelain plates are constructed thicker in some parts than others, according as it is intended to produce greater depth of tint, or otherwise. When a plate thus contrived is held against the light, the thicker portions appear shaded compared with the rest; and if the blending has been arranged with care, representations of exquisite softness and gradation in tints are obtained. The manipulation and firing are, however, attended with considerable difficulty.

Some very interesting and important experiments have been made by BROGNIART and MALAGUTI, with reference to the nature of porcelain, and which also furnish valuable hints connected with its manufacture. Masses of porcelain clay, composed of different suitable materials, and affording the same per centage composition as the porcelain mixture adopted during the last sixty years at Sèvres, 58 silica, 34.5 alumina, 4.5 lime, and 3 potassa—were submitted to the different processes of manufacture with the following results:—

When chemically pure substances were taken, such as—1, Precipitated silica, in part fritted with the proper quantity of potassa; 2, alumina, perfectly free from potassa, prepared by precipitation from alum; 3, pure lime instead of chalk—the mass melted at the lowest degree of heat in the kiln to a spotted enamel.

Another specimen of the same mixture, with less frit, contracted in the biscuit oven eighteen per cent., and in the firing twenty-eight per cent.

When the kaolin was replaced by fire-clay, and the potassa was added, having been previously fritted with silica, a mass was produced which, after exposure to

the biscuit fire, exhibited the fluxed appearance of ordinary stoneware, and which when fired could scarcely be termed porcelain from its spotted nature and slight degree of transparency.

By using a similar mixture of plastic clay, in which a proportion of leucite, instead of the necessary amount of potassa, was present, a well-glazed porcelain was obtained, though somewhat spotted. When lime was employed in place of chalk, or the quartz-sand was replaced by flint, no alteration in the properties of the normal mass was observed.

These experiments show that it is by no means a matter of indifference of what materials or of what minerals the elements of the mass are composed, even though its relative proportions remain the same.

Fig. 434x.



Parian or *Carrara Biscuit Ware*, introduced some fourteen or fifteen years ago, is the finest description of biscuit made, and differing only from porcelain by the employment of a soft, more fusible felspar in place of Cornish-stone. In effect, statuettes and other objects made of this ware, present a great similarity of appearance with the beautiful marbles after which it is named. The general introduction of this art was due to a suggestion of the great sculptor JOHN GIBSON, to reproduce his *Narcissus* as a statuette in the statuary porcelain, and was first successfully carried out by the firm of COPELAND and GARRETT, the eminent manufacturers of Stoke-upon-Trent, under the artistic direction of Mr. THOMAS BATTAM, a gentleman well known as the director of the Ceramic Court at the Crystal Palace. The perfection to which the manufacture is now carried, is evidenced by the grace and beauty of outline of the

works both of ancient and modern art reproduced in this material by the Messrs. COPELAND, MINTON, WEDGWOOD, KERR and BINNS, RIDGWAY, MAYER, and other eminent potters. Outlines of two of these groups—the production of Messrs. COPELAND and GARRETT—are annexed; Narcissus, by GIBSON—Fig. 484N—the first Parian statuette ever produced, and executed for the Art Union of London; and the second, a reduction of Sabrina, by J. C. MARSHALL, —Fig. 484O. It is hardly necessary to add, that other eminent sculptors have lent their aid in the development of beautiful models in this material, so nearly approaching the true marble. In the *Parian* body the agreeable creamy or yellowish-white tint which it possesses is not due to any coloring matter mixed up with the ingredients, but is owing to the presence of a small quantity of oxide of iron in the clays and felspar, which during the firing forms with the silicic acid a silicate of sesquioxide of iron, imparting the color. The making of figures with the Parian body requires great care, knowledge, and skill, being cast in different parts, and afterwards united together. The *slip* for this purpose is in a liquid state, the deposit

tained in the slip, the mass contracts in the firing process no less than one-fourth of its bulk. Some of the ingredients composing the Parian bodies are given below:—

No. 1.—FRIT.

Well washed Lynn or Isle of Wight sand,....	80 pounds.
Felspar,.....	35 "
Cornish stone,.....	15 "
Pearlash,.....	12 "

The whole mixed together with water, and fired in flinted seggars, at the earthenware heat.

MASS.

Frit,.....	50
Felspar,.....	130
China clay,.....	130
Fine powdered glass,.....	20

These ingredients being all well ground together.

No. 2.—FRIT, made as before.

MASS.

Frit,.....	50
Felspar,.....	35
Felspar calcined at a gloss heat,.....	35
China clay,.....	75
Bone,.....	75
Powdered glass,.....	15

The above for statuettes and finer productions.

No. 3.

Felspar,.....	350
China clay,.....	200
Flint,.....	25

No. 4.

Felspar,.....	300
China clay,.....	180

No. 5.

Felspar,.....	200
Cornish stone,.....	100
China clay,.....	150

For vases, small figures, jugs, *et cetera*.

The beautiful perforations and network first introduced into porcelain statuary manufacture at Coalport, such as lace, drapery, *et cetera*, are made by a very ingenious and at the same time simple process, being a kind of incrustation of the original fabric, which, dipped into the slip, is afterwards allowed to dry, a deposit of slip being everywhere formed upon it. The subsequent process of firing destroys the original tissue inside.

In practice the process may be described as follows:—Upon a gypsum slab, over the surface of which a film of the fluid slip has been brushed, the piece of net is evenly spread out and a second coating of slip afterwards laid over the whole. The porosity of the gypsum absorbing the water leaves only the clay in a thin film surrounding the fibres of the net, which, when lifted, is wrapt around the statuette to be decorated, and placed in the oven. If it were not for this absorbing of the gypsum, the minute interstices of the lace would become filled up with the liquid and present a solid part when fired.

STONEWARE.—Under this denomination two varieties of claywares may be classed—*fine stoneware* and *ordinary stoneware*—differing essentially from each other in the nature of their constituents. The chief

Fig. 484O.



in the mould being allowed time to harden before removal; after which those parts which, from the softness and yielding of the mass might sink, are supported by props. From the large proportion of moisture con-

substances used in the manufacture of stoneware are the layers of pipe and plastic clay which lie above the chalk, and generally abound in the coal formations. The plastic clays, like the varieties of kaolin, must be considered as definite combinations of silica and alumina, probably $2 \text{ Al}_2 \text{ O}_3$, 3 SiO_2 , with water of hydration more or less contaminated with other mineral substances by mechanical agency. A distinguishing characteristic of these clays is the small quantity present of those mixtures of bases which tend to promote easy fusibility, the greater portion of the plastic clays being infusible. On analysis, these clays show from 1 to 4 per cent. of oxide of iron, from 0.5 to 2 per cent. of lime, a rather smaller amount of magnesia, and from 0.5 to 1 per cent. of potassa, ingredients not necessarily all present at the same time. In color the clays vary; passing from the most general one, white, to whitish-grey, or into greenish, rose color, or violet; at other times bluish-black or black. At a temperature of 212° only a portion of the water they contain is expelled; the other portion, amounting to 6.12 or 18 per cent., being held in chemical combination, can only be completely driven out at a red heat, the temperature at which the clay burns and loses its plasticity. At that temperature a chemical action occurs, the alumina being rendered much more soluble in acids than is the case with fresh clay. Thus, clay when burnt loses 44.3 per cent. of alumina in sulphuric acid, while fresh clay only parted with 23.4.

The plastic clays in general contain little of the undecomposed fragments of rock and coarser ingredients, but sand and finely divided silica are mixed with them in very varied proportions. In the analysis of thirty different varieties at Sèvres, the amount of silica was found to vary from forty-two to seventy per cent., alumina twenty to forty per cent., and of water between six and nineteen per cent., the remainder being oxide of iron, lime, *et cetera*. Plastic clay, after burning, is white or reddish from the presence of oxide of iron, the other colors arising from organic substances being eliminated in the fire.

Fine Stoneware.—The production of this ware is most extensively carried on in England at the potteries, where the manufacture has attained the highest degree of perfection. With it may also be included that known as Wedgwood jasper-ware—from its celebrated discoverer—and famous for its unrivalled production of cameos and medallions. As it is manufactured in great quantity and in almost every conceivable form, it will be treated of under *Wedgwood-ware*.

The mass composing fine stoneware is a mixture of plastic clay and a flux of a felspathic nature. The hard texture of plastic clay after burning, and the shrinking it undergoes, cause it to become very fragile, while the application of long and intense heat is necessary to produce that semifusion which is one of the characteristics of the ware. This semifusion is fac-

ilitated by the addition of the flux, which acts precisely in the same manner as in real porcelain; the chief external difference between fine stoneware and real porcelain being the almost entire absence of translucency in the former.

Mixture.—The mass composing the body of fine stoneware is more complex than that of common stoneware, and being harder and more brittle after firing than the latter, is distinguished from it by the term *dry body*. It is generally composed of *kaolin*, *plastic clay*, and *Cornish-stone* as a flux, sometimes the kaolin, and sometimes the plastic clay taking the preponderance; but the proportion of the flux generally amounts to fifty per cent. of the whole—a much larger proportion than in the true porcelain body. It is from this cause that fine stoneware, when subjected to the heat of a porcelain kiln, melts, and requires therefore a more moderate temperature in baking. The mass is much more plastic than that of true porcelain, a circumstance which enables it to bear a much larger proportion of a poor flux, such as felspar, than the kaolin. Fine stoneware may therefore be considered a substitute for real porcelain, the manufacture being cheaper, from the greater ease and facility with which it is fired, and possessing also the property of non-permeation by liquids.

Some of the proportions in mixing the mass are given below:—

White stoneware bodies for jugs, <i>et cetera</i> .	I.	II.	III.	IV.
Cornish stone,	80	40	100	30
Cornish clay,	20	10	20	10
Blue clay,	40	20	18	18
Flint,	20	—	40	2

with the addition of a little blue cobalt to whiten.

Mortar bodies.	I.	II.	III.	IV.
Cornish stone,	200	90	50	50
Blue clay,	80	80	25	20
China clay,	—	30	20	40
Glass,	—	—	1	—

These separate ingredients are all ground to a fine powder—see *Earthenware*—and mixed together with the greatest care, in order to increase the plasticity of the mass in working.

The wares are formed in a similar manner to that described under *Earthenware* by means of the *wheel* and *lathe*, or pressed into plaster of Paris moulds, when the irregularities of the outline render this necessary. Many kinds of this ware are decorated with *basso-relievos*, the manipulation of which will be found under *Wedgwood jaspers*. These bas-reliefs, from the more binding character of the material, are fixed on to the body with greater facility than is the case with true porcelain. Many varieties of stoneware are composed of a colored mass, care being taken that the metallic oxides used for that purpose are not applied in such quantities as to impart easy fusibility, or endanger the stability of the ware in firing. The ingredients in use for forming certain colors are given below:—

Colored stoneware bodies.

Sage—White stoneware body :—Stain—Oxide of chrome and cobalt.

Drab—White stoneware body :—Stain—Fifteen per cent. common marl, and a little nickel.

Dove—White stoneware body :—Stain—One per cent. manganese with one-fourth part per cent. cobalt.

Other colored bodies being merely modifications, according to the tints required. The after process of

firing the mass is much the same as that described under *Earthenware*.

Wedgwood Jasper-wares.—Amongst this celebrated description of fine stoneware, the manufacture of Mr. WEDGWOOD, may be enumerated those known as *jasper*, *terra-cotta*, *basalt*, *granite*, and *porphyry*; wares which, from the particular composition of their bodies, are capable of receiving the most exquisite degree of finish and delicacy in their manipulation, rivalling in beauty of form and chasteness of outline the art productions of the ancients.

One of the most remarkable of these bodies is the *jasper* or *onyx*, which presents to the eye a white biscuit of a porcellaneous nature, and which has the property of receiving, through its entire mass, by the admixture of metallic oxides, the same colors that those oxides would impart to glass or enamel in a state of fusion. This property, peculiar to itself, renders it applicable in a manner no less pleasing than extraordinary to the production of *cameos*, *portraits*, *vases*, and all subjects which require to be shown in relief, the ground being made of one color, while the raised figures are of the purest, most delicate white.

The composition of this jasper or onyx body may be given as follows, the blue color being imparted by the admixture of oxide of cobalt, in proportions varying from one-third of a part to one part per cent., or more, according to the depth of tint required:—

White jasper bodies.	II.	III.	IV.	V	VI.	
Sulphate of barytes, . . .	150	40	30	50	32	160
China clay,.....	35	—	—	15	10	60
Blue clay,.....	45	20	12	35	25	90
Flint,.....	35	—	3	10	8	40
Gypsum,.....	6	—	—	—	1	8
Cornish stone,	50	20	20	—	7	—
Bone,.....	—	—	—	25	—	—

The proportion of *stain* being one part of cobalt to from fifty to seventy-five parts of the body, according to the depth of color required. The various other colored jaspers are obtained by the addition of other oxides to the several white bodies.

The *green* jasper is obtained by the admixture of the oxide of chromium.

This jasper body resembles so nearly in appearance the glassy vitreous substance of the ancient gems, that it has become celebrated throughout the world for the beautiful imitations of medallions, cameos, and vases it is capable of producing. It constitutes also the dark-blue ground, with its gem-like surface, of WEDGWOOD'S copy of the Portland vase, a sepulchral urn of great antiquity, discovered in the neighborhood of Rome between the years 1623 and 1644. The careful investigation of this gem of art has pronounced the body of the vase to be formed of a transparent glassy structure of a deep amethystine hue, but which, when viewed by reflection, appears black and opaque, while the raised figures on its surface are white glass, of a sufficiently transparent nature to admit of the blue color of the ground tinting their form through the thinner parts, while the thick possess sufficient opacity to appear of a pure white. The examination both of the ground and bas-reliefs lead to the belief that the blue body of the vase when formed, and still red-hot, was coated all over as far as the bas-reliefs were intended to reach with the white glass, and the handles applied afterwards while in the same red-hot condition—a fact demonstrated by

the intervention of a layer of this white enamel between the body of the vase and the lower extremity of the handles, the upper portions being in direct contact with the vase itself. The figures seem to have been produced by a subsequent cutting away of this white coating down to the blue ground, after the manner of real cameos.

The extent to which the manufacture of imitative ancient gems was carried in the Wedgwood jasper body was enormous, and is again considerably upon the increase at the present time; the original purity and other pristine qualities being revived at Etruria, the seat of the manufacture, by the energies of Mr. GODFREY WEDGWOOD, the eldest son of the present FRANCIS WEDGWOOD, the descendant of the great JOSIAH WEDGWOOD. This, from the re-discovery, as it were, of the first jasper body, together with the possession of all the original models and moulds designed by FLAXMAN and others, renders it more than probable that the ware will again attain the high standing of former years, and that the mantle of the great WEDGWOOD will once more descend amongst his own people.

Manufacture.—In wares of this description the mass is frequently white, and only covered on the surface with a thin colored coating of the same body, the shrinking properties of the mass not being essentially affected by the addition of small quantities of the metallic oxides. The mass, after formation upon the throwing wheel in the usual manner, receives when sufficiently hardened the proper outline upon the lathe; and if a vase or other similar shape, such rims or fillets are turned as are intended to appear white upon the dark ground in the after manipulations. The piece is then taken into the dipping-room, where it is immersed in a tub containing the colored slip of a consistency approaching thick cream, and receives a thin even film over its whole surface. It is then allowed to harden until it is sufficiently firm to admit of being placed a second time upon the lathe, when a burnisher is run over it to give uniformity and smoothness to the surface; the blue dip, at the same time, being turned off, and exposing those portions intended to appear white, such as mouldings, lines, *et cetera*, produceable on the lathe.

The piece is then taken to the *decorator*, who affixes the various ornamentations intended to complete the design. Taking the vase in one hand, he with a small hair pencil moistens with water that portion of the surface intended to receive the pattern, which is affixed in its proper position by a very gentle pressure of the finger and the aid of a damp sponge; each separate ornament being added in this manner, until the whole decoration is complete. The piece is then sent into the oven to be fired in the usual way.

The ornaments in relief are obtained, like an impression from a seal, by pressure in a mould made of baked clay or plaster of Paris. The moulder sits at a bench with a number of these small moulds before him, a lump of the plastic material forming the body of the ware being placed at his side, and from which, by means of a small spatula, he separates pieces of the clay, and rapidly fills or presses them into three or four of the moulds. This done, he takes the one first

in order, and with the smooth flat end of his tool burnishes over the surface of the mould, removing the surplus clay, and causing the sharp-cutting edge of the die to give a clean sharp outline to the impressed clay, which, yielding slightly to the rubbing process by suction, leaves the mould, and is turned out on a slab for use by the decorator, who has to exercise considerable care and dexterity in preserving the sharp outline of the relief in its application to the ware. In the *original* WEDGWOOD fabrications, so much of the beauty of the piece depending upon this particular, the outlines were sharpened and restored by modellers before the ware was sent into the oven, producing such exquisite embellishments that now, sixty-five years after his death, connoisseurs are eager to purchase them at three times their original price. Those decorations, such as flowers, *et cetera*, which are not capable of receiving their form by pressure in the mould, are modelled by hand separately, and united afterwards piece by piece together. The other bodies of WEDGWOOD, which in composition resemble agate, jasper, porphyry, and other variegated stones of a vitrescent or crystalline fracture, are used largely in the formation of ornamental wares. These bodies are composed of various colored clays, placed in layers to represent when pressed together the several stones they are intended to imitate, care being taken that they shall not so amalgamate as to destroy the beauty of the imitation.

The *Basalt* or black Egyptian biscuit, so called from its resembling basalt in appearance and color, forms the mass from which the most esteemed forms of ancient Egyptian art are modelled, and which is enriched with bassi-reliefs both in red and white; many articles

of domestic requirements, such as tea-pots, milk-jugs, ink-stands, *et cetera*, are moulded in the same style from this mass. In composition it may be given as follows:—

Basalt or Black Egyptian bodies.	I.	II.	III.	IV.	V.	VI.
Blue clay,.....	200	330	200	—	100	—
Red clay,.....	—	—	30	500	—	500
Ochre calcined,.....	200	300	100	75	100	—
Iron scales—protoxide of iron,.....	—	30	—	—	35	—
Manganese,.....	60	80	100	75	40	100

Red body—terra-cotta ware.

Red marl very carefully sifted,.....	10 parts.
Common marl,.....	2 parts.

with the addition of ten per cent. of Cornish clay, if a light color is required.

The revival of painting upon vases and other similar articles in the manner of the ancient Etruscans, without the glossy appearance of ordinary painting upon porcelain or earthenware—an art lost since the time of PLINY—is due to Mr. WEDGWOOD, who, after careful examination of original Etruscan vases, finding it impossible to imitate the colors by *enamels*, devised other substances, termed *encaustic* colors, producing an entirely different effect, and without any of the glossy lustre of the enamels in the firing. This discovery at once enabled successful imitations of the ancient vases to be made in all their variations of light and shade, and of equal durability with the enamels, without the defect of a varnished or glassy surface. Encaustic colors are applied with great ease and certainty, changing but little in the firing, and have no tendency to run or spread on the design. The composition for certain colors may be given as follows:—

ENCAUSTIC COLORS.

White.	Black.	Green.	Blue.
Blue clay,..... 20	Egyptian black,.... 12	White slip,..... 12	White slip,..... 25
China clay,..... 10	White slip,..... 3	Blue slip,..... 1	Blue cobalt,..... 1½
Flint,..... 10	Blue slip,..... 3	Nickel,..... 1	
Cornish stone,.... 5			

These clays, finely ground and brought to the consistency of thick slip, are painted upon the wares while in their moist state, and before firing in the biscuit oven.

It is impossible to conclude this notice of the jasper wares of JOSIAH WEDGWOOD, without quoting some remarks upon the manufacture of pottery which conclude his catalogue—dated and published in 1777—remarks peculiarly applicable to the manufactures and productions of the present day. He says:—

A competition for cheapness, and not for excellence of workmanship, is the most frequent and certain cause of the rapid decay and entire destruction of arts and manufactures.

The desire of selling much in a little time, without respect to the taste or quality of the goods, leads manufacturers and merchants to ruin the reputation of the articles which they make and deal in; and whilst those who buy for the sake of a fallacious saving, prefer mediocrity to excellence, it will be impossible for them either to improve or keep up the quality of their works.

All works of art must bear a price in proportion to the skill, the taste, the time, the expense, and the risk attending the invention and execution of them. Those

pieces that, for these reasons, bear the highest price, and which those who are not accustomed to consider the real difficulty and expense of making fine things, are apt to call dear, are, when justly estimated, the cheapest articles that can be purchased, and such are generally attended with much less profit to the artist than those that everybody calls cheap.

Beautiful forms and compositions are not to be made by chance, and they never were made, nor can be made in any kind, at a small expense.—*Wedgwood.*

Fine stoneware in general is never glazed, though at times a glaze is produced spontaneously with the firing by a process called *smearing*, the inner surface of the seggars being coated with a glaze composed of—

DRY SMEARS OR GLAZE FOR FINE WHITE STONEWARE.

No. 1.

Lead,.....	6
Stone,.....	3
Salt,.....	3

No. 2.

Flint,.....	10
Bone,.....	5
Nitre,.....	3
Salt,.....	5

No. 3.	
Lead,.....	4
Stone,.....	1
Salt,.....	2
Flint,.....	1

No. 4.	
Glaze,.....	4
Salt,.....	1
Potassa,.....	$\frac{1}{2}$

No. 5.	
Calcined bones,.....	3
Common salt,.....	1

No. 6.	
Bones,.....	5
Salt,.....	3

No. 7.	
Flint,.....	10
Bones,.....	5
Salt,.....	5
Nitre,.....	3

WASH SMEARS.

No. 8.	
Lime at twenty-four ounces,.....	3 quarts.
Slip at twenty-four ounces,.....	2 quarts.
Salt,.....	2 pounds.
Nitre,.....	1 pound.

The ingredients dissolved in hot water, and the seggars washed inside with the mixture.

This in part becoming volatilized during the firing, a portion of the alkali and oxide of lead is absorbed by the surface of the ware, forming a thin layer of glaze, both the surfaces containing silica appropriating a fair proportion of the vitrifiable bases. Sometimes a glaze containing a large quantity of lead or borax, is applied by the process described under *Porcelain* to either both or only one surface of the ware. When pigments are mixed with the glaze, colors—as is the case with yellow—are communicated to the ware which could not otherwise be produced. The firing of this kind of ware takes place in seggars, in furnaces of similar

description as those described under *Earthenware*, and often at the same time as wares of that description, being placed in those portions of the kiln where the temperature is highest.

Varnished and Larva Ware.—Other kinds of wares manufactured in Germany at Pirna and Saargemündt, and recently brought into extensive circulation for ornamental purposes, may be classed under fine stonewares, and possess a mass exhibiting a striking resemblance to porphyry or jasper, and capable of receiving the most delicate and refined forms in manipulation. The ware manufactured by UTZSCHNEIDER at Saargemündt exhibits several peculiarities—the contraction in the firing amounting to twenty per cent., while the mass is composed of three local varieties of clay, partly ferruginous, and quartz. The body, which is not glazed, but ground after firing with emery and polished with tripoly, requires the same precautions in the manufacture as that described under *Fine Stoneware*. The ware manufactured at Pirna on the Elbe has likewise a colored body, the chrome green and black masses being without glaze and dull; while the ochre-yellow mass of other varieties is often concealed by a coating of very brilliant varnish color, very different to potters' pigments, from its soft nature, fatty lustre, and easy destructibility in the fire, being, in fact, an oil paint. This varnish is laid on very smoothly and with great care, to preserve the outlines of the ornaments in relief, and afterwards when dry covered with a thin coating of copal varnish. It is secure from injury by hot water, but neither withstands abrasion by the knife, or use over the fire. Fine stoneware, as a general rule, does not stand well against heat or sudden changes of temperature.

The relative values of plastic clay for the manufacture of *fine* and *common* stoneware, with and without glaze may be here given—

STONEWARE GLAZED.

Place,	Silica,	Alumina.	Oxide of iron.	Lime.	Magnesia.	Alkali.	Loss.	Parts.	Description.
St. Amand,....	75.00	22.10	1.00	0.25	traces	0.84	0.81	100.00	Common body, earthy glaze.
Helsingborg,...	74.60	19.00	4.25	0.62	traces	1.30	0.23	100.00	Coarse greyish body, ill moulded, glazed with salt.
Voisinlieu,....	74.30	19.50	3.90	0.50	0.80	0.50	0.50	100.00	Fine whitish body, well moulded, salt glaze.
Vauxhall,	74.00	27.04	2.00	0.60	0.17	1.06	0.13	100.00	Fine whitish body, well moulded, with a porous external surface, salt glazed.
Freehen,	64.01	24.50	8.50	0.56	0.92	1.42	0.09	100.00	Dark brown body, fine, well moulded, covered with an earthy glaze.

STONEWARE UNGLAZED.

Place,	Silica,	Alumina.	Oxide of iron.	Lime.	Magnesia.	Alkali.	Loss,	Parts,	Description.
Baltimore,.....	67.40	29.00	2.00	0.60	—	0.60	0.40	100.00	Very fine whitish body.
Wedgwood, ...	66.49	26.00	6.12	1.04	0.15	0.20	—	100.00	Very fine yellowish body, very sonorous, well moulded.
Saveignies,....	65.80	27.64	4.25	1.12	0.64	0.24	0.31	100.00	Clear brown body, coarse, very sonorous.
Japan,	62.04	20.30	15.58	1.08	traces	traces	1.00	100.00	Very fine body, well moulded, of a deep brown-red color.
China,	62.00	22.00	14.00	0.50	traces	1.00	0.50	100.00	Very fine body, well moulded, of a deep brown-red color.

From which tables it appears that stonewares may be divided into two classes—those containing from seventy-five per cent. of silicic acid, and others of from sixty-two to sixty-six per cent. Experiment further proves that an excess of silica in the body is very favorable to the production of a good glaze.

Ordinary Stoneware—one of the characteristics of which, namely, the semi-fused state of the mass, results from the much stronger heat of the kiln, and not from the addition of flux. The composition is more simple; only one addition being made to the plastic clay, which, having no tendency to shrink in the furnace, prevents the clay from any very serious contraction, the amount of which varies, as in the finer stonewares, from eight to ten per cent.

As the plastic clays generally possess this property of contraction in a high degree, objects formed from them without this addition and tolerably thick in the sides, infallibly crack in the firing.

The action of such additions has been determined experimentally upon the plastic clay of Dreux mixed with—

	Contracts,
10 per cent. ground fragments of stoneware,	15 per cent.
25 “ “ “ “ “ “	5 “
10 “ whole sand from Aumont,.....	18 “
25 “ “ “ “ “ “	15 “
50 “ “ “ “ “ “	9 “
10 “ “ “ “ “ “	17 “
25 “ “ “ “ “ “	15 “
50 “ “ “ “ “ “	12 “
No addition, clay in natural state, .....10 to 11	“
No addition, clay purified by suspension in water,.....	17 “

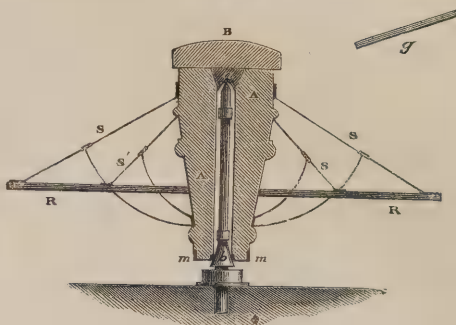
From which it appears that the plastic clay under experiment contained in its natural state an admixture of some substance that diminished its power of contraction, and which was removed from it by decantation in water, increasing the contractile power. In the potteries a very important practice is adopted, that of combining together the several kinds of clay found to produce the best result in the fire, both as regards the contraction, color, and refractory nature of the mass.

In the manufacture of ordinary stoneware vessels, such as jars for preserves or pickles, milk pans, *et cetera*, the process of decanting the clay from water would be too costly, and the coarser impurities which might interfere with the formation of the ware, are therefore either removed by repeated kneadings and treading out of the mass by manual labor, or separated by passing the clay through the *pug mill*—see *Earthenware*.

The low price at which these wares are purchased in the market necessitates the adoption of the most simple modes of forming and manipulation; they are generally, therefore, thrown upon the potter's wheel, already described under *Porcelain*. From the large dimensions of the vessels that sometimes require to be formed, increased facilities are given to the workman for producing greater persistence in the rotatory motion of the wheel, and using larger plates or discs for the support of the mass. These arrangements are shown in Fig. 484P. The cast-iron wheel, R R, is connected to

the hollow shaft, A A, carrying the head or disc of the lathe by double spokes, s s', s s'. The top of the hollow shaft at a is fitted with an iron cup, into which the top bearing of the supporting axle running through the centre works, while the lower extremity of the hollow

Fig. 484P.

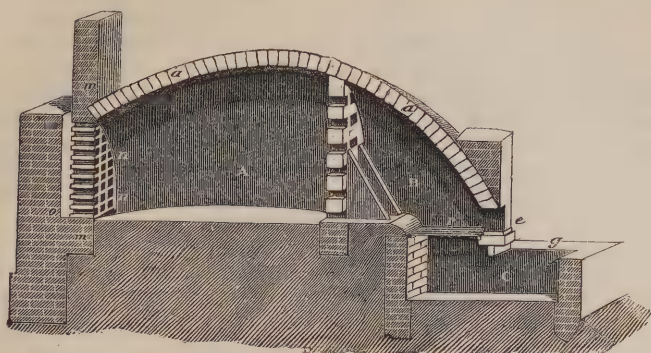


shafts, m m, being of iron, rests upon the conical support, b, of the axle. The wheel and shaft, therefore, turn with little friction, being suspended after the manner of a ship's compass. For the greater convenience of the workman, who sits at the bench, g, the surface of the disc, B, is placed below his level. Impulse is given to the iron wheel by a pointed rod, the rotatory motion lasting long enough for one operation, and the high degree of plasticity in the mass being of great assistance. The help of an assistant to turn the wheel is therefore only required when a great amount of resistance has to be overcome. Vessels of a wide bulging shape and of moderate dimensions are first thrown in the form of a hollow cylinder of the intended height and width, the contraction being afterwards effected by pressure against the mass in its revolution; larger vessels of similar form are put together from two halves separately formed, the handles, *et cetera*, which are made by hand, being simply pressed on to the mass. In the firing of common stoneware, horizontal kilns or furnaces are used, in which the draught has a direction more or less parallel with the floor. It is only in kilns of this construction that the wares can be placed alongside of each other, instead of being piled up in columns or bungs. By such an arrangement of draught, however, the heat of the furnace is very irregularly distributed. All common stoneware in the firing is exposed directly to the action of the flame, the nature of the surface not rendering the protection from dust and scratches by the use of seggars necessary.

The kiln—Fig. 484Q—is in general roughly constructed, the grate, r, separating the ashpit, c, from the hearth, B. The portion of the kiln where the wares are fired is shown at A, an elliptical arched dome, a a, covering the whole. The draught is regulated by a plate covering the aperture, g, the fire being supplied with fuel through e. By this arrangement the flames carried by the draught pass through the apertures, i, i, in the wall, m m, to the chamber containing the wares, from which they enter the chimney, o, by the holes, n n. The wares are introduced into the kiln by doors which

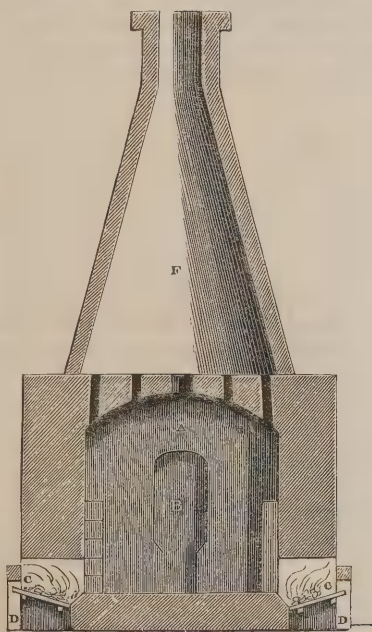
are bricked up during the firing. At Lambeth, near London, the kilns assume a vertical character, are about ten feet in diameter in the baking chamber, and

Fig. 484q.



eleven feet high to the centre of the crown; they have five fire grates, each twelve inches wide and three feet long, containing five or six fire-bars, a bag or chimney flue about five feet high being placed opposite each fire. Fig. 484R represents a section of one of these

Fig. 484R.



kilns: A is the baking chamber; C the fire-grate; D the ash-pit; and F the bag or chimney, the wares being introduced by the opening, B, bricked up during firing. In the kilns used for common stoneware, the smaller articles are placed at the bottom part of the kiln,

in square cells formed by placing stout tiles upright in rows, with others laid horizontally upon the top—the heavier and coarser portions of the ware being placed upon the top. These cells or boxes generally occupy one-half the height of the kiln. Great care and experience is required in the management of the fires, as, if too little air is admitted, the smoke and gas will be imperfectly consumed, and the wares discolored; while, on the contrary, if air enters too freely the heat is not sufficiently intense to vitrify the clay. The heat of the furnace often attains 120° Wedgwood, this ware requiring the most intense heat, after real porcelain, of any kind of pottery.

Common stoneware, being sufficiently dense and vitreous in its mass to be impermeable, requires no glaze, but by a very cheap and simple process the dull surface is made smooth and lustrous. A natural glaze, or the waste from other branches of the manufacture, is used, ground to a fine powder, and sifted or sprinkled over the moist ware in a thin stratum; it is afterwards burnt on in the process of firing. Iron slag is generally used for this purpose, the large proportion of the oxides of iron and manganese which it contains rendering it of easy fusion.

Salt-glaze.—The simple and old-fashioned salt-glaze is also of very general application. Its discovery, dating about the year 1680, is said to have been accidental, the tradition being that at Stanley farm at Bagnall, about five miles East of Burslem, the servant of Mr. JOSEPH YATES was boiling a strong brine of salt, to be used for curing pork; during her temporary absence the liquor boiled over the sides of the earthen vessel used for this purpose, and, becoming very hot, the vessel on cooling had a glazed surface. A Mr. PALMER, who carried on a small pottery about a mile from the farm, availed himself of the hint, and commenced a manufacture of ware glazed with chloride of sodium, which was readily procured from the salt wyches—Middlewich and Northwich in Cheshire. The process of glazing with salt takes place towards the end of the firing, when salt is thrown into the kiln through particular apertures. The temperature of the kiln being considerably above a red heat, volatilizes the chloride into a vapor which, filling the chamber, surrounds the wares, and causes a reaction to take place with the silica of the mass. These two substances, silica and common salt, only act upon each other in the presence of aqueous vapor, and which is always present in the flame of the furnace. With the sodium of the chloride, the oxygen of the water produces soda, which enters into combination with the silicic, while the hydrogen unites with the chlorine, and is evolved as hydrochloric acid— $\text{NaCl} + \text{HO} = \text{NaO} + \text{HCl}$. The glaze is, therefore, a soda glass, and exists as a very thin coating upon the surface of the wares. Clays which contain less than fifty per cent. silica are without action, and do not decompose salt. A brown color is

communicated to the wares by throwing into the furnace, during the glazing process, substances which afford a large volume of smoke, such as the bark of the birch tree.

Common stoneware generally varies in color from grey to bluish-grey, yellowish-red, brownish-red, and brown.

The manufacture of stoneware by *moulding*, has recently been brought to great perfection, and most of the vessels used in chemical laboratories are formed in this manner, the smaller articles being remarkably thin and light. The larger vessels for chemical works, such as acid bottles, *et cetera*, are sometimes of enormous dimensions, and constructed to contain from one hundred to three hundred gallons. The agreeable brown color of these vessels is produced by dipping them into water containing oxide of iron in suspension.

The principal seats of the manufacture of common salt-glazed stoneware are at Glasgow, Lambeth, Belper, and Nottingham; the other variety of common glazed stoneware being produced at Bristol and Chesterfield, while the fine stoneware manufacture is almost exclusively confined to the neighborhood of the Staffordshire potteries. On the Continent the manufacture is extensively carried on at several places, particularly at Buntzlau in Silesia, and at Vallendar, on the Rhine opposite Coblenz, where two kinds of clay are worked—a blue clay for grey ware, and a yellow clay for red ware. At Buntzlau the wares are colored brown by immersion into a solution of marly clay after the manner of a glaze.

EARTHENWARE.—Under the term *earthenware* are embraced many varieties of pottery, which in fracture have all an earthy appearance, are perfectly opaque, and are coated with a soft, easily fusible glaze,

containing lead or borax. But, notwithstanding they all possess these characteristics, the modifications and varieties of this ware are more numerous than those of any other kind. The several kinds of clay—plastic or pipe-clay, potters' clay, and marl, to which quartz is sometimes added—enter into the composition of all earthenware. The absence of any real flux, and the circumstance of its being fired at a temperature which precludes the partial or entire fusion of any one of its constituents, distinguishes earthenware from porcelain and stoneware, while the greater care bestowed upon the preparation of the materials, and consequent greater purity of the mass, together with the general absence of color, are sufficient to mark the distinction between this and delftware.

Fine Earthenware.—The English manufacture may be selected as the type of this ware; it is composed essentially of a mixture of plastic clay and quartz, and is, therefore, more refractory, harder, and denser than the delftware, the chief ingredients of which are potters' clay and marl, and which is in consequence soft and calcareous. Fine earthenware again is always coated with a transparent glaze; the commoner sorts with enamel, producing the favorite *Majolica* ware. Neither kinds, however, are fitted for culinary use, as they either split when exposed to heat, or the glaze becomes cracked and crazed.

The crude materials used in England in the manufacture of fine earthenware, are Cornish stone and China clay, a kind of kaolin brought from Cornwall, two varieties of plastic clay, both of which burn white, and chalk-flints. That class called *ironstone china* is made from a mixture of plastic clay, kaolin, Cornish stone in excess, and silica, the formula of which is subjoined:—

IRONSTONE CHINA BODIES.

	I.	II.	III.	IV.	V.	VI.
Cornish stone	180	200	700	600	600	400
China clay	120	150	500	600	100	250
Blue clay	60	100	300	—	180	150
Flint	80	120	250	400	60	75

A small proportion of cobalt blue is added as a stain to whiten the mass.

These are the three principal modifications into which this class of claywares may be subdivided, leaving innumerable others of an intermediate character. Mixtures for the mass of the following varieties are given below:—

FRENCH.

Plastic clay from Montereau and Dreux	87
Quartz.....	13

ENGLISH.

CREAM COLORED WARE BODIES.

Slip mixtures by measure; Dry mixtures in parts.

	Dry mixtures.			Slip mixtures in inches.		
Blue clay	22	12	11	13	12	12
China clay	9	12	6	3½	4	4
Flint	5½	10	4	2½	3	3
Cornish stone	—	—	3½	¾	—	—

Turquoise Body.

Blue clay	300 lbs.
China clay	175 lbs.
Flint	200 lbs.
Cornish stone	60 lbs.
Turquoise stain	20 lbs.

Turquoise stain consists as follows:—

Blue cobalt	1 lbs.
Flint	2½ lbs.
Oxide of zinc	10 lbs.
Calcined together in earthenware biscuit oven, and finely ground for use.	

Pale Drab Body.

Fine white earthenware body	700 lbs.
Stain—nickel	4 lbs.
Cobalt calx	1½ lbs.

Buff Body.

Finely ground grey marl	100 lbs.
Fine earthenware body	100 lbs.

Inside Wash for above colored bodies.

China clay	40 lbs.
Blue clay	20 lbs.
Flint	20 lbs.
Cornish stone	10 lbs.
Cobalt calx, to whiten	15 drachms.

This wash is poured smartly into the interior of the ware after forming, and immediately emptied.

COLORED CLAYS FOR ORNAMENTATION.

Turquoise or blue, take of the body of the ware 40 lbs., and 1½ lb. of the turquoise stain.

Green Clay.

Body	40 lbs.
Nickel	3 lbs.
Cobalt calx	¾ ounce.

Dark Chrome Green Clay.

Body	40 lbs.
Oxide of chrome	3 lbs.

Drab Clay.

Body	60 lbs.
Nickel	12 ounces.
Cobalt calx	3 ounces.

Orange Clay.

Body	40 lbs.
Fine red marl	20 lbs.
Flint	7 lbs.

In general use for moulding and pressing.

FINE EARTHENWARE BODIES.

In *Slip* by measure.

Slip mixtures in inches in tub.

	Ounces to the pint.	I. Inches.	II. Inches.	III. Inches.	IV. Inches.
Blue clay	24	7½	12½	7	9
China clay	26	9	5	9	7
Flint	32	3	3	5½	5
Cornish stone	31½	½	—	2½	3

Dry in parts.

	I.	II.	III.
Blue clay	200	500	500
China clay	200	800	650
Flint	200	800	450
Cornish stone	75	300	200

TERRA-COTTA, OR POROUS BODIES FOR WATER BOTTLES, ETC.

	Green.	Blue.	Red.
Earthenware body	100	100	300
Cornish stone	15	10	100
Oxide of chrome	3	3	Turquoise stain.

	Cane.	
Grey marl	120	The marls should be very carefully sifted through fine lawns, and if ground finely in a pan at the mill, the body will be much improved. This remark applies to all colored bodies.
Blue clay	13	
Flint	6	

These porous bodies are all fired in the glazing oven.

Preparation of the Material for forming the Mass.

The flints are prepared for the grinding process by crushing in their calcined state under the stamping-mill—Fig. 484s—which consists of a series of upright beams, *a, a, a*, of wood, shod at their lower extremities with heavy iron shields, *b, b*. These beams being alternately raised in a vertical direction by means of projecting pins, *c, c*, catching the arms of a revolving drum, *d*, fall with great force into a long narrow trough, *f*, placed in a horizontal direction underneath, and having its bottom formed of perforated cast-iron plates, *m*, through the holes of which the broken calcined flints pass, and are then ready to be conveyed to the block-mill.

The mill room where this grinding process takes place is fitted with a number of circular vats—Fig. 484t—from ten to twelve feet diameter; the bottoms of which are paved with square blocks of a very hard stone. These vats are fitted with arms in the same

manner as the mixing vats described under *Porcelain*. Blocks of stone weighing from ten to fifteen hundred-weight are placed against the arms, which are driven round by machinery. Into these vats the broken calcined flints are thrown, and water is introduced to prevent the escape of the finer particles of dust, which would be very injurious to the workmen. By this process the flints quickly acquire a state of minute division. After a period of about twelve hours the contents are run off through troughs into washing tubs or vats, where the coarse or heavier particles subside, the fine liquid flint passing into spacious reservoirs built and paved with bricks, and which are furnished with plugs, to enable the workmen to draw off the first water with which the grinding process took place, and bring the flint into a state fit for use.

The *Cornish stone* is brought from Cornwall in masses for the purpose of being ground and prepared, but without the process of calcination, and is used in

the bodies, besides being a most valuable ingredient in the composition of the glazes.

The process of grinding *glazes* is similar to that of

durable than the materials formerly employed, whilst, from the purity of its substance, and the entire absence of any injurious ingredient, the flint slip is left pure and free from admixture caused by the abrasion of the mill-stones. When by friction the *pavers* or *runners* have become too light, they are calcined with the flints, and afterwards ground up with them.

To increase its plasticity, the China or Cornish clay is mixed with as much blue clay as the quality of the ware admits. Where machinery is employed the lumps of clay are thrown into the blending vat, and stirred up with water, as already described under *Porcelain*. The liquid with the clay in suspension is then decanted, and passes into vats in the *mixing* or *slip house*—Fig. 484u. The clays are brought up by a lift to the floor of the



Fig. 484s.

flint grinding, but the vats or pans employed are generally of smaller dimensions. The requisite machinery not being erected at all the manufactories, the potters are usually supplied with the materials prepared ready for use, by mills established in the localities where this process is carried on.

A species of stone, which has been termed *Lagnatia quartzite*, and is found in Scotland upon the estate of

room where they are macerated by water, and pass into the tubs, *a* and *b*. The China clay, *a*, is brought to the standard of twenty-six ounces to the imperial pint, and that at *b*, containing the Dorsetshire or blue ball clay, to the standard of twenty-four ounces; the ground flint contained in the trough at *c* is likewise brought to the standard of from thirty-one and a half to thirty-two ounces, while the Cornish stone at *d* is of the standard weight of from thirty to thirty-one and a half ounces to the imperial pint. The China clay and blue ball clay having been admitted into the tanks, *e* and *f*, severally, in the proportions marked upon the gauge rods, *s s*, are united in the mixing cistern, *g*, the blue ball clay passing by the trough, *n*. The relative proportions by measure of Cornish stone and flint are now added, and mixed with the mass, which then passes into the trough, *t*, furnished with plugs and holes, *c' c' c'*, in its bottom, immediately over a set of fine silken sieves, *a' a' a'*, fixed in a frame, *p*, to which a sifting motion is imparted by attachment to the eccentric and rod, *d'*, worked by the engine. This lateral to and fro motion of the sieves cause a complete filtration of the slip into the tank, *h*, all the coarser impurities being left behind. From this tank, *h*, it is conveyed by the pump, *j*, and spout, *k*, into the trough, *e'*, where it undergoes a second and similar process of filtration through finer sieves, falling into the reservoir, *i*, and is conveyed away by the pumping apparatus, *m*, to the purifying machine, and for conversion into *slip* of the proper degree of consistency for working.

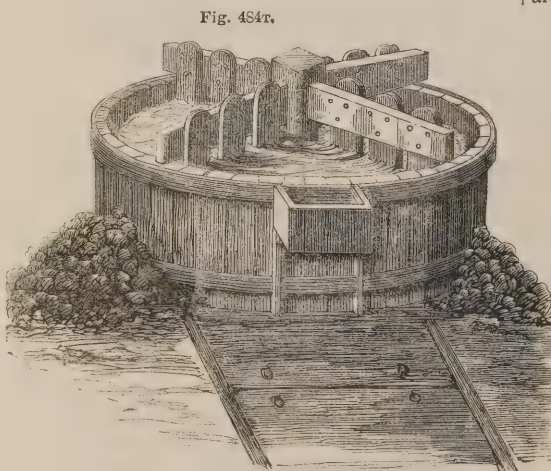


Fig. 484r.

Ardsheal, Argyllshire, has been recently introduced by Mr. MILES LOCKHART into the Staffordshire potteries for the purpose of grinding the flint. Being composed almost entirely of pure silica, it is harder and more

The *purification* of the slip by the abstraction of all particles of iron which have become incorporated with

it, from the abrasion of the iron hoops of the mill during the process of grinding, is one of great importance,

as were these impurities to pass with the mass through the process of firing, the iron, being converted into an

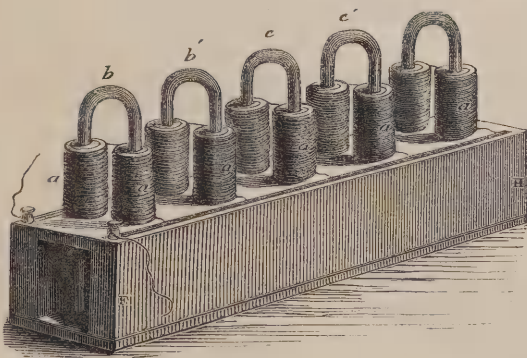
Fig. 484u.



oxide, would produce a brown or yellow stain upon the white surface of the ware. A clumsy and expensive method is frequently used to extract these par-

iron removed—a work of extreme labor and time, in consequence of the electricity of the magnets remaining constant. Greater simplicity, economy, and cer-

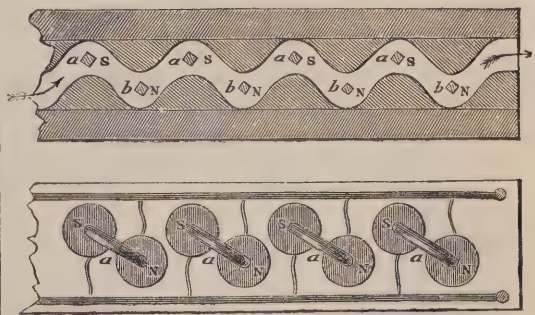
Fig. 484v.



ticles from the mass, by placing in a box a large number of small horseshoe magnets suspended upon a frame. The slip or glaze, as the case may be, is poured by an attendant into the box, and the frame containing the magnets afterwards agitated to bring the slip into contact with them; by this means the iron particles are attracted to the poles of the magnets, which are afterwards taken out one by one from the trough, and the

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Fig. 484w.



tainty have been given to this operation by Messrs. HOLMES and CORDON, who have recently patented an invention which, by the application of electric currents for inducing magnetism in soft iron, effectually purifies the slip or glaze from all such particles in a much shorter time, and at a great saving of expense to the manufacturer. One form of the apparatus is shown at Fig. 484v. *a a a*, are a series of coils inclosing the electro-magnets, *b b', b b', c c', c c'*, the coils being placed in such

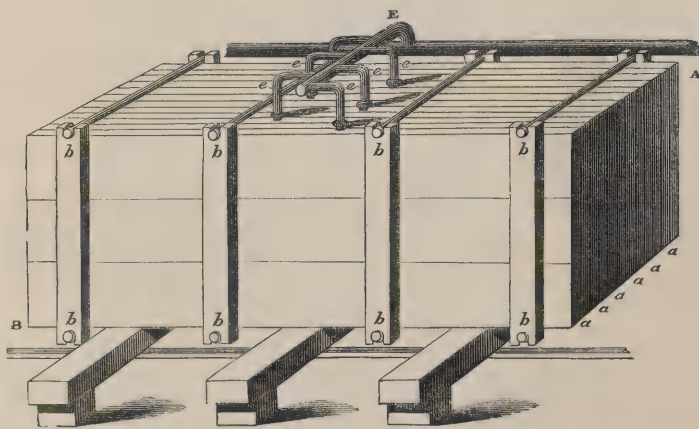
5 M

a manner that the induced magnetism in the alternate poles of each set shall be of an opposite nature—Fig. 484w; the arrangement of the North and South poles is shown at *a* and *b*. The slip, in its passage through the machine, comes into contact successively with the several poles of the magnets; and the particles of iron being attracted by them, the slip is thoroughly cleaned from iron by the operation. The apparatus is placed in a strong box, *E*, with two apertures, *F* and *H*, for the passage of the slip through the machine.

The slip, which is now much too liquid, passes into the slip-house for consolidation in troughs of brickwork from eighty to one hundred feet or more in length, and about four feet wide by fourteen inches in depth. The fire, placed at one end, passes by means of flues under the bottom, which is constructed of tiles, into the chimney at the further end, by which means the whole of the heat is economized. The slip, upon reaching the boiling point, throws up a dirty scum, which is scooped off, the tumultuous ebullition preventing the separation of the particles, and securing the uniform mixture of the mass. This process requires about eighteen hours, care being taken to prevent any portion of the mass from burning during the evaporation.

In extensive manufactories where machinery is used, the beautiful apparatus patented by Messrs. NEEDHAM and KITE, for consolidating the slip by pressure, is being introduced, and is a decided improvement upon the old process of evaporation by heat.

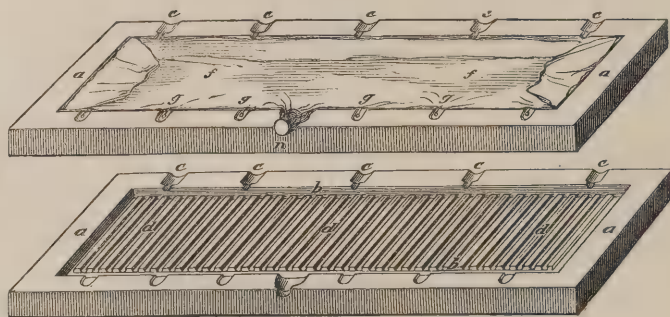
Fig. 484x.



The machine—Fig. 484x—constructed of stout wood, in the form of a rectangular mass, is composed of a series of separate chambers or compartments, *a a a*,

bolted together by iron clamps, *b b*, in pairs, and forming the mass, *A B*. These separate compartments are each fitted up with a series of small wooden grooves or channels, *d d d'*—Fig. 484y—sunk half an inch below the level of the frame, *a a*, and having a canal or passage, *b b*, cut top and bottom of the passage of the

Fig. 484y.



water pressed from the slip through the holes, *c c*. By this arrangement each pair of frames when placed together will have a space between the grooves of one inch, into which the slip is forced by means of the connecting pipes and apparatus, *E*, each pair of frames having its separate supply pipe, *e*. The interior of the chamber is prepared for the reception of the slip by the insertion of a strip of fine hempen cloth, *f f*, the edges being wrapped and folded up to form a large bag, and the nozzle, *n*, for receiving the supply pipe, *e*, being permanently fixed on the double fold of the cloth. The weight of the bag is supported by the

hooks, *g g*, upon the upper portion of the frame. The machine being screwed up tightly by the rods, *b b*, the pressure is brought on by the pumps, and the water passes out through the fibres of the cloth and grooved channels, leaving the slip in the form of a thin, solid, compact, and plastic sheet of clay. The time required for the operation varies from an hour to two hours and a half according to the composition of the mass, the charging and discharging of the machine occupying an hour. Each machine can produce at the rate of four tons of prepared clay in the day. In order to strengthen the fibres of the cloth, and to enable it to with-

stand better the pressure and abrasion of the grooved surfaces of the chambers, it is dipped into a solution containing half an ounce of alum to a gallon of water,

an operation found greatly to increase its durability and resistance to wear and tear. Some statements of the expense and performance of these machines, compared with the old process of evaporation, are given below:—

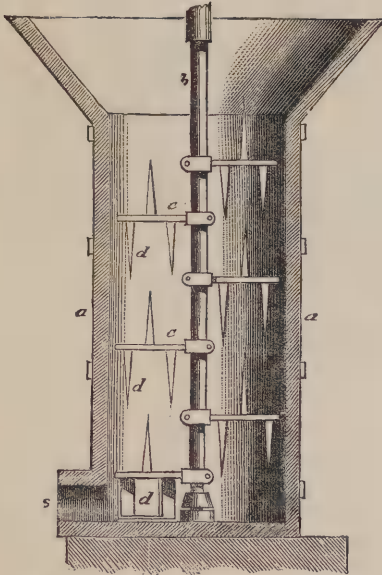
COMPARATIVE COST OF CONSOLIDATING THE CLAY FROM THE SLIP.

By the Old Evaporating Kilns, over a period of six months.			By Needham and Kite's patented process, over a period of six months.		
1000 tons clay at 1s. 4d.,	£66	13 4	1000 tons clay at 3s. 6d.,	£175	0 0
Wear and tear of kilns,	32	0 0	Milling, at 4d.,	16	13 4
750 tons coal at 4s. 9d.,	178	2 6	Steam-power,	20	0 0
			Patent right per ton 6d.,	25	0 0
				£236	13 4
			Saving,	40	2 6
				£276	15 10

The cost of preparing the slip is in each case 8d. per ton.

The slip in this state passes through the *clay* or *pug-mill*—Fig. 484z—in order to bring the mass to a

Fig. 484z.

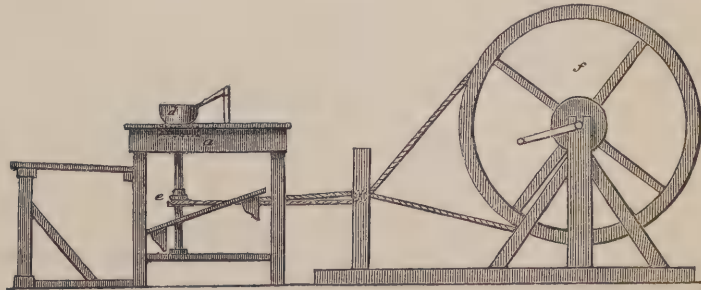


uniform consistency. The mill consists of a circular iron vat or cylinder, *a a*, bound together by iron hoops, through the centre of which the iron shaft, *b*, revolves, carrying with it several horizontal arms, *c*, armed with the sharp blades, *d*; these are fixed in a horizontal position, and inclined at a certain angle; by this arrangement the clay in its passage through the mill is cut up and forced out at the aperture, *s*, the mass constantly sinking as it is supplied with fresh clay from above, and separated as it issues from the machine, by means of a fine wire, into blocks, which are carried away to the store house for the process of *ageing*—see *Porcelain*. Before the mass is placed in the *thrower's* hands it under-

goes a further state of preparation, termed *slapping* or *wedging*, by being forcibly thrown upon a strong slab of plaster of Paris. The workman then divides the mass, and the piece cut off is again brought down with considerable force upon the other portion, a continual dividing and slapping of the mass being continued until the whole is of a perfectly homogeneous texture; at the same time care is taken not to cross the mass, but to *slap* the pieces together in the relative position from which they were cut, as, if this precaution were not observed, the ware would afterwards contract unequally in the firing. From twenty to twenty-five blows are given to the mass before it is sufficiently homogeneous for manufacture.

Throwing.—From the much greater plasticity of the mass used for earthenware, the operation of throwing upon the wheel is one of greater rapidity than is the case with the manufacture of either porcelain or stoneware, an experienced *thrower*, assisted by two boys, often producing as many as from twelve hundred to fifteen hundred eight-inch basins in a working day of ten hours; while between two thousand and three thousand of the small round ink bottles may be produced in the same time by a lad and his assistant. This extreme facility in the manipulation is certainly one of the principal reasons for the low price of the ware. The potter's lathe, in its general form, where machinery is not employed, is shown at Fig. 484AA, and consists of a fixed table, *a*, carrying an upright shaft, *b*, to which the *throwing* disc or head, *d*, is fixed for receiving the

Fig. 484AA.



mass of clay. *e* is a pulley fixed on to the shaft with grooves of different diameters, and receives motion from the driving wheel, *f*, by a cord passing under the

guide pulley upon the frame, *g*. The workman, seated upon the bench, *h*, regulates the velocity of his disc in the shaping of the mass by corresponding signals to the assistant who turns the wheel, *f*.

In the manufactories of WEDGWOOD and COPELAND, the lathes are driven by engine power, the arrangement

for regulating the speed, *et cetera*, being shown at Fig. 484BB. *a* and *b* are two conical drums, connected together by the belt, *c*, and to which motion is communicated by the driving wheel, *d*. The thrower sits at his table, and the axle, *e*, carries the disc, on which are placed two pulleys, *m*, *n*, one fixed, the other loose,

Fig. 484BB.



in connection with the drum, *b*, by means of the strap, *f*. The revolution of the lathe is thrown off and on by the treadle, *h*, under command of the operator's foot. The speed of the lathe is regulated by the assistant, who elevates or depresses the belt, *c*, upon the drum, *b*, by means of the winch and carrier, *s*, through which the strap works.

The *baller*, who prepares the mass for the *thrower*, is shown at *D*. Each piece is weighed when the vessels require to be of a uniform size, a stroke or two of the hand being given before it is pressed into the balls, *r*, ready for use by the thrower, who, after the formation of the vessel, dexterously separates it at the base from the disc by a fine brass wire, and places it on a board, where it remains until the mass becomes sufficiently firm to bear without injury the subsequent processes of turning, handling, *et cetera*.

Turning.—This manipulation requires considerable dexterity on the part of the workman, to avoid destroying or fracturing the piece whilst turning it to the requisite size, thickness, and shape, and presents also numerous opportunities for the exercise of skill, taste, and genius in giving to the several parts the prominence required, and to the whole the degree of elegance suggested by the pattern.

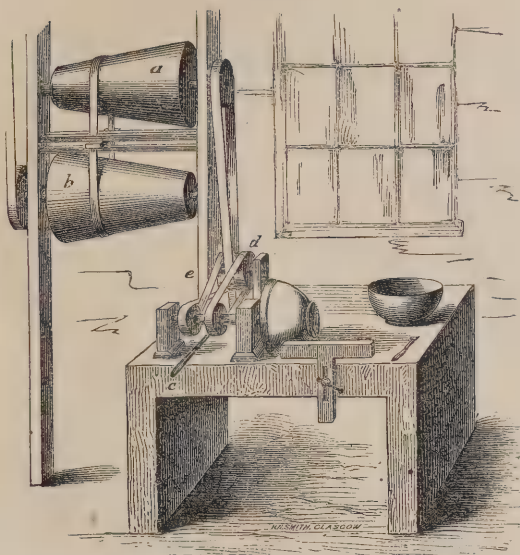
The common horizontal lathe resembles that in use for wood turning, and is generally set in motion by

male or female assistants, who by practice become remarkably apt in adapting the velocity of the motion to the requisitions of the turner, and at the same time perform all the necessary attendant operations, such as stamping the goods, and bringing them to or from the lathe. The vessels are fixed upon the head-stock of the lathe by insertion upon a chuck of a tapering form, which easily adapts itself to the inner surface of the vessel. The engine-lathe, turned by steam power—Fig. 484CC—has the speed regulated by the gauge, *b*, shifting the position of the band upon the driving drum, *a*. The motion of the lathe is reversible by the lever, *c*, changing the position of the driving belt from the direct motion pulley, *d*, to that of the reversed one, *e*. This retrograde motion is required for the final operation of smoothing, solidifying, and polishing the vessel after turning.

The turner's tools are of iron, thin, and well forged, about eight inches in length, and varying in breadth from a quarter of an inch to two inches, the cutting end being turned up at a right angle about half an inch, and made sharp and level upon the grindstone. All wares that are not circular in section, and such as are ornamented with bas reliefs, are made in plaster moulds, into which the mass is pressed with a sponge, *et cetera*. Thin vessels are made at the wheel, with the assistance of plaster moulds and tools, as already

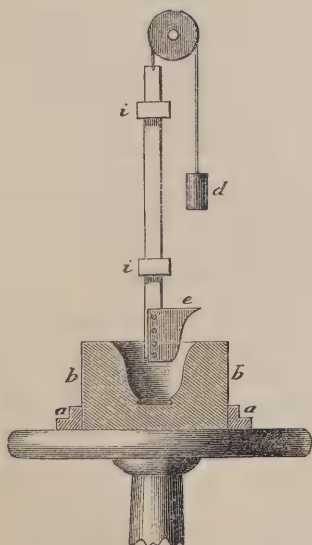
described. When simple forms are required in great quantities, the hand of the moulder has lately been replaced by machinery, more particularly in some of the Northern potteries about Glasgow, Newcastle-upon-

Fig. 484cc.



Tyne, and Yorkshire. Fig. 484DD represents a form of the apparatus in which the cups are formed by means of the plaster mould, *b*, giving the exterior form, while

Fig. 484DD.

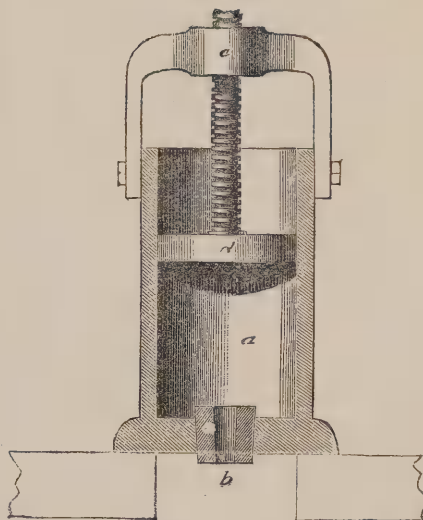


the tool, *e*, gives the interior shape. The plaster mould is fixed in its proper position upon the head of the disc by the iron ring, *a a*, in such a manner that its centre corresponds exactly with the point of the tool. The mould is brought into revolution by means of a treadle, while the tool, *e*, counterpoised by the

weight, *d*, is lowered to the proper distance through the guides, *i i*, by means of a second treadle. When a ball of clay is placed in the mould, and the treadles moved, the tool, *e*, descends into the revolving mass of clay and bores a hole, forming a cup, the thickness of the sides of which will correspond to the distance at which the tool, at its lowest point, is separated from the sides of the mould. When the forming is finished, for which a few seconds suffice, the treadles are set at liberty, and the mould brought to a state of rest; the tool being raised up above the mould by the weight of the counterpoise, *d*. The mould, with the finished piece, is then exchanged for another, and the operation repeated. A machine of this kind can be worked by female labor at a less cost than that of experienced moulders.

Handling, et cetera.—These manipulations are performed, for the better class of wares, by moulding in the same manner as that described under *Porcelain*, while for handles of a less ornamental nature, recourse is had to a small machine, called the *squeezing box*. This consists of an iron cylinder, *a*—Fig. 484EE—about six inches in diameter, and twelve inches deep, the

Fig. 484EE.



bottom of which has a hole, into which a piece of lead, *b*, is inserted, pierced of the size and section of the intended handle. The upper edge of the cylinder carries a strong iron frame, *c*, into which works a screw plunger, *d*; this, upon depression, forces the clay through the aperture in stripes of the proper form, and which afterwards, when cut into lengths and bent as required, are left to acquire their proper consistency before application to the wares. In this operation the handler cuts away from the edges or ends all superfluous clay, and, after moistening with slip the parts of contact, presses them gently against the body of the ware; they are afterwards trimmed with the knife to remove all superfluous matter. The vessel is then rubbed over with a moist sponge to remove all dust, previous to drying and placing in the seggars for the baking process.

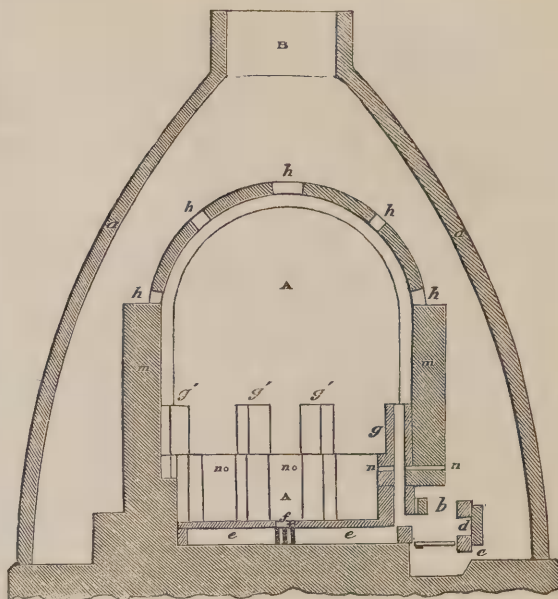
Pressing, or hollow-ware squeezing, is a more laborious manipulation connected with this branch of manufacture.

The clay having been prepared by beating with the bat upon the gypsum slab to the proper thickness and dimension, is placed upon one of the sections of the mould, and with a moist sponge well worked into every part. All the sections being thus lined with clay, the edges are trimmed, and the parts of the mould carefully placed together, and secured in their position by a strap passed round them. The presser then passes his finger up every joint, so as to make a groove, into which a thin roll of clay is inserted, and worked into the mass by the finger, and smoothed with moist leather. All marks are removed with a sponge moistened with slip, and the inside is afterwards washed with clean water and a sponge. The mould and its contents are then set aside until firm enough to receive polish with a flexible horn plate. The article is afterwards removed from the mould, trimmed and polished with proper tools, to remove all appearance of seams, and the handle, spout, or other ornamentation, added in the usual way before baking. One mode of decoration which may be here described consists in the formation upon the ware, while in the lathe, of rings and devices in various colors. This decoration is produced in different ways. When an inlaid pattern in various hues, the workman, while the ware is in the plastic state, and revolving upon the headstock of the lathe, impresses the pattern upon the surface by a roulette, and afterwards blows through a fine tube, out of a bottle, thick colored slips into the several sunk parts, the bottles containing the slip being furnished with a mouth-piece and tube for that purpose. The surplus colored clays being afterwards turned off in the manner described under *Fine Stoneware*, the various inlaid rings of color are produced. When a marbled appearance is required, the tinted mixtures are placed in separate compartments of one vessel furnished with a spout in connection with the several chambers. On their exit from the vessel, all the colors flow out in a single stream, but unmixed with each other. This stream flowing upon the ware causes a waved or variegated appearance according to the regularity of the motion given to the piece, and articles so decorated, are commonly termed *depped* and *mocha* ware. All these colored clays require to be in the *slip* state, and not of an oily nature. The wares are afterwards fired and glazed as usual, according as the nature of the operation has been performed while in the plastic or biscuit state. A pleasing arborescent effect is sometimes given to these wares by a mixture of tobacco water, with manganese, nickel, oxide of iron, and a small quantity of cobalt, dropped on to the soft colored slip surface of the ornamentation.

Firing.—The temperature at which fine earthenware is baked being much higher than that required for the glaze, renders it necessary that vessels composed of this substance should be fired twice. At the first firing

the ware is completely baked, or converted into biscuit, the glaze only being burnt on in the second firing. Two separate furnaces are employed for these distinct operations. The kiln used for baking—Fig. 484FF—has only one chamber, A, and is surrounded by a

Fig. 484FF.



conical brick building, *a a*, termed a *hovel*, that serves at once the purpose of roof and chimney. The construction is nearly the same as that of an upright reverberatory furnace, differing from the porcelain kiln by a better arrangement for the distribution of the flame, and the use of coal for firing in place of wood. The draught is regulated by the aperture, *b*, and passes into the furnace in a downward course, carrying with it the flames in a horizontal direction; *c* is the opening for removing the clinders, and *d* that by which fuel is introduced into the furnace. The flame, before entering the chamber of the furnace, is divided; part of it retaining its original direction, passes through channels below the sole of the furnace, along the horizontal flues, *e*, and enters at the central point, *f*, the remainder circulating upwards through the small chimneys or bags, *g*, situated against the wall, *m*, of the kiln, *A*. Each fire, of which there are six or eight, has a corresponding chimney, *g' g'*, and horizontal flues converging towards *f*, and becoming narrower as they approach the centre. The flame finally escapes through the openings, *h h h*, in the dome of the chamber, *A*, and out of the top of the hovel, *B*. The small openings, *n n*, are for the removal of the *watches* from the seggars placed opposite, and by which the potter ascertains the state of the kiln. The height of the chamber, *A*, averages about eighteen feet, the diameter about sixteen feet.

It being generally the custom, in the manufacture of fine earthenware, to prepare several kinds of goods

at the same time, care is taken in the firing to place those wares, such as ironstone china, *et cetera*, that require the greatest amount of heat, in the hottest portion of the kiln. As has already been stated, no kind of earthenware can withstand the direct action of the flame, especially that from a coal fire; the wares are, therefore, always inclosed in seggars, while the comparatively low temperature at which the wares are baked admits of a great economy of space, the individual pieces being packed closely. The seggars are

arranged in the kiln in columns or bungs after the manner described under *Porcelain*. The temperature of the biscuit kiln ranges from 90° to 100° Wedgwood. The following tabular statements will show the approximate number of bungs and seggars contained in the biscuit kilns at each firing. It must, however, be observed, that the bracket mentioned in the table is not general throughout the Staffordshire Potteries, but has been successfully used for many years by Messrs. COPELAND in their kilns:—

No. 1.—LARGE OVEN—Dimensions, 18 feet diameter; 17 feet 6 inches high.

Bracket,.....	containing	39	bungs	of	ovals,.....	13	high,	or	507	seggars.		
Arches,.....	"	8	"	"	16 in. ovals	22	"	or	176	"		
First ring,.....	{	"	15	"	ovals	}	26	"	or	624	"	
		"	8	"	14 in.							"
		"	1	"	16 in.	"						
Second ring,.....	{	"	3	"	20 in. 23	high	}			or	312	"
		"	5	"	18 in. 23	"						
		"	1	"	16 in. 24	"						
		"	1	"	14 in. 26	"						
		"	3	"	ovals 26	"						
Third ring,.....	{	"	5	"	ovals 30	"	}			or	326	"
		"	1	"	18 in. 28	"						
		"	4	"	plates 37	"						
Middle ring,.....	{	"	3	"	ovals 31	"	}			or	237	"
		"	1	"	14 in. 30	"						
		"	3	"	plates 38	"						
Number of bungs,.....		101		Number of seggars,.....		2182						

No. 2.—SMALL OVEN—Dimensions, 15 feet diameter; 14 feet 6 inches high.

Bracket,.....	containing	40	bungs of ovals,.....	13	high	or	520	seggars.				
Arches,.....	"	8	" 16 in. ovals....	24	"	or	192	"				
First ring,.....	{	" 20	" ovals	}	29	"	or	725	"			
		" 5	" 14 in. ovals									
Second ring,.....	{	" 2	" 20 in. ovals	}	22	high	}	or	234	"		
		" 5	" 18 in. ovals								23	"
		" 1	" 16 in. ovals									
		" 2	" ovals	26	"							
Third ring and middle,	{	" 1	" 16 in. ovals			}	26	"	or	220	"	
		" 1	" plates	34	"							
		" 4	" ovals									27
		" 2	" 14 in. ovals	26	"							
Number of bungs,.....		79	Number of seggars,.....			1444						

No. 3.—LARGE OVEN—Dimensions, 18 feet diameter; 17 feet 6 inches high.

Bracket,	containing	40 bungs	of	ovals,	13 high	or	520 seggars.
Arches,	"	8	"	16 in. ovals....	24	"	or 192 "
First ring,	{	" 20	"	ovals	} 29	"	or 725 "
		" 5	"	14 in. ovals			
Second ring,	{	" 8	"	18 in. ovals	29 high	}	or 386
		" 3	"	20 in. ovals	29 "		
Third ring,	{	" 9	"	ovals	32 "	}	or 379 "
		" 2	"	plates	41 "		
Middle ring,	{	" 5	"	ovals	33 "	}	or 212 "
		" 1	"	plates	42 "		
Number of bungs,		103		Number of seggars,		2414	

The mode of constructing the *seggars* for firing the fine earthenware is shown at Fig. 484gg. The marl, after beating out by the bat, *a*, upon the iron or stone slab, *b*, is cut to the required height of the seggar, and wrapped round the wooden drum or shape, *c*; the necessary thickness of clay to form the bottom of the seggar having previously been placed on the wooden shoard, upon the whirler, *d*, the workman now unites

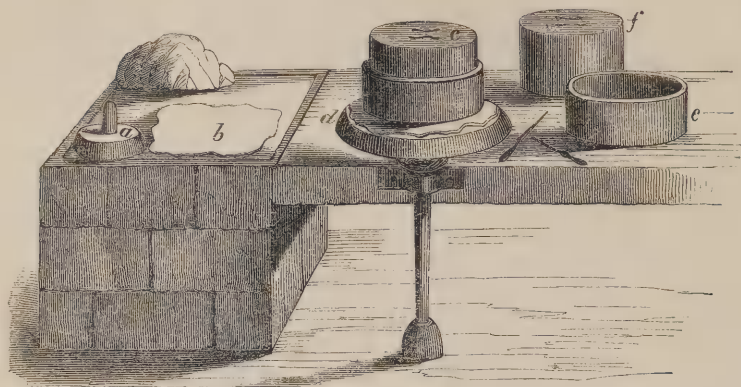
the edges of the sides together by moisture and subsequent kneading of the fingers; the bottom mass is also trimmed round, and luted up into the side in the same manner, the operation being assisted by the rotatory motion imparted by the left hand to the whirler, *d*. The seggar, after the withdrawal of the drum, is shown at *e*, and the drum at *f*. The composition forming the mass of the seggars is as follows:—

Various grey and black marls from the coal-beds mixed together with the addition of from twenty to twenty-five per cent. of coarsely-crushed old biscuit

seggars, these proportions depending upon the plasticity or porousness of the marls used.

In firing earthenware, that quality of coal is selected

Fig. 484hr.



which produces a long flame, and is not of a caking character. The heat is moderated at first until the furnace and its contents have gradually been raised to a red heat; the temperature is then increased, the draught entering from below, and regulated by the opening or closing of the lid. The state of the biscuit is ascertained by the introduction of hollow balls of red clay, bored through on two sides, to enable their removal from the kiln—the degree of color produced affording a clue to the state of the furnace. These balls or watches become first pale-red, and after passing through several tints become red-brown; at which stage those varieties of earthenware equal in quality, or nearly allied to *iron-stone* ware, are sufficiently fired. The softer varieties are fired when the tests appear slightly tinged with dark-red. The firing in the biscuit kiln occupies about forty to forty-eight hours, the average amount of coal consumed varying from fourteen to eighteen tons, according to the size of the kiln.

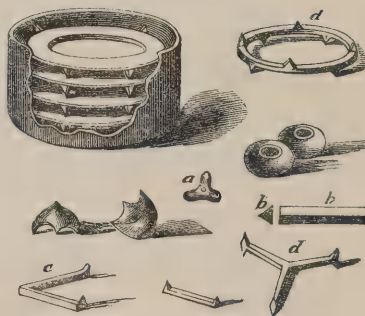
The kilns employed for the after-operation of glazing are of the same construction, but somewhat smaller than the biscuit kiln; the temperature of the furnace for burning the glaze being ascertained by the introduction of balls of clay, previously coated with glaze, into the chamber, and which assume progressively the same changes of color with the heat of the furnace. Frequently the trials from the most successful bakings are preserved in order to use them for the purposes of comparison in future operations of the same kind.

Flat pieces, such as plates, *et cetera*, are separated from each other in the seggars by small pointed supports or rests, made of hard baked clay or earthenware, called *cockspurs*, *stilts*, *triangles*, *et cetera*, as shown in Fig. 484ii; those as *a a*, *b b* being fixed into separate holes made in the side of the seggars, the plate resting upon the edges of the prominent portion, rim downwards, or, as is the case with hollow

wares, separated one from the other by the triangle *c* or *d*.

The extent and importance to which the earthenware and pottery manufactures of England have risen,

Fig. 484ii.



can only be estimated by taking the approximate returns of material used and goods manufactured over a given time, in one of the principal localities—such as the Staffordshire potteries—and which may be taken as follows:—

The total quantity of *potters' material*—such as Cornish stone, flint, kaolin, china clay, pool clay, felspar, *et cetera*—used in the various departments of manufacture in the Staffordshire potteries, during the year 1859, is estimated at not less than two hundred and twenty thousand tons; the manufactured ware sent out of the district during the same period, reaching over one hundred and ten thousand tons, which, taken at an average value of twenty-five pounds per ton, will give the enormous sum of two millions five hundred thousand pounds sterling.

Glaze.—In the composition of the glaze the following substances are used in greater or less proportions:—Felspar or Cornish-stone, flint, sand, borax, soda, tincal, boracic acid, crystal glass, minium, litharge, white lead, borate of lime, china clay, carbonate of lime, smalt; the proportions of which differ considerably, partly on account of the variable nature of the body, and partly according to the requirements of the ware, whether white, printed, or painted. The *glaze* is, however, always white, and contains lead, alumina, and soda. Minium and the preparations of lead exert a softening action, while the oxide of cobalt, used in very small proportions, rarely exceeding one-thousandth part, is for the purpose of imparting a delicate blue tinge to the glaze, and counteracting the yellow color of the body of the ware. The essentials of a good glaze are transparency, absence of color, sufficient hardness to resist abrasion, and the property of expanding by heat in nearly the same ratio as that of the body of the ware. The various ingredients are mostly fused together or fritted, and afterwards ground, sieved, and purified, as described, to free the slip from iron to form the glaze. When melted with borax or boracic acid and soda, it is a perfectly transparent green color; with tincal it is impure in color, and of a dirty-brown. The preparations of lead do not always enter into the composition of the frit, but are added to the glaze in the grinding process, with the stain also finely ground. These materials being formed into a thin water fluid, the process of glazing is the same as that described under *Porcelain*. Subjoined are several mixtures for glazes:—

RAW GLAZES.

Common Cream Color Glaze.

Cornish stone.....	150
Flint.....	35
Borax.....	4
White lead.....	300

Rockingham Glaze.

No. 1.

Red lead.....	42
Cornish stone.....	6
Flint.....	4½
China clay.....	4½
Manganese.....	6

Ground finely for use.

No. 2.

White lead.....	60
Cornish stone.....	6
Flint.....	18
Red marl.....	6
Manganese.....	10

Ground finely for use.

No. 3.

Red lead.....	100
Cane marl.....	2
Cornish stone.....	15
Flint.....	20
Manganese.....	15

Ground finely for use.

Yellow or Saffron Glaze.

Underglaze yellow color.....	10 lbs.
White lead.....	20 lbs.

Very finely ground.

Add to which 20 quarts of cream color glaze—4½ lbs. per quart—well sifted together.

VOL. II.

Chrome Green Glaze.

Chrome oxide—green.....	2 lbs.
Flint glaze.....	4 lbs.

Ground for stain.

Add to which 48 quarts of printed glaze—28 oz. per pint—and well sift together.

Dessert Green Glaze.

No. 1.

White lead.....	3 lbs.
Calcined copper.....	3 lbs.
Flint glass.....	1½ lbs.
Flint.....	2 lbs.

Finely ground together. And mix—

Of the above.....	4 quarts.
Printed glaze.....	12 quarts.
Cream color, ditto.....	9 quarts.
Earthenware slip.....	3 pints.

Well lawned together.

No. 2.

Calcined copper.....	10 lbs.
Cobalt calx.....	1 lb.

Ground for color.

White lead.....	23 lbs.
Flint.....	15 lbs.
Blue clay.....	3 lbs.

Ground finely,

And to the above compounds add—

Printed glaze.....	36 quarts.
Cream color glaze.....	36 quarts.

No. 3.

Calcined copper.....	3 quarts.
Ground finely; 29 ounces per pint.	

Cream color glaze.....	20 quarts.
39 ounces per pint.	

Printed glaze.....	10 quarts.
29 ounces per pint.	

Black Glaze.

No. 1.

White lead.....	50
Cornish stone.....	20
Flint.....	10
China clay.....	7
Manganese.....	10

Ground for dipping.

Body as for lustre body.

No. 2.

Red lead.....	25
Cornish stone.....	10
Flint.....	5
Red marl—sifted.....	5
Manganese.....	2

Ground as before.

No. 3.

Cream color glaze.....	20 quarts.
2½ pounds per pint.	

Cobalt blue.....	6 lbs.
------------------	--------

Dark red or lustre body to be used with this glaze.

Royal Blue Glaze.

The same glaze, used upon white body, produces a fine royal blue glaze.

For lighter tints, according to the quantities of stain employed.

FRITTED GLAZES.

Cream Color Glaze.

	I.	II.	III.	IV.
Cornish stone....	180	200	—	50
Flint.....	60	50	50	80
Flint glass.....	50	75	50	—
White lead.....	600	350	200	260
Frit.....	—	—	100	—
China clay.....	—	—	—	45
Whiting.....	—	—	—	45
Frit composed of Cornish stone....	20	} Calcined in gloss oven.		
Frit composed of soda.....	1½			
	1			5 M*

PAINTED WARE GLAZES—FRITTED.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
Cornish stone	100	180	80	90	40	50	120	100	120
Felspar	—	—	—	—	40	—	—	—	—
Flint	60	100	70	5	—	35	70	20	80
Lynn sand	—	—	—	—	30	—	—	—	—
Whiting	25	—	—	—	—	40	30	30	80
Chalk	—	—	25	—	15	—	—	—	—
Tincal	—	120	—	—	—	—	—	—	—
Borax	70	—	75	65	60	100	75	60	120
China clay	10	10	—	25	—	30	10	—	30
White lead	60	—	—	—	—	—	—	—	—
Red lead	—	—	—	—	—	—	30	—	—
Soda	—	—	—	25	—	—	10	15	20

Fritted in kiln, and mixed as follows:—

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
Cornish stone	60	—	100	150	160	35	75	100	180
White lead	60	100	100	200	160	45	60	—	120
Whiting	—	80	—	80	—	—	—	—	—
Flint	—	—	—	80	—	35	—	—	—
Frit	500	300	300	180	300	240	500	300	700

Others as follows:—

	Frit.	
	I.	II.
Cornish stone	100	100
Flint	75	—
Whiting	50	35
Borate of lime	150	100
Soda	25	—
China clay	25	15
White lead	25	30

Fritted in kiln, and mixed as follows:—

	I.	II.
Cornish stone	150	35
White lead	100	60
Flint	50	30
Frit	300	250

Another glaze as follows:—

Felspar	30	Boracic acid	35
Flint	20	Soda	35
Whiting	20	China clay	15

Fritted in kiln, and mixed as follows:—

White lead	120	Felspar	150
Whiting	40	Frit	60
Flint	60		

To every charge of 600 pounds weight of the above glazes, about three ounces of cobalt blue are mixed to stain, but varied according to the color of the body.

Drab, turquoise, buff, and other fancy bodies, are dipped into glazes such as are here given; or sometimes into mixed glazes, varying between the common and the best.

The furnace for preparing the frit is shown at A—Fig. 484II. *a* is the fireplace, the flames passing over

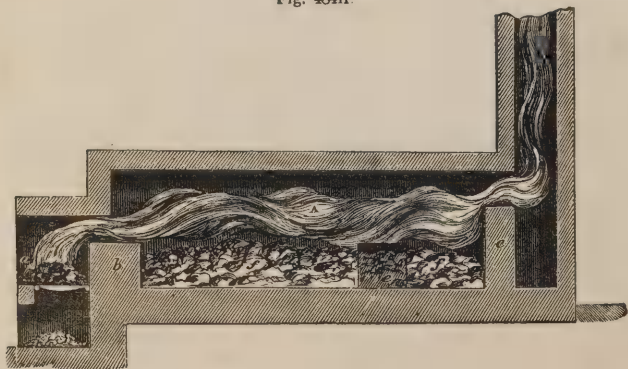
mass, *f f*, and finally escape over the bridge, *c*, into the chimney, *d*. The frit is withdrawn from the kiln in its molten condition by the opening, *e*, and thrown or run into cold water. This aperture likewise serves for the recharging of the oven, and is closed during firing.

When the dipped biscuit has become sufficiently dry, the glaze is burnt in, being placed in seggars similar to the biscuit seggars, and glazed on the inner surface, to prevent absorption during firing of a portion of the basic ingredients of the glaze, particularly oxide of lead, by which the glaze upon the ware would be rendered rough and deficient in lustre. The pieces are separated from each other by contrivances similar to those already described under *Firing*. The marks caused by the points of contact are easily discernible in the earthenware of commerce. These little inequalities are afterwards removed by females from the ware by sharp steel dressing-tools. The junction of every two seggars in the *bung* is luted with clay to make a perfectly secure mass.

Firing.—The time occupied by the firing of the gloss or glaze kiln is about sixteen hours, and consumes from five to seven tons of coal, according to the size of the kiln, the temperature of which is ascertained by the progressive changes in color assumed by balls of red clay coated with glaze, and introduced for that purpose; but it is usual to preserve these trial balls from the most successful firings for comparison in future operations of the same kind.

Printing.—Although, from the nature of the body, it would be inappropriate to devote the same expense to the decoration of earthenware as to that of porcelain, the former very generally receives ornamentation either with the brush or by printing, and is likewise to a great extent decorated with metallic lustres. The process of printing consists of two parts—first, the production of an impression upon thin paper in a suitable ink, and then transference of the ink upon this paper to the surface of the biscuit. The vehicle which serves as the preparation for embodying the necessary colors, is a composition formed of boiled

Fig. 484II.



the bridge, *b*, into the body of the furnace, *A*, where they are reverberated upon the surface of the fritted

linseed oil, resin, tar, and oil of amber, and which becomes, when mixed with the colors, sufficiently liquid for use by spreading out upon a hot iron plate. In the selection of tints, those only must be chosen which, in chemical properties, are compatible with the character of the glaze, the temperature of the kiln, *et cetera*. Cobalt blue, manganese black, and chromium green, are very common colors, and then various proportions of these, generally incorporated with the ink for the following colors, are here given:—

UNDERGLAZE, PRINTING, AND PAINTING COLORS FOR EARTHENWARE.

Yellow.

Lead and tin ash ..	4 parts.	} Mix well together, and calcine at a gentle heat in a glazing oven; to undergo a second calcination at a higher temperature in the same oven.
Antimony	1 part.	

Orange.

Antimony	3 lbs.	} Calcination as above.
Litharge	3 lbs.	
Lead and tin ash ..	$\frac{1}{2}$ lb.	
Ochre calcined	3 oz.	

Fine Brown.

Chromate of iron	1	} Calcine only once.
Chromate of lead	$\frac{3}{4}$	
Calcined sienna	2	
Oxide of zinc	3	

Brown.

Oxide of manganese ..	4 lbs.	} Well calcined.
Green oxide of chromium	$1\frac{1}{4}$ lbs.	
Cornish stone	4 lbs.	

Yellow Green.

Flint glass	4 lbs.	} Calcined at biscuit oven heat, and well pounded, washed with boiling water until clear, and calcined a second time.
Whiting	$2\frac{1}{2}$ lbs.	
Green oxide of chromium	$1\frac{1}{2}$ lbs.	

Yellow Green.

Green oxide of chromium	3 lbs.	} Calcined together.
Yellow color	3 lbs.	
China clay, burnt at biscuit heat	2 lbs.	
Fine sand	2 lbs.	

Blue Green.

Green oxide of chromium	10	} Calcined together in biscuit oven.
Oxide of cobalt	2	
Flux composed of equal parts of borax and flint	15	

Rose Color Pink.

Oxide of tin	$2\frac{1}{2}$ lbs.	} Calcined in biscuit oven.
Whiting	1 lb.	
Green oxide of chromium	$\frac{1}{2}$ oz.	
Cornish stone	6 oz.	

Purple.

To 15 pounds of rose color pink add 1 pound of cobalt calx and $1\frac{1}{2}$ pounds of fine sand. These proportions may be varied according to tint required.

Black.

Oxide of chromium	6 lbs.	} Calcine in glazing oven.
Calcined manganese ore	9 lbs.	
Cobalt calx	7 lbs.	
Gold litharge	10 lbs.	

Black.

Calcined chromate of iron ..	12	} Calcine together.
Cobalt calx	1	

Blue for flowing.

Black prepared oxide of cobalt	12 lbs.	} Calcine in glazing oven.
Flint glass	4 lbs.	
Oxide of zinc	2 lbs.	

The above for strong color, to be reduced for weaker tints by a flux composed of equal parts of flint glass and flint.

Blue for ordinary printing.

Blue cobalt calx	1 lb.	} Grind for use.
Cornish stone	$1\frac{1}{2}$ lb.	

Or a mixture of half stone and half flint.

May be reduced to 1 part of blue and 5 parts of fluxing material. The fluxing of these blues are much varied by manufacturers.

Of late a manufacture has been introduced of a *flowing blue* and other colors, giving a softness to the coloring upon fine earthenware, which has been much esteemed. This is produced by what is termed a *flow*, introduced into the seggar or fire-case; a few of the *flows* are here given:—

Quick lime	5	} Well mixed together and sprinkled carefully round the bottom edge of the seggar.
Salt	2	
Nitre	$\frac{1}{2}$	
Borax	$\frac{1}{4}$	

Again—

Whiting	4	} Mix and use as above.
Salt	$2\frac{1}{2}$	

Again—

Nitre	4	} Mix and use as above.
Salt	1	
Bone	$1\frac{3}{4}$	
Alum	$1\frac{1}{4}$	

Again—

Quick lime	25	} Mix and use as above.
Chloride of ammonium ..	$2\frac{1}{2}$	
Red lead	5	

These and various other mixtures are introduced for the like purposes.

But the most admired is the *pink color*, obtained from acid stannate of oxide of chromium, with stannate of lime, and very extensively applied to decoration. This pigment, originally a profound secret, has been chemically decomposed by MALAGUTI, from the results of which analysis, a practical mixture has been prepared with great success, more especially at Montereau in France. Analysis gave—

Oxide of tin—Sn O ₂	78.31
Lime	14.91
Silica	3.96
Alumina	0.95
Water	0.61
Oxide of chromium	0.52
Chromate of potassa	0.26
Potassa and loss	0.48

100.00

and from this has been deduced the following mixture:—

Oxide of tin	100
Chalk	34
Oxide of chromium	1 to $1\frac{1}{2}$
Chromate of potassa	3 to 4
Silica	5
Alumina	1

The mixture and preparation of the oil for receiving the colors is as follows :—Mix together—

Old linseed oil	2 gallons
Rape oil	1 quart

To which add—

Red lead	2 ounces
Flowers of sulphur	1 ounce

Place the mixture into an iron cauldron suspended over a clear fire until it begins to boil; the scum which rises is then ignited and burnt off, a close-fitting iron disc covered with flannel being used to extinguish the flames. When the scum is consumed, add gradually two ounces more of red lead, and let the scum be burnt off a second time as it rises. As soon as the oil is sufficiently boiled to become adhesive and stringy to the finger, mix with the mass—

Burgundy pitch	2 pounds
Spirits of tar	1 quart
Gum mastic.....	1 ounce

These ingredients, previously warmed together in a pan, are added very gradually to prevent ebullition, the oil being removed from the fire for that purpose. After the whole has been stirred together for fifteen minutes, it is strained off through a hair sieve and allowed to cool for use. Other oils are sometimes used, but all possess similar powers to the above.

Printed colors are seldom transferred upon the glaze, but are generally printed upon the biscuit, in which case the addition of a flux is not essential, its place being supplied by the glaze.

The process of applying the pattern to the biscuit is as follows :—The design is engraved upon a copper plate in a broad open style, to prevent the lines from running into each other, and forming a blurred appearance. Those portions intended to produce a shaded effect are cut deeper to retain more color. The ink, which is first spread over the surface by a printer's dabber while the plate is on the hot stove, is, after the pattern is well filled in, removed by passing a knife over the surface and wiping with the boss to clean the surface from superfluous oil. The impression is then taken from the plate much after the manner of ordinary copperplate printing, a similar press being employed.

The paper upon which the impression is taken is of a fine, soft, uniform, and durable nature, much about the consistency of tracing paper, and previous to use is saturated with soft soap and well damped. This particular paper is manufactured only in the district under FOURDRINIER's patent. In this manner the various patterns are printed closely upon the paper to economize space, their size being proportionate to that of the ware intended to receive them. After the patterns are separated by scissors, they are placed with the printed side next the ware, and rubbed down upon it with the end of a firmly bound roll of flannel. This is done gently at first, and afterwards more forcibly, until the ink is transferred to the surface of the biscuit. The ware is then plunged into water, when the paper is easily removed after a short time by the gentle application of a sponge. Accurate impressions by this

process can only be obtained when both the surface receiving the transfer and that of the paper bearing the impression are flat. In ordinary manipulations the paper has to be applied to a curved surface with a certain amount of pressure to avoid the creasing, and this, unless carefully performed, is apt to cause a doubling up and distortion of the pattern.

From the circumstance that each differently shaped piece of the same pattern, and each piece of the same shape, but of different size, such as plates, *et cetera*, require a separate engraved copperplate, this becomes a very expensive operation—the process of engraving a set of plates ranging from eighty to one hundred and fifty pounds for the full service, even of the most simple design. This expense is again increased by the unequal wear and tear of the plates, and consequent frequent reproduction of the pattern necessary for a particular piece, such as a plate or saucer, the numbers of which printed, in proportion to other pieces, such as dishes, vegetal covers, *et cetera*, is very large, so much so that often a thousand plates of a pattern are thrown off against one cover or dish.

A very important change in the manipulation as regards the whole process of preparing the designs, regulating the sizes, engraving, and reproducing the plates, has been patented by Mr. WILLIAM MACKENZIE of Glasgow; and the improvements which he proposes are so applicable to the process of decorating clay wares, as regards not only the exactitude and simplicity of the process, but also the economy of production it develops, that ultimately no doubt it will entirely supersede the present expensive system already described. This process may be briefly described as follows :—The intended design is first of all either engraved upon copper or drawn upon stone, of such a size as to fit one of the pieces of the set, say a plate of medium size, and from which an impression in transfer ink is taken, and by a peculiar process transferred to the prepared surface of an elastic sheet. This sheet is afterwards placed on a frame and extended equally in all directions, until the design is accurately brought to the scale required for the plate next in size; while in this extended condition, the pattern is retransferred to the prepared surface of a zinc plate by the ordinary process of lithographic printing. The zinc plate, which has now received the pattern upon the enlarged scale, accurately corresponding in every particular with the original, line for line, is after a little further preparation subjected to the engraving process, *electricity* taking the place of *manual* labor, and in the course of six or eight minutes the plate is finished, presenting all the gradation of depth and tone of the original, only of a different size. The subsequent operation of printing may be greatly simplified, by a chemical preparation of the surface of the zinc, causing a reaction to take place with the oily nature of the ink which then only attacks the engraved parts, and leaves the surface of the plate perfectly free from the ink or grease of the filling-in process. The facility and cheapness with which particular designs can be reproduced, as also the extreme accuracy and uniformity of outline obtainable in repeated patterns, constitute the chief recommendations of this patented process.

After printing, the biscuit cannot immediately be glazed, the oily nature of the mordant or color-vehicle preventing the absorption of the glaze by such portions of the ware as are covered by it. It therefore becomes necessary to destroy this oily consistency by heat before the glaze is applied—a process technically termed *hardening on*. The temperature is raised only sufficiently to burn the oil without producing any chemical action on the color. An oven sometimes employed for this purpose is of the size of a moderate room, quadrangular in shape, and arched above. The room, packed as closely as possible with wares, is luted up, and a small iron box or movable wind furnace, called a *davy*, introduced through a trap in the floor. At the four corners of the chamber, pipes protrude through the roof, and descend nearly to the floor of the room, acting as so many flues to distribute the heat by drawing the flame from the burning cinders to the sides of the chamber. A short pipe is placed in the centre of the roof, the outside aperture of which, furnished with a valve, is connected to those of the four others by levers in such a manner that when the centre one is closed the others are opened, and *vice versa*. After the chamber is fired, this centre valve is kept closed by a rod of lead, the four others being open. The heat from the stove gradually increasing from below upwards, until the temperature of the chamber is raised to the heat at which the leaden rod melts, receives a sudden check by the opening of the centre valve, and the draught being cut off by the closing of the four side valves, the fire is soon extinguished. Other forms of *hardening on* kilns are used for the purpose of destroying the oil; but by such an arrangement as that just described, the most accurate regulation of heat is attained, and at very small expense, the stove consuming the cinders and waste from the baking kilns. The operation of glazing then proceeds in the usual manner.

When the printed pattern is applied to the ware above the glaze, the mordant receives a larger proportion of gum mastic; but where enameling colors are used for the muffle, a *size* is applied to the surface of the glaze, composed of spirits of turpentine, with a small portion of gum mastic dissolved in it; sometimes rosin and sugar of lead being added.

Decoration.—The ornamentation of fine earthenware by the hand and brush is practised only for the production of a certain class of designs, such as flowers, leaves, garlands, dots, *et cetera*, and executed by *artistes* expressly trained for that purpose, and each excelling in a particular branch of ornamentation, such as flowers, foliage, scrolls, and the like.

In the preparation of the several tints used in the higher decorations of porcelain and fine earthenware, great care is required to regulate the exact degree of heat to which the biscuit is raised, with a view to the development of the required tints in the several firings through which the wares pass. The following is the mode of preparation of the various colors and their compounds:—

PREPARATION OF ENGLISH AND FRENCH ENAMEL COLORS FOR PAINTING PORCELAIN AND EARTHENWARE.—*English*.—The beauty and success of the hues in the firing depend in a great measure upon

the purity of the oxides from which they are prepared. They should, therefore, in manipulation always individually represent the same body both in chemical composition and molecular arrangement, so as to be subject to the same changes under similar circumstances. For example, the oxides of iron, chromium, purple of cassius, gold, platinum, *et cetera*, although they may be perfectly pure, are very difficult to work if their precipitation has taken place too rapidly, or at an improper temperature. Under the name of vitrifiable colors are generally classed pigments, without distinguishing between the coloring matter and its base, it being generally supposed that the two substances unite chemically by fusion, and form a homogeneous base; this is only the case, however, in some instances, as, for example, with the oxides of cobalt and the oxides of copper; while in others, on the contrary, as the oxides of chromium, the oxides of iron, *et cetera*, the base is only the vehicle which contains the color, and which serves to fix it upon the surface it is applied to. In considering, therefore, the preparation of the colors properly so called, the *oxides* will be given distinct from the bases or fluxes by which they are fixed upon the surface of the wares.

Oxides.—Amongst the *simple oxides* may be classed—oxide of chromium, oxide of iron, oxide of uranium, oxide of manganese, oxide of zinc, oxide of cobalt, oxide of antimony, oxide of copper, oxide of tin.

Amongst the *oxides mixed with earthy matter*, may be classed chromate of iron, chromate of baryta, chromate of lead, chloride of silver, purple of cassius, umber, sienna, and red and yellow ochres. The mode of preparation of these various materials causes the greatest difference in the quality of the colors into which they severally enter.

Sesquioxide of Chromium—chrome green— Cr_2O_3 —is generally prepared for potters' use by calcining a mixture of equal parts of chromate of potassa and sulphur in a close earthenware crucible at a red heat, the green mass which is produced being well washed to dissolve out the sulphate and sulphide of potassium. The oxide of chromium which remains is further purified by repeated elutriation.

GUIGNET has recently discovered—1859—a new method of preparing oxide of chromium for coloring purposes. A mixture of three parts boracic acid and one part bichromate of potassa is calcined at a temperature of about 932° . An evolution of water and oxygen gas takes place, and there is formed a double borate of sesquioxide of chromium and potassa. This salt, which is stable at the ordinary temperature, is decomposed by water, giving bichromate of potassa and sesquioxide of chromium; the latter in the nascent state combines with water, and forms a hydrated sesquioxide of a remarkably fine color. This is separated from the bichromate of potassa by decantation and washing, leaving a chrome green of a very solid and brilliant description.

Sesquioxide of Iron— FeO .—This is prepared by the calcination of green vitriol, upon the purity of which the brilliancy of the color in a great measure depends. For the calcination a thick cast-iron vessel or earthenware retort is required. During the operation the

sulphate must be kept continually stirred with an iron rod; the powder at first assumes a yellow hue, passing into brown, and finally a greenish brown, which upon cooling changes to red, a sulphuric acid vapor being eliminated during the process, which continues until the powder is reduced about two-thirds of its volume. It is then taken from the fire and allowed to cool, the red deposit being thoroughly washed from all impurities until the water exudes from the filter perfectly tasteless. A red color of a more brilliant tone is obtained from iron by calcining together a mixture of equal parts of sulphate of iron and sulphate of potassa in a crucible slowly up to a dull-red heat. The pigment is afterwards washed with hot water to remove all impurities.

Alum may also be substituted for the sulphate of potassa, or sienna combined with sulphate of potassa may be substituted for the sulphate of iron; but whichever process is adopted, the preparation of the red oxide requires very careful manipulation.

Oxide of Uranium— U_3O_8 —*Uranoso-uranic oxide*—is prepared from pitchblende, which contains from forty to ninety-five per cent. of oxide, and certain proportions of sulphur, selenium, phosphoric acid, lime, magnesia, alumina, silica, manganese, vanadium, arsenic, bismuth, antimony, zinc, tin, lead, iron, cobalt, nickel, copper, and silver. The powdered pitchblende is dissolved in warm nitrohydrochloric acid, and, after all action has ceased, the excess of acid is expelled by evaporation. The residue being heated with a small quantity of hydrochloric acid and water, the solution is filtered from the sulphur and silica, and also from chloride of lead and silver. The arsenic, lead, and copper, with bismuth and tin, are then precipitated from the filtrate by sulphide of hydrogen, and the solution again filtered and boiled, nitric acid being added to convert the protoxide of iron into sesquioxide, which is precipitated by super-saturating the liquid with a large quantity of carbonate of ammonia; this throws down the iron, together with any lime that may be present, and the greater part of the cobalt and zinc oxides, retaining in solution the uranic oxide, together with portions of the cobalt and zinc. The filtrate is then boiled as long as ammonia continues to be evolved, by which means the three metallic oxides, cobalt, zinc, and uranium are precipitated, with the exception of a small quantity of cobalt, which colors the liquid red. The precipitate is collected upon a filter and afterwards washed, dried, and ignited, till its yellow color changes to a blackish-green; it is lastly digested for several hours with cold dilute hydrochloric acid, which dissolves the two compounds of cobalt and zinc, and leaves the pure uranoso-uranic oxide undissolved.

Manganese—Bin oxide of Manganese— MnO_2 .—One of the commonest ores of manganese is found in a state of great purity in Sweden and other parts. The purest variety is that known in commerce under the term of pyrolusite, or black oxide of manganese.

Sesquioxide of Manganese— Mn_2O_3 .—may be obtained by heating pure bin oxide of manganese in a crucible to redness until it ceases to evolve oxygen; or by exposing protonitrate of manganese to a red heat, the sesquioxide remains as a black powder.

Protoxide of Manganese— MnO .—may be economically prepared by heating chloride of manganese to redness with twice its weight of carbonate of soda and a little chloride of ammonium, exhausting the fused mass with water when cold; the residuum is protoxide of manganese.

Oxide of Zinc— ZnO .—is obtained by distilling zinc from clay retorts into chambers through which a current of air is maintained, the volatilized metal burns at the high temperature to which it is exposed, and the oxide is deposited in a series of condensing chambers. The hydrated oxide may be obtained by precipitation from the solutions of the salts of zinc by the addition of an alkali. An excess of the alkaline liquid redissolves the oxide.

Oxide of Cobalt, the ores of which, after grinding and roasting, to drive off as much as possible the excess of arsenic and sulphur, are dissolved in hydrochloric acid, sometimes with the addition of a small quantity of nitric acid. The copper, lead, silver, arsenic, antimony, *et cetera*, are precipitated by sulphide of hydrogen, and to the filtered solution carbonate of lime is added in the form of chalk, by which all the iron, alumina, and a trace of cobalt are thrown down, the nickel and cobalt remaining in solution. To this solution, which must be hot and neutral, a solution of bleaching powder is added in sufficient quantity to precipitate the cobalt, and the menstruum is then well boiled to remove the chlorine as fast as possible. The oxide of nickel is afterwards precipitated from the filtrate by the addition of hydrate of lime, and ebullition.

Oxide of Antimony— SbO_3 .—This is found native as white antimony ore, and may be prepared artificially by boiling pulverized antimony with moderately strong nitric acid, until it is converted into a white powder, which is freed from the excess of acid by repeated washings in boiling water. One part of powdered antimony digested with two parts of aqua-regia and four parts of water, yield 96.6 parts of antimonic oxide. A mixture of seventy-four parts antimony, thirty-nine of nitrate of potassa, and thirty-four of bisulphate of potassa is projected into a red-hot crucible, the ingredients being added rapidly one after another. The resulting mass, after boiling first with pure water, then with water containing a small quantity of sulphuric acid, and afterwards with pure water, will be the antimonic oxide.

Oxides of Copper—red oxide of copper— Cu_2O .—is prepared by heating one hundred parts of blue vitriol with fifty-seven parts of carbonate of soda until the water of crystallization is expelled. The residuum is afterwards mixed with twenty-five parts of copper filings, and the mixture finely stamped into a crucible. It is then exposed to a white heat for about twenty minutes, and after cooling and pulverization, the mass is well washed with water. This process yields about fifty parts of fine colored red oxide of copper.

Black Oxide of Copper— CuO .—The red oxide passes into the protoxide of copper when heated in the air; or it may be conveniently prepared by exposing a mixture of one part of copper filings and two parts of the deliquesced nitrate of copper to the air until the whole is converted into a basic salt, and then igniting

the salt. It communicates a green, and sometimes a blue tint to vitreous compounds; and DAVY has shown that it is the basis of certain colors used by the ancients, which had been supposed to contain cobalt.

Oxide of Tin— SnO_2 —may be prepared by treating the metal with nitric acid. In its most concentrated form the acid does not immediately act, but will violently effervesce with heat upon the addition of a few drops of water. The peroxide of tin remains in the form of a white insoluble powder, and is purified by washing with boiling distilled water, and drying at a dull-red heat.

Chrome Iron Ore— $\text{FeO Cr}_2 \text{O}_3$.—The native chromate of iron is a compound of oxide of chromium with protoxide of iron, but part of the ferrous oxide is replaced by magnesia, and part of the chromic oxide by alumina. By analysis the constituents are as follow:—

Magnesia	7.49
Iron	20.99
Oxide of chromium	59.96
Alumina	11.56
	100.00

Chromate of Baryta— BaO CrO_3 —is prepared by dropping a solution of chromate of potassa into a solution of chloride of barium; the yellow precipitate must be well washed, and is as insoluble in water as the sulphate of baryta.

Dichromate of Lead— $2 \text{ PbO}, \text{CrO}_3$ —*chrome red*—may be obtained by boiling oxide of lead, or its carbonate, with an aqueous solution of monochromate of potassa, or by digesting the neutral chromate of lead in a dilute solution of caustic potassa. LIEBIG prepared it by adding a neutral chromate to fused nitre, and washing the residuum; it is an insoluble, scarlet colored powder.

Chromate of Lead— PbO, CrO_3 —*chrome yellow*.—When chromate of potassa is added to a soluble salt of lead, both solutions being hot, a fine colored anhydrous precipitate is obtained; if the solutions are cold, the precipitate will be pale yellow, and will contain an equivalent of water.

Chloride of Silver— Ag Cl —is best obtained by adding a solution of chloride of sodium in excess to a slightly acidulated solution of nitrate of silver. The curdy precipitate of chloride of silver requires very careful washing.

FLUXES.—General Flux.

Red lead	3	} Fritted together into a perfect glass, and pounded for use.
Borax	2	
Flint	1	

Soft Lead Flux.

Red lead	3	} Ditto.
Flint	1	

White Flux.

Glass	12	} Ditto.
Borax	14	
Flint	9	
Red lead	6	

Chrome Flux.

Red lead	4	} Ditto.
Flint glass	$1\frac{1}{2}$	
Flint	1	

Purple Flux.

Glass	16	} Fritted together into a perfect glass, and pounded for use.
Borax	10	
Lead	9	
Flint	4	

Soft Borax Flux.

Borax	4	} Ditto.
Flint glass	3	
Cornish stone	$\frac{1}{2}$	

COLORS.—White Opaque Enamel.

Flint glass	16	} Run into mass in flinted crucibles or seggars in glazing oven.
Arsenic	$1\frac{1}{2}$	
Nitre	1	
Red lead	$4\frac{1}{2}$	

White Opaque Enamel.

Oxide of tin	1	} Calcined in biscuit oven, and $1\frac{1}{2}$ of calcine added to 2 parts of general flux, and afterwards run down again in glazing oven.
Felspar	$1\frac{1}{2}$	

Yellow.

Under glaze yellow	1
General flux	$2\frac{1}{2}$

Orange.

Under glaze orange	1
General flux	$2\frac{1}{2}$

Red.

Green vitriol calcined to drive off the water of crystallization, and brought to a pale red tint, and then well washed until perfectly free from the sulphuric acid. Here great care is required to obtain the proper tint, neither too pale nor too dark.

Of this calcine take	$1\frac{1}{2}$
General flux	$2\frac{1}{2}$

Chocolate.

Same preparation of vitriol at the heat of a glazing oven, well washed as the foregoing, and fluxed.

Calcine	1
General flux	3

Dark Brown.

Umber	1	} Calcine together in glazing oven, well washed, and to 1 part of calcine add 2 parts of general flux.
Sienna	$\frac{3}{4}$	
Red oxide of iron	1	
Oxide of zinc	$1\frac{1}{2}$	

Another Dark Brown.

Umber	1 part.	} Calcined in glazing kiln.
Calcined terra sienna	$1\frac{1}{2}$ parts.	
Oxide of iron	1 part.	
Oxide of zinc	$1\frac{1}{2}$ parts.	

To one part of the calx add three parts of general flux. Ground for use.

French Yellow Brown.

Oxide of tin	$2\frac{1}{2}$ lbs.	} Calcine in kiln, and to 1 part of calcine add $2\frac{1}{2}$ parts of general flux.
Oxide of zinc	2 lbs.	
Red oxide of iron	$1\frac{3}{4}$ lbs.	

Another Yellow Brown.

Oxide of tin	3 parts.	} In glazing kiln.
Oxide of zinc	2 parts.	
Oxide of iron	$2\frac{1}{2}$ parts.	

To one part of the above add three parts of general flux.

Base for Copper Green.

Flint glass	12	} Run down in glazing oven.
Red lead	27	
Borax	9	
Flint	6	
Oxide of copper	2	

Black.

Calcined umber	1	} Calcine in kiln, and to every 4 parts add 3 parts of general flux.
Blue cobalt calx	1	
Flint glass	1½	
Red lead	1½	
Borax	1½	
Flint	1	

Another Black.

Black oxide of cobalt	2½
Turkey umber	1½
Soft borax flux	2½

Another Black.

Black oxide of copper	1 part.	} Calcined in glazing oven.
Oxide of cobalt	1 part.	
Oxide of manganese	1 part.	
White flux	10 parts.	

To four parts of the above add one and a half parts of white flux.

White Enamel.

Flint glass	20	} Run down in glazing kiln.
Red lead	5	
Nitre	1½	
Arsenic	1½	

Sometimes an addition of the oxide of tin.

Blue Green.

Base as above	10 parts.
White enamel	1½ parts.

Yellow Green.

Base	10 parts.	} Run down.
Enamel yellow	15 parts.	
White enamel	1½ parts.	

Chocolate Brown.

Crocus mentis	4 parts.	} Run at gentle heat.
General flux	12 parts.	

Deep Blue.

Flint glass	4 parts.	} Run in glazing kiln.
Red lead	1½ parts.	
Pearlash	1-16th part.	
Muriate of soda	1-16th part.	
Carbonate of cobalt	½ part.	
White enamel	½ part.	

Mat Blue.

Carbonate of cobalt	2 parts.	} Run in glazing kiln.
Oxide of zinc	2 parts.	
Borax flux	4 parts.	

To two parts of the above add one part of borax flux.

Run down at a gentle heat.

Rich Chrome Red.

Red lead	3 parts.	} Run down at a gentle heat.
Chromate of lead	1 part.	
Chrome flux	2 parts.	

Green from Oxide of Chrome.

Oxide of chrome green	3 parts.	} Calcined at high heat, and well washed.
Carbonate of cobalt	1 part.	
Felspar	2 parts.	

To one part of the above add four parts of soft borax flux.

Run down.

Various tints of green obtained by the addition of enamel yellow, previously given.

FRENCH ENAMEL COLORS.

FLUXES.

No. 1.—*Rocaille Flux.*

Red lead	75	} Run down at low heat.
Sand	25	

No. 2.—*Grey Flux.*

Red lead	66	} Run down as above.
Sand	22	
Calcined borax	12	

No. 2 S.

Red lead	60	} Run down at low heat.
Sand	15	
Boracic acid	25	

No. 3.—*Carminé Flux.*

Red lead	12	} Run down as above.
Sand	33	
Calcined borax	55	

No. 4.—*Purple Flux.*

Red lead	36	} Run down as above.
Sand	14	
Boracic acid	50	

No. 5.—*Violet Flux.*

Red lead	68	} Run down as above.
Sand	5	
Boracic acid	27	

No. 6.—*Green Flux.*

Red lead	73	} Run down as above.
Sand	9	
Boracic acid	18	

FRENCH COLORS.

Dark Grey.

Carbonate of cobalt	6	} Run down at low heat.
Oxide of zinc	13	
Yellow oxide of iron	13	
Flux, No. 2 or No. 2 S	68	

Russet Grey.

Carbonate of cobalt	6	} Run down to the tint required.
Oxide of iron	3	
Oxide of zinc	3	
Flux, No. 2	88	

Black Grey.

Carbonate of cobalt	10	} Run down.
Oxide of cobalt	5	
Flux, No. 2	85	

Brown Black.

Carbonate of cobalt	16	} Ditto.
Oxide of iron	8	
Flux for greys, No. 2 or No. 2 S	76	

Iridium Black.

Sesquioxide of iridium	25
Flux for greys, No. 2	75

Dark Indigo Blue.

Carbonate of cobalt	14	} Calcined in kiln.
Carbonate of zinc	26	
Flux for greys, No. 2	60	

Sky Blue.

Carbonate of cobalt	7	} Ditto.
Carbonate of zinc	14	
Flux, No. 2	79	

Blue Green.

Oxide of chrome	50	} Calcined at a high heat.
Carbonate of cobalt	25	
Carbonate of zinc	25	

To twenty-five parts of the above add seventy-five parts of flux,

No. 3 or No. 6.

Ground for use.

Clear Yellow.

Antimoniate of potassa	12	} Run at gentle heat.
Carbonate of zinc	6	
Oxide of iron	2	
Flux, No. 2 or No. 2 S	80	

Jonquil Yellow.

Lead and tin ashes	8	} Mix and run down.
Calcined carbonate of soda	3	
Antimoniate of potassa	3	
Flux, No. 1	86	

Chrome Orange.

Chromate of lead 25 } Run down together.
 Red lead..... 75 }

Uranium Orange.

Oxide of uranium 25 } Run down.
 Rocaille flux, No. 1 75 }

Red.

Red oxide of iron, prepared from sulphate of iron by gentle calcination to the required tint.

To twenty-five parts of the above add seventy-five parts of flux, No. 2 or No. 2 S.

Sepia Brown.

Red oxide of iron 12 }
 Oxide of zinc..... 12 } Run down.
 Carbonate of cobalt 3 }
 Flux, No. 2 or No. 2 S .. 70 }

Russet Brown.

Oxide of iron..... 12 }
 Oxide of zinc..... 12 } Run down.
 Sepia brown 3 }
 Flux, No. 2 72 }

Various tints of green are produced from the oxide of chrome, with the addition of yellow as given.

Carmine, purple, and rose colors are from the purple of cassius, prepared by precipitating gold from the solution of aqua-regia by nitromuriate of tin; to which precipitate is added a small proportion of chloride of silver, and the flux—No. 3 for carmine, or No. 4 for purple—in proportion, according to the heat required in the process of firing, to produce a fine tint.

Purple of Cassius.

The acids used for the solution of gold for this process are, hydrochloric 1·13, and nitrous 1·41—three parts of the former to one part of the latter. Ten pennyweights of the above aqua-regia will dissolve one pennyweight of fine yellow gold. For the solution of tin, twenty pennyweights of hydrochloric acid, ten pennyweights of nitrous acid, and twenty pennyweights of pure water, dissolve in these quantities ten pennyweights of well granulated tin. The tin must be added by small pieces, each being allowed time to dissolve before more is added, and so on to saturation, when the solution, if properly performed, should assume the clear and bright color of brandy. Great care is required for the performance of these processes.

Many other forms are given by various authors, each preferring their particular methods. The solutions here described having been prepared, the processes will be now given.

Into a vessel of sufficient dimensions pour two quarts of good pure water, into which the solution of gold is to be poured, when it will, in its diluted form, assume a pale straw color; into this the solution of tin is to be carefully added, and stirred continuously with a glass spatula until the cassius is well formed, and the precipitate should be of a brilliant carmine tint. Time having been allowed for the cassius to subside, the water is to be carefully removed by a syphon, and washing continued, by changes of the water, until the cassius is perfectly free from the acids. The cassius must then be carefully collected on a filter, and, whilst in a moist state, is ready for further use.

Rose Color.

The cassius, with fifteen grains of silver and sixteen ounces of flux.

Flux.

Flint glass 4 parts.
 Borax 2 parts.
 Red lead..... 2 parts.
 Flint 1 part.

VOL. II.

To form the Cassius for Purple Color.

Gold solution 10 pennyweights.
 Tin solution 20 pennyweights.

The Cassius with

Silver..... 10 grains.
 Flux 6 ounces.

Purple flux is already given.

Fine earthenware, although chiefly confined to the potteries in Staffordshire, is also made in considerable quantities abroad—in France, in the neighborhood of Paris, at Bordeaux, Saargemünd, *et cetera*; in Germany, at Mettlach, near Saarbrück, and Poppelsdorf, near Bonn. Earthenware is also made at Baireuth, Aschaffenburg, Kelsterbach, *et cetera*, and at Carlsbad in Bohemia; at all of which places several kinds are produced simultaneously with the fine earthenware. The differences in the manufacture are confined chiefly to the manner of preparation of the clay, the composition of the glaze, and the ornamental decoration. At Mettlach four varieties are manufactured.

1. *Stoneware*, composed of plastic clay from the Palatinate, ground quartz from Oberwald or Berncastle, calcareous tufa from Sierk. The glaze contains lead, and the ware has a yellow tint.

2. *Yellow or Nankin-colored earthenware*, composed of grey plastic clay from Vallendar, near Coblenz, and clay from Eifel, which burns yellow. The glaze contains lead.

3. *Hard Stoneware*, containing plastic clay from the Palatinate, and ground quartz and gypsum from Luxemburg. The glaze a tolerably hard lead glass, containing boracic acid.

4. *Porcelain Stoneware*, containing plastic clay from the Palatinate and from Vallendar, with ground quartz and bone ashes. The glaze free from lead, and composed of borax, alkali, and felspar.

Amongst the varieties of fine earthenware may be classed the peculiar manufacture of *clay pipes*. The clay used in the construction of these requires extreme plasticity, together with a certain amount of porosity upon firing. The plasticity found in the layers forming the basis of the clay deposit, is used without the addition of a flux, but to insure the perfect uniformity and pliability of the mass, great care is taken with the kneading and slapping processes.

The manufacture of tobacco pipes, in consequence of the immense demand for them, is one of considerable importance in the potter's art. From a prepared lump of the clay the moulder separates a number of pieces, each sufficient for the construction of a pipe, and rolls them out on a table two at a time, one in each hand, to nearly the form and dimen-

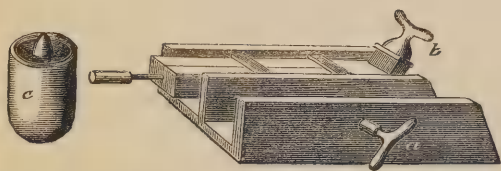
Fig. 484kk.



sions of the intended pipe, the thinner portion having rather more than the thickness of the future tube, whilst the bulbous portion at the end is somewhat less in diameter than the bowl. When these rolls have become sufficiently hardened by exposure to the air, a second workman receives them in bundles for the operation of boring the tube by means of an oiled wire mounted in a wooden handle. With his left hand he forces forward the oiled wire, whilst the thumb and forefinger support the roll, and with a kind of feeling motion guides the point of the wire very accurately along the axis of the roll. The point of the wire is rounded like a button to facilitate the operation, which is performed with surprising celerity.

The whole length of the pipe is not pierced at once, an inch being left unbored, and the unfinished pipe with the wire is placed in the half of the copper mould, *a*, *b*—Fig. 484KK—previously brushed with oil to give smoothness to the stem upon removal. The two halves of the mould, closed accurately together by means of pins, are then placed in a frame—Fig. 484LL—and the edges kept in contact by the screw vice, *a*.

Fig. 484LL.

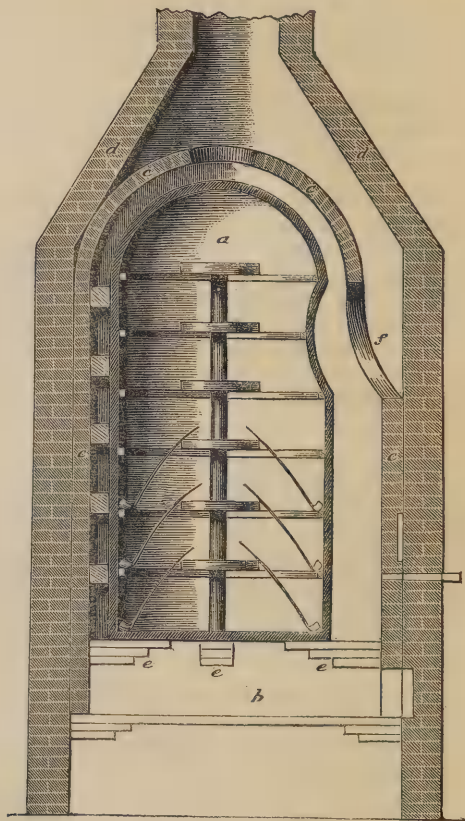


The stem is thus shaped in the mould, together with any impress or name that may have been cut upon it. The bowl of the pipe is first roughly formed by the introduction of the finger, and afterwards completed by the insertion of the plug, *b*, into the mould. Upon opening the mould the operation of boring is completed, the small pellet of clay which precedes the wire being removed by a little hook attached to the handle of the knife used for forming the edges and bowl of the pipe, which is done by removing the superfluous clay. Finally, the rim of the bowl is formed by the small copper mould, *c*. When the pipes have been removed from the moulds, and the wires drawn out, any ornamentalions not given by the pipe mould are added by means of roulettes and stamps. The pipes are then laid out to dry, the sutures removed with a sharp knife, and polished by grooved agates. When the stem of the pipe is required to be curved instead of straight, the two extremities only are supported upon the drying boards, causing the centre to sink down. The number of complete pipes produced by a good moulder will average five hundred a day, notwithstanding the number of operations each pipe has to undergo.

The white color of the pipe being an essential requisite, requires that they be fired in seggars. When the pipes are short, and there is little risk of fracture or bending, as many as possible are placed in the seggar without reference to any particular arrangement;

but for firing long pipes, ring-formed projections upon which the bowls of the pipes rest, are made on the inside of the seggars, a grooved column in the centre supporting the ends of the stems, which, when projecting above the seggar are protected by a conical lid. In London the clay-pipes noted for elegance of form are fired in a close kiln—Fig. 484MM—shown in section, and from which the flame and smoke of the fire are totally excluded. The bottom and sides of

Fig. 484MM.



the kiln are constructed of similar material with the pipes themselves, the refuse and fragments of old pipes being worked up for this purpose. This close kiln, *a*, is supported over the fire-place, *b*, by the brackets, *e*, a space of several inches being left between the sides of the kiln and the outer casing of the fire-brick, *c*, and the whole inclosed by the *hovel* of brickwork, *d*. The flame circulates freely in the intermediate space between the kiln and casing, *c*, supports being introduced at intervals to keep the kiln in its proper position, and which, being connected together by occasional apertures, serve at the same time the purposes of flues to regulate the direction of the flame. The opening, *f*, in the lining of the kiln, *c*, for the introduction and removal of the pipes, is closed during firing by an iron door luted with clay. The corresponding opening in the kiln itself is plastered

up after charging with clay and broken fragments of pipes. The pipes are supported in the kiln by rings of clay, *g g*, surrounding the sides and the central bearings, *m m*, the weight of the whole charge being distributed between the sides of the kiln and the central column, so as not to bear upon the lowest layer of pipes. These kilns vary in size, and sometimes fire a hundred gross of pipes at once. The firing lasts from ten to fourteen hours, the temperature being gradually raised to the full intensity required for baking. The fuel used is coke, and a small opening, *r*, is left in front of the kiln to enable the workman to judge of the interior temperature.

The porosity of the biscuit causes the burnt pipes to absorb water with avidity, and to adhere in a very unpleasant manner to the lips. The ends of the stems are therefore either rubbed with a mixture composed of gum, soap, and wax, or coated with resin or shellac. Sometimes they are glazed by dipping into a very fusible lead glaze; the covered ends being afterwards exposed to the flame of the furnace for about ten minutes.

Common Earthenware or *Delftware* is characterized by its extreme opacity, its open porous structure, and soft texture; in fracture it is earthy, and always colored, while, instead of a transparent glaze, it is coated with enamel.

In the composition of the mass, certain proportions of potter's and plastic clay, clay marl, and quartz or sand, will always be found—these constituents varying in their nature according to the different localities in which they occur. Thus Paris earthenware consists of—

Plastic clay from Arcueil,	8
Greenish clay marl,	36
White calcareous marl,	28
Yellowish marly sand,	28
	100

Still the various combinations always contain a mean proportion of clay, silica, and carbonate of lime, as will be seen by the following analyses of earthenwares from various localities:—

Description of earthenware.	Silica.	Alumina.	Lime.	Magnesia.	Oxide of iron.	Carbonic acid and loss.	Remarks.
Italian, from Lucca della Robbia,	49·65	15·50	22·40	0·17	3·70	8·58	All effervesce with acids.
Majolica,	48·00	17·50	20·12	1·17	3·75	9·46	
Old Spanish,	46·04	18·45	17·64	0·87	3·04	13·96	
Manasses, near Valencia,	54·71	18·80	19·69	trace	2·20	4·60	
Delft,	49·07	16·19	18·01	0·82	2·82	13·09	
Persian,	48·54	12·05	19·25	0·30	3·14	16·72	
From Rouen,	47·96	15·02	20·24	0·44	4·07	12·27	
From Nevers,	56·49	19·22	14·96	0·71	2·12	6·50	
From Paris,	61·50	12·99	16·24	0·15	3·01	6·10	

The mean of these proportions corresponds nearly with equal parts of silica, pipe-clay, and carbonate of lime. These analyses likewise show that the greater portion of the carbonate of lime has been decomposed by the silica during firing, the amount of carbonic acid contained in the vessels being far too small a quantity to combine with the whole of the lime. All kinds of delftware melt and swell at a high temperature into the form of a dark-brown or green glass, without becoming translucent. The liability to crack, when exposed to sudden variations of temperature, is likewise increased by the large amount of marl in the mass. A corresponding increase of pure clay diminishes the risk.

All the ingredients for delftware are suspended in water, and mixed in the slip state; the mass being brought to the proper degree of consistency for working by evaporation in slip kilns. The operation of forming or moulding upon the throwing-wheel is one of extreme rapidity from the great plasticity of the mass; the finishing processes being afterwards performed upon the lathe. Sometimes plaster moulds are employed; but, in every case, the processes are the same as those already described.

Firing.—Delft earthenware, like fine earthenware, is fired twice; the first baking producing the *biscuit*, which, after receiving the glaze, is fired the second time. Both these operations are carried on in similar kinds of kilns, which are generally upright reverberatory furnaces heated by one or more fire-places, after the manner of those already described. In the firing, the wares of better quality are protected from the flame by inclosure in seggars, while the commoner kinds receive

support in the kiln by clay slabs specially prepared for this purpose, and arranged in separate layers or floors, between which the wares are placed so as to afford free circulation to the flame. The pieces are separated from each other in the seggars by triangles and pegs, as already described. The first firing lasts from fifteen to sixteen hours, and the second for burning on the glaze from twelve to fourteen hours.

The temperature of the kiln averages about 27° Wedgwood. The mass shrinks in the baking from ten to twelve, fourteen, or even fifteen per cent. according to its composition.

The analysis of common delft earthenware is as follows:—

Alumina and sesquioxide of iron,	68·55
Silica,	29·13
Lime,	1·24
	98·82
Specific gravity,	2·363

The glaze or enamel is composed of quartz-sand, soda, common salt, and a mixture of calcined tin and lead. The two metals are more easily oxidized when mixed; the oxide of tin produced— Sn O_2 —acting the part of an acid to the oxide of lead— PbO . The mixture is prepared by placing the lead with about one-fourth of tin in a special furnace, where it is exposed to heat and a current of air. A yellowish ash of tin and lead is formed, which is carefully calcined to oxidize thoroughly all the metallic particles. This metallic ash is mixed to form the enamel in the following proportions:—

No. 1.	
Lead and tin ash, . . .	100 parts.
Sand,	100 parts.
Salt,	15 parts.
Red lead,	5 parts.

{ All sand for opaque glazes should be fritted with soda as follows:—150 sand to 100 soda.

No. 2.	
Lead and tin ash, . . .	32 parts.
Soda,	9 parts.
Salt,	5 parts.
Cornish stone,	25 parts.

{ Fritted together, with the addition afterwards of 50 pounds of white lead.

No. 3.	
Calcined sand,	100 lbs.
Soda,	50 lbs.
Tin ashes,	25 lbs.

{ Fritted together, with the addition afterwards of 100 pounds of white lead.

No. 4.	
Best earthenware glaze,	10 quarts.
Oxide of tin,	40 oz.
White lead,	60 oz.

The larger the proportions of tin in the ash the harder the enamel produced, and *vice versa*. The frit, ground and mixed with water, is applied to the wares in the usual way.

Majolica ware—the revival of which in this country is due to Messrs. MINTON, under the direction of M. ARNOUX. The body consists of a soft calcareous clay, or common delftware body, gently fired and covered with an opaque enamel composed of sand, lead, and tin, forming an excellent surface, upon which the decorations in color are afterwards painted by hand in the various preparations and fired into the glaze. Very elegant cisterns, vases, flower stands, *et cetera*, are now produced in this ware; it is also applicable for the production of friezes and other architectural ornaments. It likewise affords a cheap material for enamel painting, the brightness of tints attained being equal to that produced upon copper. The mode of production may be thus described:—The ware, after formation in the usual manner, is twice fired, first for the biscuit, and afterwards to receive the enamel or basis for receiving the color. In this state it is taken to the decorator, who with his brush paints on the several pigments prepared for the purpose, the ground color being only laid upon such portions as are to be covered, and the several ornamentations added in the same way, each only receiving its particular tint. Great care and nicety are required in this manipulation to prevent the unequal blending of the colors at the edges. Sometimes a shaded effect is given to the ground or ornamentation by the running of the colors into the hollows of the pattern, causing in the firing a greater depth of tone. At other times color is laid over the first ground, and a pleasing blended effect is produced by the running together of the enamels in firing. After the decoration is completed in this manner, the piece is taken to the *muffle*, where the colors are all burnt or fired into the glaze, giving that rich solidity of tone and lustre so peculiar to majolica ware. The proportions for the enamel are here given:—

ENAMEL GLAZING FOR MAJOLICA WARE.

No. 1.	
Lead,	77
Tin,	23

Calcine together, and take—

12

Calcine,	44 parts.
Sand,	44 parts.
Red lead,	2 parts.
Salt,	8 parts.
Soda,	8 parts.

No. 2.	
Lead,	82
Tin,	18

Calcine, and take—

Calcine,	47 parts.
Sand,	47 parts.
Salt,	3 parts.
Soda,	3 parts.

No. 3.	
Lead,	77
Tin,	23

Calcine together, and take—

Calcine,	45 parts.
Sand,	45 parts.
Red lead,	2 parts.
Salt,	5 parts.
Soda,	3 parts.

No. 4.	
Lead,	82
Tin,	18

Calcine together, and take—

Calcine,	45 parts.
Sand,	45 parts.
Salt,	7 parts.
Soda,	3 parts.

All these compounds are fused together, and sometimes yield a blackish mass; but when ground and applied to the wares, they appear as a white enamel glazing.

The following are the colors applied to them:—

Yellow.

White enamel glazing,	91 parts.
Oxide of antimony,	9 parts.

Blue.

White enamel glazing,	95 parts.
Cobalt calx,	5 parts.

Green.

White enamel glazing,	95 parts.
Oxide of copper,	5 parts.

Yellow Green.

White enamel glazing,	94 parts.
Oxide of copper,	4 parts.
Naples yellow,	2 parts.

Violet.

White enamel glazing,	96 parts.
Peroxide of manganese,	4 parts.

Other colors are merely modifications of these, with other compounds.

The white glazing of some of the modern majolica is composed of felspar, borax, and the oxide of tin. This glazing, as well as the colors, is frequently applied directly to the biscuit ware, which considerably reduces the labor of ornamentation, without detracting from the beauty of the manufacture.

ORDINARY POTTERY, such as is now everywhere produced, is intended to afford the less wealthy classes cheap utensils, that are *impervious to liquids*, and which at the same time will *bear changes of temperature*, so as to admit of general domestic use. Ordinary pottery is made in almost every locality, and therefore, of necessity, from very different kinds of clay. Its

extreme cheapness obliges the use of those clays that can be obtained at least expense, such as potter's clay, marl, *et cetera*, and the application of the most ordinary methods of moulding and firing. From the circumstance that ordinary pottery is generally manufactured by a class of persons without the means and opportunities of introducing improvements, the advance of the manufacture is slow; the waste of fuel in badly constructed kilns is frequently a source of great loss, while many of the clays worked into the mass will not withstand a sufficiently high temperature. Ordinary pottery is, therefore, always fired at a comparatively low heat, which renders the mass porous and of low density, and necessitates the use of a glaze. As the temperature required to burn on this glaze must be lower than that which would cause the fusion of the ware, it is generally a lead glaze, and of a very fusible nature. This glaze is always transparent, no attempt being made to conceal the body of the ware, which is generally of a dirty-red, yellowish-brown, or greyish color. The glaze may either be colored or not, the rude paintings with which ordinary potters' ware is sometimes decorated being produced by glazes of different colors, the one forming the ground and the other the ornamentation. In general, a very low style of art pervades the tone of this class of clay wares, though occasionally exceptions are met with, such as the wares produced at Marburg, where the brown colored vessels are neatly ornamented with floral designs, that appear to advantage through the light yellow glaze.

In the preparation of the mass two operations only are required—one, the mixing the clay with the necessary amount of water to bring it to the proper consistency, and during which operation the clay is frequently stirred and turned over to render the action of the water uniform; the other, after evaporation, is the working the mass into lumps, and the removal of all knots, stones, *et cetera*, by the aid of the wire, as already described under *Earthenware*. Clay, when of good quality, is easily worked upon the throwing wheel, and does not shrink so much in the kiln as to cause cracks, besides possessing the qualification of carrying the glaze. These properties, which cannot be previously determined, are all matters of experience, different clays being frequently mixed together for that object, with the addition of sand to diminish contraction when the clay is too fat.

The glaze in use upon ordinary potters' ware is an aluminous lead glass prepared from litharge or galena, which in the firing forms oxide of lead and lead salts, the former combining with the silica.

The substances containing the lead are finely ground and mixed in proper proportions with loam, or if a transparent colorless glaze, with sand. When color is required, metallic oxides are used as pigments—oxide of copper for *green*; manganese for *brown* and *black*; zaffre for *blue*; red antimony ore for *yellow*; and iron for *red*, *et cetera*.

The glaze is generally applied to the surface of the ware either by coating or sprinkling the moist vessels with the glaze powder, the operation of dipping being in general too expensive for this kind of ware.

The proportions between the oxide of lead and silica in the glaze are very variable, sufficient time being generally allowed in the furnace for the oxide of lead to become fully saturated with silica. That this is the case when the heat of the furnace has been sufficiently intense, is demonstrated by the following results of experiments made on twelve vessels specially marked, and after firing digested for some time in distilled vinegar—

Those *too hard fired* gave no indications of lead.
Those *hard fired* gave no indications of lead.
Those *well fired* gave in some cases only traces of lead.
Those *ill fired* gave in every case indications of lead.

In badly baked ware, therefore, acid liquids upon the *first* application dissolve the oxide of lead which is uncombined, or only in weak combination. The amount of lead so dissolved, however, is very small, and the application of lead glaze to the wares is not attended with any danger to the consumer, notwithstanding the great outcry that was raised against its use as engendering endemical diseases.

Often glazes free from lead are used, especially in Vienna, where the glaze contains—borax, one hundred pounds; felspar, fifty pounds; loam, fifty pounds. In Bavaria the glaze consists of the slag from the smelting furnaces, a transparent mass harder than glass, and which gives sparks when struck with steel; in color it is either bottle-green or light and dark blue passing into green; it is not acted upon by acids. In the analyses made by REINSCH it was found to consist of—

			Oxygen.
Silica,	65.00	...	33.70 in the silica.
Lime,	12.35	...	3.53
Magnesia,	2.56	...	0.99
Potassa,	2.00	...	0.34
Protoxide of iron,	5.00	...	1.50
Alumina,	8.00	...	3.73
Oxide of manganese, ...	4.45	...	1.33
			99.36
			7.37 in the bases MO.
			5.06 in the bases M ₂ O ₃ .

Corresponding very closely with the formula—



Although not identical with bottle glass, it is nearly allied to it. This slag is ground up with water, and applied by pouring it over the ware, previously coated on the outside by immersion with a thin film of loam, to give the red-brown tint. The high temperature required for the fusing of this slag, is one of the chief objections attending its use and general introduction as a glaze.

The *kilns* in which ordinary potters' wares are fired are long, horizontal, reverberatory furnaces with one fire-place, from which the flames traverse the introduction of the ware, the smaller pieces in lengthwise towards the chimney situated at the opposite end, and in which is the aperture for charging the kiln being placed inside those of larger dimensions. As the temperature of the kiln diminishes rapidly towards the chimney, a proper disposition of the wares is necessary, those coated with the more fusible lead glaze being placed where the temperature is lowest. The wares are all exposed to the direct action of the flames, precaution being taken to prevent their adhesion together

in the fusion of the glaze. Further description or illustration of the ordinary potter's kiln is here unnecessary, the wares being frequently fired in the same kilns with stoneware and *bricks*, an account of which will be found under the article *Tiles*.

The application of glaze to common potters' ware is sometimes omitted, as in the case of articles for which rapid absorption or evaporation is necessary, such as water coolers, sugar-moulds, butter-dishes, flower-pots, *et cetera*.

The cooling bottles and vessels used for holding liquids illustrate well the use that is made of the porous nature of unglazed clay. Their cooling properties arise from the permeation of the liquid through the pores of the ware to the exterior surface where, by exposure to the air, it is evaporated with great rapidity, maintaining the interior liquid at a temperature several degrees below that of the surrounding atmosphere. The porosity is sometimes increased by the admixture into the mass of substances which will be destroyed in the kiln, leaving minute pores through the body of the ware; a similar effect is produced by a low temperature of the kiln during firing.

Lustre ware is a class of common pottery which receives upon the glaze, after firing, a very thin, delicate, and brilliant coating of metal, burnt in by a subsequent process in a muffle. The reduction of the metal is effected either by some ingredient in the solution, or by a reducing atmosphere through the action of heat. Sometimes the lustre imparts color to the glaze, as well as the metallic coating, an effect of the extreme tenuity of the coating and partial oxidation of the metal.

This effect is produced in a remarkable manner by the *gold lustre*, which is obtained by precipitating a solution of gold in aqua-regia by means of ammonia, the precipitate, which is fulminating gold, being mixed while moist with essential oil of turpentine. In this state it is applied to the surface of the ware, and fired in the muffle, the lustre being brought out afterwards by friction with linen.

Another preparation for the gold lustre is as follows:—Two pennyweights of gold, dissolved in twenty-five drachms of aqua-regia, with about sixty drops of the solution of tin; the solution being gradually added to six ounces of balsam of sulphur, into which a pint of spirits of turpentine is slowly added, constantly stirring until the whole mass is smooth.

Platinum Steel Lustre is formed from a solution of bichloride of platinum in ammonia, mixed by means of a glass rod with *spirit of tar*, composed of equal parts tar and sulphur, boiled in linseed oil, and filtered. The mixture is spread upon the piece, and fired in the muffle, great attention being paid to the temperature of the kiln. If the platinum solution is too strong, it is reduced by the addition of more spirits of tar, and if too weak, concentrated by evaporation. If the wares come out black from the kiln, friction with cotton restores the proper color.

Silver Lustre, which has a silver white hue, is also obtained from platinum, dissolved in equal parts of muriatic and nitric acid; the saturated solution is poured into boiling water, and a yellow precipitate of

the metal is obtained by pouring this mixture into a warm solution of salammoniac, which, after being well washed with water and dried, is applied in the usual way to the surface of the ware by means of a flat camel-hair pencil; it is then fired, not beyond a red heat, and afterwards burnished with a piece of soft leather.

Lustre Cantharide—the remarkable iridescence of which resembles beetles' wings or Spanish flies—is produced from glass containing a large quantity of lead, and to which is added oxide of bismuth and chloride of silver. The wares after coating with the preparation are placed in the muffle, and when heated to redness, leather or similar substances thrown in, the products from which reduce the surface of the metal and produce brilliant coatings, varying in color from green, red, yellow, blue, *et cetera*.

Iron Lustre is obtained by dissolving iron or steel in muriatic acid, and mixing the solution with spirits of tar. The following may be given for the mixtures forming the body of lustre ware:—

MASS FOR LUSTRE BODIES.

I.

Red or brown clay,.....	20 parts.
Cornish clay,.....	8 parts.
Blue clay,.....	4 parts.
Flint,.....	2 parts.

II.

Red clay,.....	50 parts.
Earthenware body,.....	7½ parts.
Manganese,.....	1 part.
Flint,.....	1 part.

III.

Red clay,.....	80 parts.
Black Egyptian,.....	10 parts.

The lead glaze for lustrous ware is usually made as follows:—

Litharge,.....	60
Felspar,.....	36
Flint,.....	15

or other good cream colored glazes.

TILES AND BRICKS.—In considering the formation of the mass, and the subsequent operations by which it is made to assume the required shape, and the degree of hardness desired in this description of clay wares, a similar arrangement and classification will be adopted to that given under **POTTERY**, properly so called.

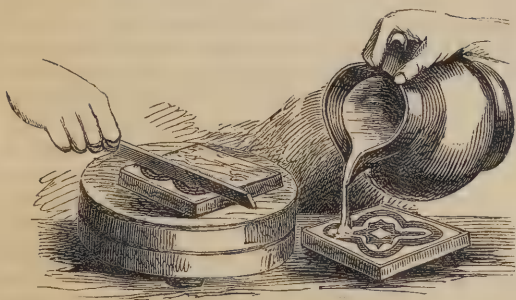
Mosaic, Plain, and Encaustic Tiles, from the superior density and vitreous fracture of the mass, together with the presence at times of a glaze, and the amount of skill and taste displayed in their design, are justly entitled to take precedence in this department of manufacture.

Mosaic Pavements and Inlaid Paving-tiles.—The manufacture of the highly decorative pavements of the medieval period has, after the lapse of ages, been revived in the art manufactures of this country by the untiring zeal and industry of the late Mr. HERBERT MINTON, under the direction of Mr. M. D. HOLLINS. The chief difficulty in the production of this manufacture is to obtain different colored clays that shall contract and shrink equally during the processes of drying and firing, and without which property it would

be impossible to produce a perfect tile of variegated colors. It is unnecessary to speak of the state of perfection to which these beautiful tiles are now brought, or their fitness for architectural and ecclesiastical decoration. The fine stone body of which they are composed being highly vitreous, and capable of receiving almost any shade of color, renders them peculiarly adapted for such a purpose. The manufacture is extensively carried on by the Messrs. MINTON. The red clay, composing the body of the encaustic tile, is found at Cobshurst, about four miles from Stoke-upon-Trent, and in manipulation receives a facing of a finer clay, to bear the ornamental or colored design, while the back of the tile has a similar layer pierced with holes, the object of which is to prevent the warping of the tile in the fire. The fine clay, composing the ornamental portion of the tile, contracting more in the kiln than the body, would cause it to bend, unless this tendency were counteracted by the layer of similar material placed at the back. The red clay, or marl, previous to working up, is allowed to *weather* by exposure to the air for about half a year. It is then thrown into the mixing vats, as required, and blunged up well with water; after which the clay slip is strained from all impurities by passing it through fine lawn sieves, and evaporated in the slip kiln to the proper consistency for working; or the mass, if for *dry tiles*, is dried into hard lumps, and afterwards ground between mill stones into fine powder, according to the particular processes for which it is intended.

The clay for the body of the encaustic tiles, after wedging and slapping in the usual manner, is shaped into a block in the form of a cube, or parallelepiped, from which the tilemaker cuts off with a wire square slabs nearly approaching in thickness that of the intended tile. These small slabs now each receive the colored facing of finer clay, which is battled out

Fig. 484nn.



and slapped down on their surface. Each tile thus formed is covered with a piece of felt and put into an iron box press of the required size, where it receives pressure upon a plaster of Paris mould having the pattern cut in relief upon its surface. The soft colored clay face thus receives the design, the indentations of which are afterwards filled up with various colored clays. The name of the maker and a few holes to cause adherence to the cement when fixing the tile and also to assist in withdrawing the moisture in the

drying process, are then stamped upon the back, and it is allowed to harden slightly before the next process of filling takes place. The colored materials in the form of thick slip are now poured over the various parts of the indented pattern so as to completely cover the surface—Fig. 484nn. In about twenty-four hours this colored slip is sufficiently hardened to allow of the superfluous clay being removed; for this purpose the tile is placed upon a small whirler, and the pattern brought out by scraping away the clay down to the face of the tile, the cavities only being filled with the colored mixtures. The tile is now properly finished, the edges squared, and all defects corrected; after which it is dried for a week in a warm room before being removed to the stove where the drying process is completed in a period, occupying from fourteen to twenty-one days, according to circumstances. When thoroughly dry the tiles are packed in seggars and fired in the manner described under *Earthenware*, the duration of the baking averaging about sixty hours. The oven is left to cool for six days, after which the tiles are withdrawn in their finished state. The mass contracts in the firing to the extent of one-eighth in every inch. To produce, therefore, an ordinary six-inch square tile, it is necessary to form the model six inches and five-eighths to allow for this shrinkage.

For the formation of encaustic tiles of a more elaborate pattern, the process is varied from that described, the tile being moulded by hand, instead of receiving pressure under a machine, and it is by this manipulation that all the rich and expensive pavements have been produced. These pavements have been introduced in Osborne House, the residence of her Majesty; and under Sir CHARLES BARRY's direction in the House of Lords and the House of Commons; Cleveland, near Maidenhead, the residence of the Duke of Sutherland; and the mansions of most of the nobility, as well as the Senate House, Washington, and St. George's Hall, Liverpool.

Plain self-colored tiles, such as black, red, chocolate, buff, *et cetera*, and also the *tesserae*, are generally termed *dry tiles*, and made of similar material to the encaustic tiles, but subjected to an entirely different process under a method patented by Mr. PROSSER. The prepared clay, after drying upon the kiln till it is quite hard, is ground between stones and reduced to a fine powder, which is afterwards placed upon gypsum slabs slightly damped, and sifted through fine sieves. In this state the quantity required is placed in a strong steel matrix or mould of the size of the intended tile, the bottom surface of the matrix being ribbed, to give a corresponding impression to the bottom of the tile, and cause its adherence more firmly to the mortar or cement in which it may be afterwards embedded, as well as to distinguish the size of tile by the different diapering. Into this matrix, a steel plate with the pattern of the intended tile upon its surface accurately fits, and is brought down with immense pressure upon the surface of the powdered clay, the pressure applied being so great, that the particles are united into a firm solid slab or tile ready for drying and firing. A thickness of three inches of powder will by this compression form a tile one inch thick, sharp in outline, and with a beautiful

polished surface. It is also found that compressed tiles shrink less in the firing than those made from the plastic mass, the former contracting only one-sixteenth in every inch. Many other articles are likewise manufactured by this compressing process, such as scale plates, table tops, furniture panels, *et cetera*, and also with smaller presses and dies, the tesserae for mosaic work, and ornamental buttons for shirt studs.

The number of tiles produced by a single machine is very large, between fifty and sixty dozen being often turned out in ten hours by the labor of one man, while the number of tesserae produced in the same time is scarcely less than from twenty to twenty-five gross.

The celebrated white-glazed tiles which are now so much appreciated for the walls of bath-rooms, dairies, and other domestic comforts, are largely manufactured by this firm under the same process.

Many other descriptions of vitreous paving tiles are also made, and are in large demand for the more ordinary purposes of architectural embellishment. At Tunstall, near Burslem, at the Tillery Works of Messrs. GARRETT Brothers, great improvements have been effected in the form and appliances into which this material can be worked. Hollow pillar shafting of red clay for churches, ventilating ridge roof tiles, and various other applications might be mentioned, as showing the immense field of constructive art into which this material, under skillful treatment, may be carried. In general, the manufacture of tiles being very similar to that of bricks, many of the operations will be described under that section.

Tiles may be classed under three divisions, paving tiles, roofing tiles, and drain tiles, each of which comprehend numerous other varieties. The great distinction between tiles and bricks arises from the greater thinness of the former, and the consequent necessity of increased purity and tenacity in the mass; greater care is also bestowed upon the processes of their manufacture, tiles being always dried under cover.

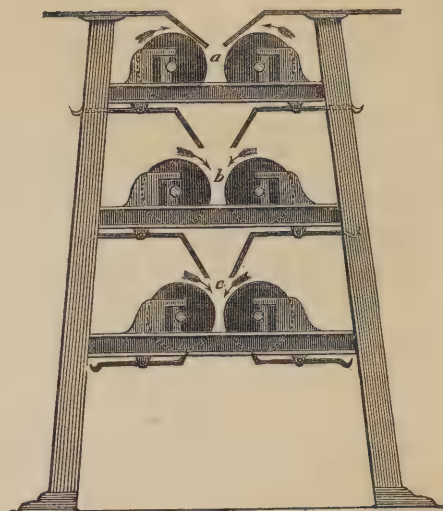
Roofing Tiles are of three kinds—pan tiles, which are of a curved shape; plain tiles, flat and of various shapes, often arranged to form elegant patterns when laid upon the roof; and ridge roof tiles, formed to cope the top of the roof, and often highly ornamental.

Drain Tiles belong to the coarsest class of earthenware, and are of various shapes; sometimes curved over a mould, and sometimes formed by forcing the material through a machine by mechanical means. Other articles, likewise, come under this denomination of wares in their manufacture, such as chimney-pots, tubular pipes for water or drains, and which sometimes require the assistance of the lathe to complete their formation.

Processes of Manufacture.—The marls used to form the mass for working are previously weathered and tempered, the period of exposure depending upon the state of the weather; a frosty atmosphere or a warm sun is more conducive to speedy tempering than a succession of wet and dry days. The marls, when in a proper condition, are taken to the crushing mill—Fig. 48400—where, by passing successively between the sets of rollers, *a, b, c*, through a gradually narrowing aperture, the mass becomes thoroughly pulverized, and

in this state is thrown into layers of the various marls, where it is again weathered, and left for a considerable time to mellow or ripen, and sometimes water is added to hasten this process. It is afterwards tempered and

Fig. 48400.

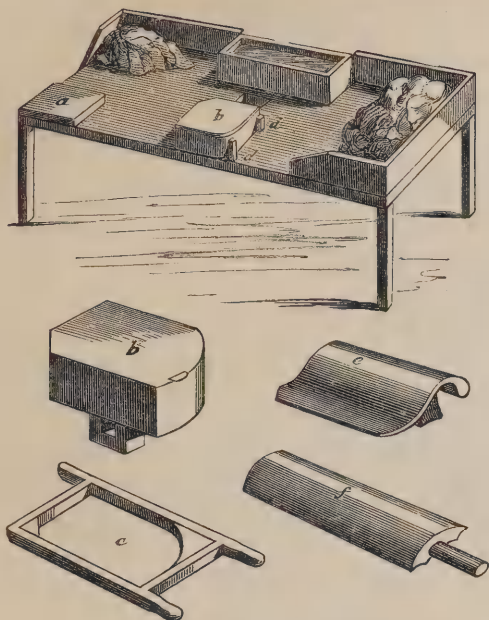


prepared for the moulding processes by passing through the pug mill—see *Earthenware*—from whence it comes oozing out in a mass thoroughly kneaded together and possessing great tenacity. This plastic mass, after separation into blocks or lumps, is conveyed away and stored under cover for future use.

The *moulding* or forming of pantiles is carried on under sheds, the moulding tables being placed on one side, while the remaining space is filled with the *blocks* or drying shelves to receive the pantiles after forming. The prepared clay, after being cut into lumps termed *half pieces*, is brought to the moulding table—Fig. 48400—where the lumps are batted and squared up by an assistant into masses or slabs, *a*, about the size of the mould, and about four inches thick. From this block, by means of a wire, he separates a thin slice the size of a tile, and passes it over to the moulder. The *block* and *stock board*, *b*, for receiving the tile-mould is firmly secured to the moulding table by a strong tenon and mortice; four pegs, *d*, driven into the table at the corners of the block and stock, serve as a support to the mould, *c*, and at the same time regulate the thickness of the tile—five-eighths of an inch. The moulder, having sanded his stock-board and placed his mould on the four pegs, takes the slice of clay from the assistant, and placing it in the mould, smooths the surface with wet hands, and with a brass wire strained upon a wooden bow cuts off the surplus clay level with the mould, and turns the tile out upon the *washing-off frame*, *e*, where it is pressed by the hand into the requisite curved form. It is now struck smartly with the splayer, *f*, and turned over upon that implement for conveyance to the block, where, on withdrawal of the splayer, it is deposited for drying with the convex side uppermost, remaining here for

one or two days. When the tiles are nearly dry they are taken to the *thwacking-frame* or horse, the top of which is curved to correspond with the intended outline

Fig. 484pp.



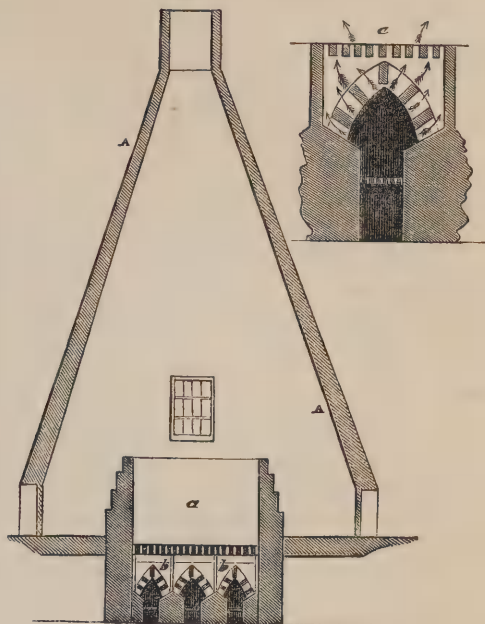
of the tile, and fitted with a wooden block similarly curved. Six or seven of the tiles are now placed upon this horse, and the workman lifts up the wooden block and gives them two or three smart blows, which corrects any warping that may have taken place during the drying process. The tiles are now carried to the kiln.

Firing.—The tile kiln—Fig. 484qq—as constructed in the neighborhood of London, consists of an oven or chamber, *a*, heated underneath by furnaces, *b*, from which the flames circulate freely through the oven by the flues shown in detail at *c*; the whole is inclosed in the brick hovel, *A A*. The time occupies six days, the fires being lighted on Monday morning, and not put out until Saturday evening. The consumption of coal for each firing is about eight tons, but varies with the nature of the goods to be burnt; hollow goods, such as chimney-pots, garden-pots, *et cetera*, requiring less than the more solid wares. These kilns average seventy-five feet in height to the top of the hovel, with an interior diameter of about thirty-six feet; the oven itself being about fourteen feet square by ten feet high.

In the Staffordshire potteries the kiln is of more moderate dimensions; and the fires not being placed in vaults underneath the body of the kiln, are in general protected from the set of the wind by a wall about six feet high surrounding the kiln, and placed at a convenient distance to allow space for the proper regulation of the fires. After the oven is filled, the doorways are built up with bricks daubed over with street-sweepings or clay as a luting; and the fires, after kindling, are burned slowly for the first five hours, after

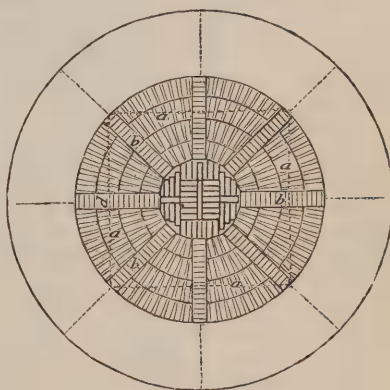
which the heat is progressively increased for the next thirty-three hours; the space of thirty-eight hours being in general sufficient for hard fired blue tiles or bricks.

Fig. 484qq.



The temperature of the kiln is determined by the appearance of the mouths and top outlet of the kiln, as well as by trial pieces. When sufficient heat is attained, and before the fires burn hollow, the mouths are banked up with ashes to prevent the passage of cold air through the oven; and the whole is allowed

Fig. 484rr.



to cool gradually for twenty-four hours before the contents are removed. The operation of firing the kiln generally takes place once a week, and consumes from five to six tons of coal and slack. In charging the oven, the floor is first laid with about two thousand bricks placed edgewise in courses one above the other, *a*—Fig. 484rr—the bricks in the first seven courses being so

disposed as to leave a flue from each fire-place of an average width of seven inches, and the top course, *b*, so as to cover this space, and form the flues. Upon this foundation the tiles are placed in bungs of twelve laid alternately cross and lengthwise; the nibs on the tiles spacing them off, and supporting them in a vertical position. Each side of the square is built up with bricks, *d*, allowing sufficient space in the interstices for

the uniform diffusion of heat through all the goods placed in the oven, a desideratum of the greatest importance in the firing of blue bricks and tiles, and for which the circular form of oven is found best adapted.

The following table gives the analyses of the clays used in the Staffordshire potteries, and found in the district, arranged in the order of their *fusibility*, commencing with the most easily-fusible clay:—

ANALYSES OF CLAYS FROM BASFORD AND THE STAFFORDSHIRE POTTERIES.

	1.	2.	3.	4.	5.	6.	7.	8.
Silicic acid,.....	42.84	54.38	59.44	60.02	64.32	65.78	69.87	70.17
Alumina,.....	17.61	26.55	25.93	24.26	20.33	15.16	16.79	16.25
Sesquioxide of iron, and a little protoxide,	6.97	—	10.74	9.14	10.86	8.49	8.88	8.41
Protoxide of iron, and a little peroxide,..	—	8.38	—	—	—	—	—	—
Lime,.....	15.36	—	—	1.60	trace	1.67	trace	1.29
Carbonic acid,.....	11.61	3.14	—	—	—	—	—	—
Oxide of manganese,.....	2.20	—	trace	trace	—	—	—	—
Soda, and a little potassa,.....	—	—	—	1.40	—	—	—	—
Water,.....	3.94	7.28	3.11	3.89	6.60	5.37	4.26	5.86
	100.53	99.73	99.22	100.31	102.11	96.47	99.80	101.98

The colors to which the different clays burn in the kiln are given below, the figures corresponding with those of the above table:—

1. Rotten red marl will not stand heat, but fuses.
2. Seggar marl burns *light buff*—a firebrick.
3. Mixture of clays 5, 6, 7, 8, burns *good blue*.
4. Clay from Stoke-upon-Trent burns *red*.
5. Dun-colored marl burns *good blue*.
6. Top-yellow marl burns *reddish blue*.
7. Red marl burns *blue*.
8. Mingled marl burns *blue of a reddish tinge*.

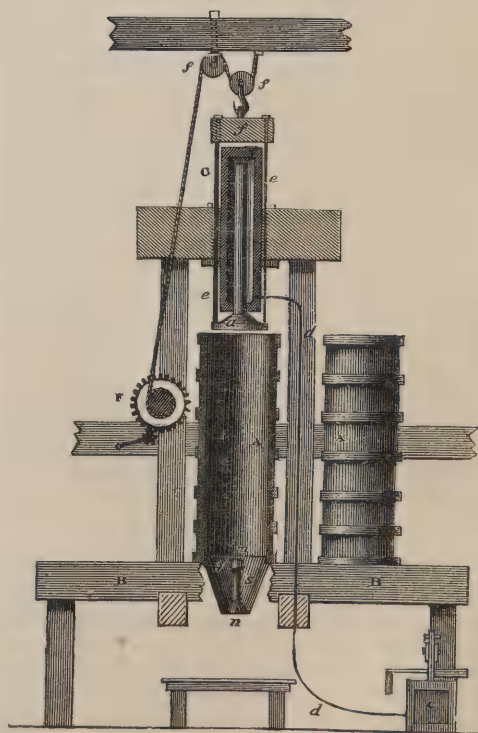
Ornamental ridge and roofing tiles are in general made by a similar process to that described, greater care being required in the moulding and formation of the piece according to the nature of the design; and if this be very elaborate, the tile is sometimes formed of separate pieces united together after moulding, much in the same manner as described under *Earthenware*.

Of late years considerable ingenuity has been exercised in the invention of machines to supersede hand labor in the production of roofing, agricultural drain tiles, water pipes, *et cetera*, all which machines are constructed upon the principle of forcing the prepared clay from a cylinder through a die-plate fixed at one extremity, which delivers the tiles or tubes in the various forms required. As similar machines for the production of bricks will be noticed under that head, it will be sufficient here to describe the method of producing drain pipes by the hydraulic press, carried on at the manufactory of REICHENECKER, at Ollweiler in Alsace; a process which will at once explain all others of a similar character. The clay mixture to form the pipes, after proper purification, is thoroughly kneaded by passing it between two cylinders revolving at different velocities, which causes them to exert a tearing action upon the mass, the distance between the cylinders being regulated by screws. The mass undergoes a further process, which is necessary before it passes to the moulding apparatus, namely, the expulsion of the minute particles of water retained in the clay by the force of capillary attraction, so powerfully as to resist the action of the press, and which would prevent the

mass from attaining that degree of density necessary to insure its durability and nonabsorbing quality when exposed to constant pressure and the action of liquids.

It is desirable that the mass shall not become too dry, otherwise the process of moulding would be

Fig. 484ss.



rendered difficult; a medium is therefore secured by breaking it up into balls of about eight inches dia-

meter, which are suffered to half dry, and are afterwards repeatedly *slapped* upon a smooth stone to produce a perfectly homogeneous mass. The moulding press—Fig. 484ss—consists of two hollow cast-iron cylinders, A A, fixed near each other on a strong movable frame or cradle, B B, by which means they can be brought alternately under the ram, *a*, of the powerful hydraulic press, *c*, and which is brought into action by the pump, *c*, and supply pipe, *d*. The rods, *e e*, which are attached to the descending beam, *f*, are for the purpose of raising the ram after each operation, the winch, *r*, and pulleys, *f f*, carrying the rope. The conical moulds, *m*, with the mouthpiece, *n*, for the pipes, are attached to the lower extremities of the cylinders, A, and are changed according to the nature of the article to be manufactured. These conical moulds carry the cast-iron mouthpiece, *n*, by the rod, *s*, passing through the centre, and secured into the crosspiece, *g*, cast in one piece with the mould. The plastic mass placed in the cylinder is thus forced by the pressure of the ram through the mouthpiece into the shape of a tube or other article, and is cut by a wire into the requisite lengths, which are removed on a tray to the drying kiln, where they are placed in an upright position upon perforated supports, to avoid as much as possible any bending or want of uniformity in the drying process, a circumstance which would infallibly cause them to split in the kiln. The operation of firing is always one of great risk, as, notwithstanding the care that is taken, the pipes often crack in a longitudinal direction. The application of hydraulic power to the formation of these pipes renders them sufficiently dense and strong to resist a pressure of from thirty-five to forty atmospheres—over one thousand pounds to the square inch—an amount far beyond the capabilities of a pipe manufactured in the ordinary manner. Their diameter varies from one inch to about eight inches, with a proportionate increase in the thickness of the substance. Pipes of a somewhat similar nature, but of larger dimensions, are manufactured by GARRETT Brothers, near Burslem Peake, and others in the locality, at Llwynnenion, North Wales, and also at Lambeth, London.

Bricks or artificial stones are intended to replace natural stone whenever this is not to be had, or the hewing and cutting becomes too expensive. Bricks, therefore, are always formed or moulded at once into the required form, varied according to the purposes for which they are intended, such as wall bricks, arch and rectangular or wedge-shaped bricks. These forms never exceed more than a few inches in thickness, on account of the contraction and difficulties attending the drying of larger masses, and they acquire the requisite solidity by burning in the kiln. From the necessary competition into which artificial bricks enter with natural stone, economy in production is an essential point; they are therefore seldom ornamented, and the color is generally confined to the natural hue assumed by the clay in firing. The preparation and purification of the mass are also extremely simple, and are generally performed upon the *field* where the materials are obtained. Bricks, being thicker and more massive than ordinary potters' ware, are necessarily subject to a much greater contraction, and consequent

liability to crack—a defect which is remedied as much as possible by mixing into the mass cheap noncontractile substances, such as sand, calcareous marl, coal and coke refuse, peat, sawdust, *et cetera*. Sometimes the brick earth contains naturally a sufficient amount of sand or lime, at others the mean quality is obtained by a mixture of clays.

In the neighborhood of London, where bricks are the only material employed for building, the clay is obtained from the alluvial deposits in the London basin that lie above the *London clay*, and consists of layers differing in composition from each other. The lowest deposit containing clay, mixed with fragments of chalk and various gravels, *et cetera*, is rarely used, and passes gradually into the middle stratum termed *malm*, also of clay, but mixed with finer fragments of chalk and sand, in place of the coarse gravel; while in the upper layer the clay preponderates, the gravel and sand being in much smaller quantities, and the proportion of lime is so small that the clay hardly effervesces with acid. This upper stratum is there too fat, and requires to be incorporated with coal cinders or sand, while the middle strata possessing more sand receive only the addition of cinders. Near London and other large towns in England the bricks of the greater number of houses are composed of the earth removed from their foundations. From the uses to which bricks are applied, it is essential that they fulfil certain conditions, as follows:—

Bricks, to be good, must be sufficiently firm and hard to support, without crumbling or giving way, the superincumbent mass they have to sustain, and not be subject to break in carriage.

Bricks must be made so as to withstand pressure, to lie flat upon one another, and have a smooth straight surface free from hollows and cracks.

They must also possess sufficient porosity to admit of a proper degree of adhesion to the mortar, and cause it when dry to form a firm and durable cement.

They must, likewise, possess a hard and uniform structure throughout, so as to afford facility in dressing with the trowel, and not split in contrary directions. They should be able at the same time to withstand changes in temperature, when placed in flues, fire-places, chimneys, *et cetera*, as well as the influences of moisture and frost from external causes.

Some of these necessary qualifications can only be attained by a proper mixture of the mass, and others by attention to the processes of moulding and firing. These varieties of clay are generally incorporated with various substances, such as lime, iron, pyrites, stones, gravel, organic remains, *et cetera*, which, unless removed, are very injurious. Thus when clay containing particles of limestone, chalk, or calcareous petrifications, is formed into bricks, the firing in the kiln converts them into caustic lime, and whenever the water has access to the bricks, and penetrates to these nodules, the slaked lime, expanding, destroys the brick. Iron pyrites is decomposed in the same manner by the fire, and leaves cavities in the mass, giving the brick a greater tendency to fracture in those parts. Vegetal remains, roots, *et cetera*, often occasion the splitting of the bricks dur-

ing firing by the sudden evolution of gas. In the selection and mixture of the clays great care is required; clay, if too *fat*, produces bricks liable to bend and crack in the fire, and with a texture denser and less porous than is required. On the contrary, if the clay is too *poor*, the bricks will be too soft, and easily crumbled to pieces.

The manufacture of bricks may be classified under five heads—*Preparation of Brick-earth, Tempering the Mass, Moulding, Drying, and Firing.*

Preparing the Brick-earth.—The clays, after digging and weathering, as already described under *Tiles*, are classed by the brickmaker into three qualities—*strong clay, mild clay, and malm.* Strong clay in general is sufficiently free from stones to be used for the purposes of brickmaking without washing, but requires that there be mixed with the mass chalk, reduced to the consistency of cream, to counteract the warping and contraction it would otherwise undergo in the process of firing, and to improve the color of the brick. Mild clay has to be passed through the wash-mill, to free it from gravel, and other impurities, before working. The amount of sand present renders it less liable to shrink and warp than the strong clays; but its texture is so loose and incoherent, that a mixture of chalk is necessary to bind the mass together, and to take up the excess of silica in the firing. Malm is an earth suitable for making bricks without any addition, but as it now exists naturally in very limited quantities, recourse is had to the production of an artificial malm by mixing chalk and clay together, previously reduced by passing through the wash-mills. The mixture is run into shallow pits, where, by evaporation and deposit, it becomes of sufficient consistency to be worked up in the subsequent operations. This process, on account of the expense, is only adopted for the best qualities of bricks in the vicinity of London, the mass for commoner kinds being simply mixed together. The object of adding chalk to the clay is twofold—first, mechanical, by diminishing the contraction of the brick; and secondly, chemical, as a flux during the firing, by combining with the silica of the clay. A well-burnt London brick is a silicate of lime and alumina, and differs greatly from an ordinary red fired brick made without lime or alkaline matter, the silica and alumina of the brick earth in this case being only in mechanical, and not in chemical combination. The preparation of the brick earth is much the same process as that described under *Tiles*. In the midland districts the clay is generally ground and crushed between iron rollers, whereas in the vicinity of London the preparation is effected by the wash-mill, and afterwards brought to the proper consistency by evaporation in pits, and *soiled*, or covered with sifted ashes, and left to mellow.

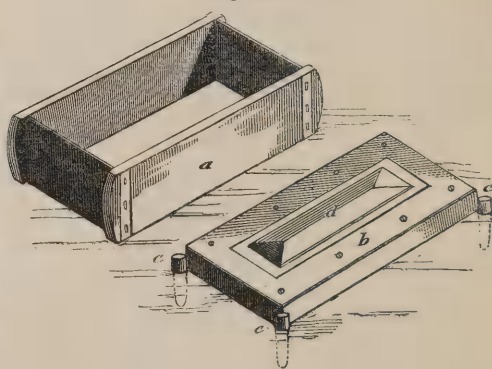
Tempering.—The *tempering* of the mass is performed in various ways, according to the practice of the locality where the bricks are manufactured. The old-fashioned way of tempering by treading consists in spreading out a moderately-thick layer of clay over a wooden floor, and kneading it well over with the naked feet, by which the workman is enabled to detect the presence of stones, roots, *et cetera*; fresh clay and

water are again added, and the operation is repeated until the whole mass becomes so stiff as to impede the action of the feet. Sand, coal-ashes, and similar additions, are sprinkled over the clay and incorporated with the mass, until the whole appears uniformly soft and moist. The extensive demand for brick generally necessitates the employment of machinery, and the *pugging* or *grinding* of the mass takes place in a mill similar to those already described under *Pottery*.

Moulding.—The moulding operation in the manufacture of bricks and tiles is simpler than that of any other kind of clay wares. The workman is supplied with a stock of prepared clay by his side, a small bench or table before him, a tub of water and some dry sand, and an assistant. Two methods of moulding are in use—*slop moulding*, where the mould is dipped in water to prevent adhesion, and *pallet moulding*, where sand is sprinkled over for the same purpose. In *slop moulding* the newly made brick is carried in the mould by the assistant to the *flat* or drying-floor, and whilst this is being done the moulder proceeds with a second mould, the first mould being returned by the time the second brick is ready.

In *pallet moulding* only one mould is used, the brick as it is formed being turned out and placed upon the hackbarrow, and wheeled away to be built into *hacks*, or low walls for drying. The mould is represented in Fig. 484TT; *a* is a four-sided frame of sheet-iron rivetted together at the angles, and strengthened with wood at

Fig. 484TT.



the two sides. The bottom of the mould is detached, and forms what is called the stock-board, *b*, consisting of a piece of wood plated with iron round the upper edge, and filling the mould accurately but easily. Four iron pins, *c c*, are driven into the moulding bench, the stock-board rests upon them, and the thickness of the brick is regulated by their height above the surface. The hollow in the bed of the brick is formed by a piece of wood, *d*, called a *kick*, of the size and shape required, and fastened upon the upper side of the stock-board. The operation of moulding is as follows:—The assistant, or *clot-moulder*, sprinkles the stool with dry sand, and, taking a *clod* or *clot* from the tempered mass, roughly kneads and moulds it into the shape of a brick, and passes it over to the moulder, who having sprinkled sand over the mould, places the clot upon

the stock-board, and dashes the half-formed mass with great force into the sanded mould; the mass which has become flattened by the shock, is forced into the angles of the mould by one or two rapid strokes of his hand; he then, with the *strike*, which has been previously wetted by immersion in the tub, removes the superfluous clay, which is received back by the clot-moulder for reworking. Finally the brick is dexterously turned out of the mould, and conveyed away, while the processes of sanding, *et cetera*, are proceeding quickly for the formation of a second brick.

The number of bricks which a workman can mould in a given time is very great, but depends very much upon the strength and ability of the operator. A moulder with proper assistance will make two thousand bricks in a working day; sometimes a much higher number is attained. The manufacture of the blue facing and paving brick is extensively carried on in Staffordshire; it possesses the same qualities as the blue pipe, ridging, and roofing tiles, and is peculiar to that locality. The annexed tabular statement received from one of the works, and showing the pieces produced there in 1859, will give some idea of the magnitude of the consumption.

STATISTICS OF A BRICK AND TILE MANUFACTORY OF
STAFFORDSHIRE.

Paving quarries,.....	1,000,000
Blue front bricks,.....	150,000
Paving bricks,.....	75,000
Roofing tiles,.....	500,000
Roofing ridges,.....	80,000
Ornamental bricks,.....	150,000
Front red bricks,.....	150,000
Common blue bricks,.....	620,000
Garden edging tiles,.....	25,000
Sanitary tubes,.....	10,000

besides large numbers of other articles not enumerated.

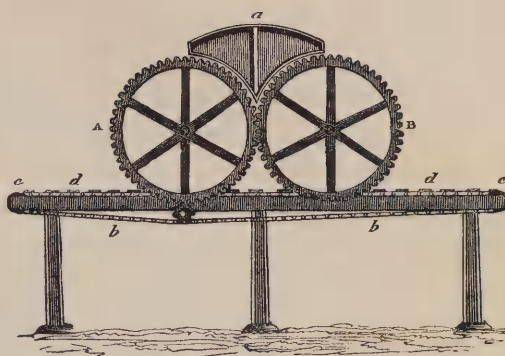
Machinery is sometimes substituted for manual labor in the process of moulding; but from the circumstance of the actual cost of moulding—about one-fourth of a penny for sixteen bricks—bearing so small a proportion to the total cost of brickmaking, it can only be employed with economy in the production of large numbers. The interest of capital, the necessity of keeping a machine constantly at work, and the cost of the motive power which such machines require, demand a very extensive market for the produce. In small brickworks, therefore, machinery effects no actual saving, and is not generally introduced for brick moulding. The mechanical contrivances for producing bricks may be classed under the following denominations:—

1. Machines with actual moulds similar to hand moulds.
2. Machines in which the moulding is performed by several moulds.
3. Machines which cut or stamp out bricks from a cake of clay.
4. Machines which produce a continuous strip or band of clay, and subsequently divide it into separate bricks.

It is unnecessary to enter into the mechanical details or respective merits of these various contrivances; the general principle being easily understood by reference to the machine constructed by Mr. HUNT, and very

generally adopted. A and B—Fig. 484UU—are two cylinders of equal diameter, geared to revolve together, and so placed as to form the front and back of the

Fig. 484UU.



hopper, *a*, the two sides of which are of iron, and arranged to form an opening at the bottom corresponding to the length of a brick, the width being regulated by the distance between the cylinders. When the hopper is filled with tempered clay, the mass forced forward through the opening by the revolution of the cylinders, will have the exact dimensions of a brick. Beneath the hopper, an endless chain, *b*, traverses over the rollers, *c c*, simultaneously with the motion of the cylinders. The pallet-boards, *d d*, are placed at given intervals, to correspond with the thickness of the brick required, and as each pallet-board arrives under the moulded mass, a wire, stretched across a frame, is brought forward and separates the brick, which is at the same time carried onwards by the motion of the endless chain—an operation repeated each time that a pallet-board comes under the hopper.

Drying.—When the bricks placed upon the drying ground in the process of moulding, have become sufficiently firm to be handled without risk of bending, they are set on edge, and piled or *hacked* in the same position until they are six or eight bricks high, spaces being left between them for the free circulation of the air through the dwarf wall thus formed. During the night, or when rain is apprehended, the walls and sides are protected with boards and straw. Sometimes during the process of drying the form of the brick is corrected in any twist by striking with a flat board; a plan that greatly improves the appearance of the brick when price admits of its adoption. Bricks that are intended to be fired in the *clamp*, require to remain in the hacks much longer than those that are fired in a kiln, from the circumstance that the firing in the clamp attains its full heat almost immediately, whereas, on account of the temperature of the kiln being capable of regulation to extreme nicety, the bricks, if *green*, can be dried in the latter by a gradually increasing heat.

An ordinary blue Staffordshire brick, wet from the mould, which weighs twelve pounds four ounces, will

weigh, when fired, only eight pounds one ounce; having lost by evaporation in the drying and burning four pounds three ounces, or thirty-four per cent. of its original weight; the specific gravity being as follows:—

Wet state from mould,	2171
Dry state, ready for kiln,	2075
Fired state,	1861

The loss in weight of a brick by drying and firing will be further illustrated by the following table:—

1859.	Hours of weighing.	Loss in ounces.	Number of hours between each weighing.	Loss of weight in ounces, during each consecutive twelve hours.
July 13.	7 A.M. weighed 196 oz.			
"	11 A.M. " 191½ oz.	4½	4	} 12 hours day, 27½ oz.
"	3 P.M. " 173½ oz.	18½	4	
"	7 P.M. " 169 oz.	4½	4	
July 14.	7 A.M. " 163½ oz.	5½	12	} 12 hours night, 5½ oz.
"	11 A.M. " 157½ oz.	5½	4	
"	3 P.M. " 153½ oz.	4½	4	
"	7 P.M. " 152½ oz.	1½	4	} 12 hours day, 10¾ oz.
July 15.	7 A.M. " 150 oz.	2½	12	

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Total loss by evaporation in drying, previous to firing in the kiln, being twenty-three and a half per cent. of its original weight, and the further loss in firing amounting to fourteen per cent.

Firing or burning is performed in very many different ways, the nature of the fuel which the brick-maker has at his disposal, together with the cost and custom, being all taken into consideration. It is also considerably influenced by the nature of the work, whether stationary or changing to different places; the prices of labor, carriage, *et cetera*, likewise enter into the calculation. The burning of bricks, however, may generally be classed under two methods:—

1st. A *kiln* specially constructed for the purpose, as in the potteries, is used and charged each time with the bricks or tiles to be fired. Such furnaces may be open, close, horizontal, or vertical.

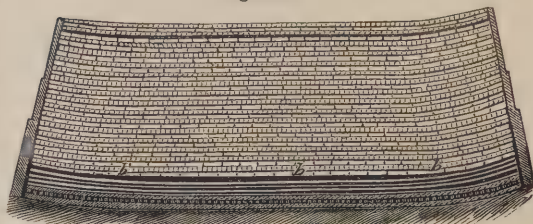
2nd. The bricks are piled one upon another to form a temporary kind of furnace, with the necessary flues; this arrangement is termed a *clamp*, and is well adapted for burning a large number of bricks at once, but not at all suitable for the finer kinds where a sharp outline is necessary.

Kilns, on the contrary, will burn all kinds of bricks and tiles equally well, but, being somewhat expensive in the construction, are only used under certain circumstances. These kilns are similar to a potter's oven, but without bags, or chimneys, or the exterior hovel, the bricks being so placed in the kiln as to form the flues to regulate the heating. In general they average from ten feet to ten feet six inches in diameter; the consumption of coal is about six tons. This construction of furnace is also modified for the firing of the better kinds of goods as well as of the salt glaze sanitary tubes now so generally used throughout England.

The process of burning in *clamps*, the great simplicity of which has given it the preference for general purposes where the locality is so far removed from any kiln as to render carriage too expensive, takes place in the open air; protection being afforded by movable straw hurdles from the too free circulation of air or wind, which might cause combustion to proceed too rapidly in one direction, and put an end to all control over the fires. The clamp, which will often comprise as many as eight hundred thousand bricks, is coated upon the exterior with loam or burnt bricks, and often occupies from eight to ten days in its construction,

according to the number of layers of bricks. Fig. 484vv represents a transverse section of a clamp; the layers of fuel used in firing the bricks, and consisting of

Fig. 484vv.



cinders and small coal, are shown at *b b b*; *liveholes* or flues filled with faggots, and extending through the whole thickness of the clamp, being left to ignite the layers of *brees*, the flames from which permeate the interstices and escape at the top. The firing of a large clamp is commenced by the successive ignition of the liveholes at one end only, and, when thoroughly lighted, the mouths of the whole are stopped with bricks, and plastered over. The proportion of *brees* for firing every hundred thousand bricks, is generally thirty-five chaldrons sifted ash mixed with brick earth, and twelve chaldrons to light the clamp, averaging a cost of ten shillings for every hundred thousand bricks. If the proportion of *brees* is too small, the bricks will be underburnt, tender, and of a pale color; if too much fuel is used, there is danger of the bricks fusing and running into a kind of slag or *clinker*. The length of time of firing varies from twenty, thirty, to even fifty days, according to the size of the clamp. Bricks situated upon the outside of the clamp, and called *turnovers*, are underburnt and placed upon one side for reburning in a future clamp. Bricks situated near the livehole, and exposed to the full intensity of the fire, will be found fused into *clinkers* or *burrs*. Considerable loss occurs in this particular, the clinkers and adjacent bricks being firmly fused together, and attached to the base of the clamp, from whence they can only be removed with crowbars at considerable cost of labor. The loss by fracture, clinkers, *et cetera*, averages about ten per cent. The different qualities of bricks may be known by their color in the firing, and a very important part of the brickmaker's business

consists in sorting the bricks as they are removed from the kiln or clamp. The hard-baked bricks, generally of a dark greyish-brown, are employed for outside work, the well-baked bricks of a red color for walls, while the half-baked yellowish-red or yellow bricks are used for interior work. The harder that bricks are burnt the more sonorous they become when struck, and *vice versa*; they also last longer when exposed to frost than those which are less burnt.

The several descriptions of brick made for the London market may be classified as follows:—

FIRST QUALITY—MALMS.

Cutters are the softest, and used for gauged arches and other rubbed work.

Malms—Best building bricks, used only in fine brickwork; color, yellow.

Seconds—Sorted from the best qualities, and used for fronts of buildings of a superior class.

Paviors—Excellent building bricks, sound, hard, well-shaped, and a good color.

Pickings—Good bricks, but soft and inferior to paviors.

Rough Paviors—Roughest sortings from the paviors.

Washed Stocks—Bricks in common use for ordinary brickwork, the commonest description of malms.

SECOND QUALITY—COMMON.

Grey Stocks—Good bricks, but of irregular color, and not suited for face work.

Rough Stocks—Irregular as regards shape and color, but hard and sound; not suited for good work.

Gizzlies—Tender, only fit for inside work.

COMMON QUALITY—INFERIOR.

Place Bricks—Only fit for common purposes, and not for permanent erections.

Shuffs—Unsound and *shuffy*, full of shakes.

Burrs or Clinkers—Used for artificial rockwork, cascades, et cetera.

Bats—Refuse.

Bricks are often adapted in shape to the purposes for which they are intended, either wedge-shaped for arches, round for chimnies, or rectangles of different forms. Sometimes they are constructed as *hollow* bricks, a form which, without impairing their strength, considerably diminishes their weight and cost in transport or carriage. A peculiar kind of brick is made at Berlin from the infusorial clay on the banks of the Spree, a cubic foot of which, weighing in the crude state sixty-one pounds, is reduced by drying and firing to twenty-five pounds seven ounces. Bricks composed of this earth weigh only one-fourth that of ordinary bricks of the same size. Bricks of this material, and containing ten per cent. of clay, were used for building the Museum in Berlin. Infusorial earth forms an admirable cement for clay in place of sand.

FIRE-CLAY goods are employed either for smelting,

as *crucibles*, or as *fire-bricks*, for lining furnaces, et cetera; their fire-proof qualities depending upon the amount of heat to which they are intended to be exposed, as a brick that would withstand the temperature of a limekiln may fuse in the heat of a porcelain furnace, and even those that withstand the highest temperature attained in manufactures will be fused, and frequently volatilized before the oxyhydrogen blowpipe, or between the poles of a powerful galvanic battery. As the success of smelting, and other operations in which high temperatures are required, depends so much on the material employed in the construction of the furnaces, and other apparatus, a general inquiry into this subject becomes necessary.

The fusibility of a substance is not solely influenced by the elements which enter into its composition, but also by the manner in which these elements are arranged and combined together. The chief constituent of clay—alumina—is a base which, in combination with silica, forms one of the most refractory substances, and this property is possessed by the clays in proportion as they are unmixed with other bases, as alkalies, oxide of iron, lime, and magnesia, in the order here given. In the purer clays, which for all ordinary purposes may be considered fire-proof, the refractory quality is augmented in proportion to the quantity of silica they contain.

In procuring fire-proof material, it is always desirable to obtain a chemical analysis; for, although this cannot supersede an actual trial, it is of the greatest service in guiding to the selection of the materials required to be added, in order to produce in the material the required properties. Such additions are generally necessary, as fire-clay must not only be infusible at the temperature to which it is exposed, but likewise free from liability to crack or fly, properties most important in the construction of *crucibles*. The chief cause of cracking is *contraction*, and this must be lessened by the addition of substances which do not themselves shrink, and at the same time do not impair the refractory nature of the clay. Pure sand, ground and free from lime and iron, and fire-clay previously burnt, are the substances most usually and appropriately employed. When fire-clay is brought into contact with substances exerting a chemical reaction upon it, and decomposing it by acting as a flux, it is much more difficult to obtain a ware capable of withstanding the combined action of heat and chemical affinity. An analysis of the most noted fire-clays employed in the construction of crucibles and fire-bricks is given in the annexed table:—

	Place of manufacture.	Silica.	Alumina.	Oxide of iron.	Magnesia.
Crucibles from	Gross Almerode	71	25	4	—
"	Paris—Beaufays	65	34	10	—
"	Saveignies, near Beauvois	72	19	4	—
"	England, for casting steel	71	23	4	—
"	St. Etienne, for casting steel	65	25	7	—
Glass pots from	Nemours	67	32	1	—
"	Bohemia	68	29	2	trace

Fire-clay wares require to be more strongly fired, in order to acquire an equal degree of solidity with those of ordinary clay—a circumstance partly occasioned by the large quantity of cement which enters into the composition of the mass. It is also of importance that the

wares acquire their maximum hardness and full amount of contraction before they are used. Crucibles do not always require firing, as is the case with the Passau crucibles, which are simply dried. Hessian crucibles, on the other hand, are burnt at about the same heat as

ordinary stoneware. The following table, according to BERTHIER, gives the elementary composition and rela-

tive proportions of the constituents in several kinds of smelting crucibles :—

Dried at 100° centigrade.	Gross Almerode.		Beaufois, Department des Ardennes.		Brierly Hill, near Stourbridge.		Schierdorf, near Passau.	
	Berthier.	Salvetat.	Berthier.	Berthier.	Salvetat.	Salvetat.		
Hygrometric water	15.2	0.43	19.0	10.3	17.34	0.50		
Combined water	46.5	14.00	52.0	63.7	45.25	16.50		
Silica	34.9	47.50	27.0	20.7	28.77	45.79		
Alumina	3.0	34.37	2.0	4.0	7.72	28.10		
Oxide of iron	—	1.24	—	—	0.47	6.55		
Lime	—	0.50	—	—	—	2.00		
Magnesia	—	1.00	—	—	—	—		
Alkali	—	trace	—	—	—	—		

Glass pots and retorts for the production of gas are, perhaps, the largest vessels at present constructed of fire-clay. The fire-clay retorts constructed by Messrs. JOSEPH COWEN and Company of Blaydon Burn, near Newcastle-on-Tyne, are sometimes as long as ten feet, with an internal width of three feet, and are constructed in one piece. In use they are found to be four times

as durable as iron. The material which furnishes these fire-proof wares consists of seven varieties of clay belonging to the coal formation, and which are found in the neighborhood of Newcastle-upon-Tyne. They occur below the coal, and are worked with them from the same pit. In color they are greyish-brown and full of vegetal remains. The analysis is as follows :—

	1.	2.	3.	4.	5.	6.	7.
Silica	51.10	47.55	48.55	51.11	71.28	83.29	69.25
Alumina	31.35	29.50	30.25	30.40	17.75	8.10	17.90
Oxide of iron	4.63	9.13	4.06	4.91	2.43	1.88	2.97
Lime	1.46	1.34	1.66	1.76	trace	2.99	1.30
Magnesia	1.54	0.71	1.91	trace	2.30	—	—
Water and organic matter ..	10.47	12.01	10.67	12.29	6.94	3.64	7.50

By this it will be seen that the amount of silica in No. 2 is to the total amount of the bases as 100:85, while in No. 6, it is as 100:16. These clays are mixed together in certain proportions according to the purposes for which they are intended. The clay is not suspended in water, the coarser particles being ground into the mass, together with the addition of one-fourth part in weight of sawdust. The gas-retorts require to resist the sudden changes of temperature, which they undergo in the processes of firing and recharging, and average three inches in thickness to give them durability. These circumstances, combined with the Ω form of the retort, would inevitably cause them to crack, if the mass was not rendered excessively porous by the destruction of the sawdust in the firing. Powdered coke may be used for the same purpose, while the loss of gas from the porosity of the mass is prevented by the layer of carbon deposited on the interior surface during the operation. The retorts are either moulded and built up by hand with the plastic material, or formed by pressure in machines, somewhat similar to those described for pipe-making, but under pressure so enormous as sometimes to rend asunder iron cylinders between two and three inches thick. The drying and burning proceeds afterwards very slowly to avoid all chances of bursting of the retort when in use. The firing lasts fourteen days, and the retorts are of a pale-yellow color.

Newcastle-upon-Tyne also carries on an extensive trade in the manufacture of fire-bricks from the same clays above enumerated, and the preparation of which is as follows :—The clays, after exposure to the atmosphere for some time, are removed to the clay-mill, and ground up with fragments of the same clay previously burnt, from whence it is taken to the pug-mill for mastication before it is taken to the moulder. The bricks are then laid out to dry, and afterwards burnt in a kiln about fifteen feet long by fourteen feet broad, and ten feet high. Each kiln will burn

about fifteen thousand bricks at once. The operation of firing lasts five days. The bricks are placed on their edge lengthwise in the kiln. Stone-bricks of a very valuable kind, and used in the construction of the arches of reverberatory furnaces employed at Swansea in smelting copper-ores, are extensively manufactured at Neath in Glamorganshire. The materials of which the bricks are composed, are obtained from the neighborhood; they are subjected to a coarse crushing process under an edge-stone, and after mixing with a little water, are compressed into form by a machine, the coarseness of the mass rendering the moulding by hand impossible. This brick is fired in the ordinary way, but resists the action of intense heat better than the Stourbridge clay-brick. It expands more by heat, and does not contract to its original dimensions. The analysis of the three materials composing the mass is as follows :—

	From Penderyn.	From Dinns.	
Silica,	94.05	100	91.95
Alumina, with traces of } oxide of iron,	4.55	traces	8.05
Lime and magnesia,	—	traces	traces
	98.60	100	100.00

These bricks may therefore be called *siliceous* or *stone bricks*, and will no doubt prove admirably adapted for the construction of many kinds of chemical furnaces. A red fire-brick is likewise manufactured at Windsor, the analysis of the clay from which it is prepared being as follows :—

Silica,	84.65
Peroxide of iron,	4.25
Alumina,	8.85
Lime,	1.90
Magnesia,	35
	100.00

Or in mechanical mixture about seventy sand, and thirty parts clay.

QUININ.—*Quinia* or *quina*.—This important substance, which was discovered by PELLETIER in 1820, is found naturally in the bark of several species of *cinchona*, which inhabit the Eastern slopes of the Cordillera in Bolivia, Peru, and New Granada. Three principal species of bark occur in commerce—the yellow, true, or Calisaya bark, obtained from *cinchona cordifolia*; the red, yielded by *c. oblongifolia*; and the pale, from *c. condaminea*. It is found, also, though in smaller quantities, in a variety of barks, which are nearly all obtained from trees of the same family, the distinctive characteristics of which are but imperfectly known.

In the bark, quinin is associated with cinchonin, cinchonidin, cinchonidin, all possessing more or less basic attributes; kinic acid; cinchona red, which occurs in two forms, soluble and insoluble; a yellow and a green coloring matter; besides starch, gum, and lignin. The quinin exists partly as kinate, and partly in combination with cinchona red.

CONSTITUTION AND PROPERTIES.—Quinin is one of the more powerful organic alkalies. It generally appears, when pure, as an amorphous, resinous mass, of a dull white color. Its formula is— $C_{40}H_{24}N_2O_4 + 6\text{ aq.}$ It may also be obtained in six-sided prismatic crystals, which are a hydrate, containing six equivalents, or 10·5 per cent. of water, which are lost on fusion.

Quinin has an intensely bitter taste; it is inodorous, and fuses readily. It dissolves sparingly in boiling, and still more sparingly in cold water. It is easily soluble in ether and in alcohol, especially if hot, and is also soluble in the essential and fixed oils.

Ammonia decomposes the salts of quinin in the cold; but on the other hand, at the temperature of ebullition the ammoniacal salts are decomposed by this alkaloid. Tartaric, oxalic, and gallic acids, and the infusion of nut-galls, precipitate solutions of its salts. Quinin menstrua, if treated with chlorine gas, become yellow, rose-red, violet, and finally deposit a red resinous matter. A solution of the sulphate, saturated first with chlorine and then with ammonia, acquires a grass-green color, and deposits a green powder. With tincture of iodine, the solution yields a clear brown liquid, which on concentration deposits saffron-colored scales of a new compound. To detect small quantities of quinin, precipitate the suspected liquid with calcined magnesia, and evaporate to dryness; then extract with one part alcohol and two parts ether. Evaporate again to dryness, and extract with ether. Now prepare a test liquor, by saturating boiling water with ferridecyanide of potassium, to which, whilst hot, are added five volumes of the strongest chlorine water, and then ammonia, until the blackish-green liquid becomes very alkaline, when the sediment is filtered off. Now mix the fluid to be tested with excess of chlorine water, and drop in the test liquor. A blood-red color indicates the presence of quinin.

Or, put a minute particle into a watch-glass, drench it with five or six drops of pure sulphuric acid and an equal quantity of water, and add a fragment of bichromate of potassa. If quinin is present, the mixture will first assume a green shade resembling that of arseniate of copper, then a beautiful yellow green, and finally a

dark green. The sulphate, similarly treated, becomes first a nickel green, next a copper green, and finally a dirty-yellow. The above-mentioned reaction with chlorine and ammonia may also serve for the detection of quinin. Quinin combines with the acids, forming a series of well-defined and persistent salts, of which the sulphate is the most important.

SULPHATE OF QUININ, usually called the *disulphate*, $HO, C_{40}H_{24}N_2O_4, SO_3 + 7\text{ aq.}$, crystallizes in small silky tufts, or in fine acicular prisms; it has an exceedingly bitter taste, and when heated becomes phosphorescent. The dry salt is composed of one equivalent of quinin, one of sulphuric acid, and one of water. In the crystalline state it takes up, in addition, seven more equivalents, or 14·4 per cent. of water. It effloresces in dry hot air. It dissolves in thirty parts of water at 212° Fahr., but is very soluble in alcohol, especially with the aid of heat.

PREPARATION.—Quinin is generally prepared as sulphate.

The bark to be operated upon is in the first place submitted to a preliminary examination, in order to ascertain the amount of alkaloid which it contains. The safest method is to take about two pounds of bark, and to treat this by the common process for the preparation of sulphate of quinine.

GUILLERMOND proposes the following process for testing bark:—reduce the bark to powder, and treat this in a displacement apparatus with ten times its weight of alcohol of eighty per cent. Add to the alcoholic product thirty grammes of powdered quicklime for every two pounds and a quarter of bark, and agitate the mixture repeatedly. By this operation the liquor is almost completely decolorized. Filter off the sediment of lime, and add to the filtrate sulphuric acid, enough to produce the very faintest acid reaction. Distil off the bulk of the liquor, filter off the slight resinous precipitate, and concentrate the filtrate to crystallization. Others exhaust two ounces of the bark with eight ounces of water, and one scruple sulphuric acid. The mixture is kept for twenty hours at a temperature of 140°, and filtered. The digestion is twice repeated with similar quantities of acid and water. Mix and add ammonia as long as anything falls; filter, wash, dry, and weigh the precipitate. A prompt, though less accurate test, is the precipitation of a decoction of the bark by means of an infusion of nut-galls, the amount of alkaloid in the bark being estimated from the greater or less amount of the precipitate formed. The ordinary procedure for obtaining quinin is to exhaust the bark with dilute sulphuric acid, boil the extract with milk of lime, and extract the precipitate thus obtained with alcohol, from which, on concentration, the crude alkaloid separates in crystals. These are redissolved in dilute sulphuric acid, and purified by treatment with animal charcoal and recrystallization. A more perfect, though less rapid process, is as follows:—Pound the bark coarsely and let it steep in water, to which one-fifth of an ounce of hydrochloric acid has been added for every two pounds and a quarter of bark employed. Next morning boil the mixture for two hours, and strain. Submit the bark to a second and a third decoction in water containing

only half the above proportion of acid. Make, finally, a fourth decoction in pure water, and keep this for the first acid decoction of a fresh quantity of bark. The bark may now be thrown away. Mix the acid liquors, heat, and add carbonate of soda in slight excess, allowing the precipitate which forms to subside. Decant off the supernatant liquid, and test it by means of ammonia. Should this reagent produce a precipitate, the liquid must be precipitated once more with carbonate of soda. The whole precipitate is placed on a linen filter, and left to drain. It is next pressed and dried at a gentle heat. When perfectly dry it is reduced to powder, and treated from five to eight times with alcohol of eighty-six per cent., at the heat of the water-bath; squeeze the grounds each time, and filter the alcoholic liquors. The alcoholic fluid contains quinin and cinchonin, with coloring matters and some fatty substances. It is next very slightly acidulated with weak sulphuric acid, distilled, and the residue allowed to cool in the distillation apparatus.

A crystalline mass appears, which is drained on a linen cloth, to get rid of the black mother liquor. It is then washed with a little water. Make the crystalline mass, which is still highly colored, into a paste with warm water; mix with this animal charcoal in powder, and leave the paste till next morning. Mix the paste with a suitable quantity of water and boil, taking care to carry the concentration sufficiently far to obtain crystals upon cooling. For this purpose, it is preferable to divide the paste into several portions, and to treat them separately. Filter the liquid boiling. Upon cooling, the sulphate of quinin separates in perfectly white crystals. At the end of forty-eight hours let the mother liquor drain off, place the crystalline mass on some double folds of paper arranged on a hurdle, and carry them to the drying stove, taking care to keep the salt covered, since otherwise it would turn yellow. As soon as dry the salt must be removed from the stove, or it will effloresce and lose weight. The mother liquor which had deposited the white sulphate is next precipitated with ammonia, which throws down all the quinin and cinchonin still contained in it. Dissolve the precipitate with the aid of heat, in water acidulated with sulphuric acid, and add, towards the end of the operation, animal charcoal, and, if necessary, a little chalk to saturate the excess of acid. Seethe the liquid to a proper degree of concentration, and filter boiling. A fresh crop of white crystals will be deposited from the filtrate.

Treat the mother liquor of this second operation in the same way, and continue to proceed in this manner until the whole of the alkaloid is converted into crystallized sulphate. After the third precipitation it is sometimes advantageous to treat the precipitate with alcohol of sixty-four per cent., which dissolves the quinin alone, instead of dissolving it in water acidulated with weak sulphuric acid. A part of the alkaloid still remaining in the mother liquor is deposited spontaneously as sulphate, in course of time, and may be purified by the usual method. To extract the quinin still remaining in the mother liquor, the following process has been proposed by GUMOURT:—Add to the black mother liquor an equal weight of a solution of chloride

of sodium of 15° Beaumé. Boil for ten minutes, decant, and submit the brown deposit which has been formed twice more to the same operation. Pour the decanted liquors together, cool and filter, and precipitate the filtrate with ammonia. Redissolve the brown deposit which had separated from the saline liquid in the third operation in water, and add gradually, and in small portions at a time, ammoniated salt-water, taking care to stop short of complete saturation. Filter the liquid off the soft brown precipitate which forms, throw the latter away, and precipitate the filtrate with ammonia. Treat the several ammoniacal precipitates with alcohol. The solution, treated in the usual way, will now yield sulphate of quinin.

The quantities of sulphate of quinin furnished by the varieties of bark which occur in commerce are:—Two pounds eight ounces of yellow, or Calisaya bark, without rind, yield four hundred and ninety to five hundred and thirty grains sulphate of quinin. The same quantity, with the rind, yields three hundred and sixty grains. Two pounds eight ounces of the red bark, *c. oblongifolia*, will yield two hundred and forty-eight grains sulphate of quinin, besides about half that quantity of sulphate of cinchonin. Two pounds eight ounces of pale bark should yield one hundred and eighty grains sulphate of quinin, and one hundred and twenty-four grains of sulphate of cinchonin.

The following process, which has been patented by Mr. HERRING, yields a product not indeed perfectly free from color, but nowise inferior in its medical properties, and at least twenty per cent. cheaper than the common sulphate of quinin. Hence it is designated by the inventor *hospital sulphate*:—

First Operation, without Alcohol.—The powdered bark is boiled in a solution of caustic soda, pressed, returned to the boiling tub, agitated with cold water, again pressed, and if much color passes from the second washing the bark is returned to the tub, washed again with cold water and pressed once more. The treatment of the liquors obtained by the soda boilings and washings is described under the second operation. The decolored bark is now boiled with dilute sulphuric acid, kept in constant agitation by proper machinery, and this first boiling is run into the evaporating pan, a large water bath kept by steam pipes at a temperature of 120°, and agitated by the paddle wheels. The bark is again boiled with sulphuric acid and water as above, and the liquid run into the evaporating pan. The third, fourth, and fifth boilings are not evaporated, but reserved to extract the next portion of decolored bark that is brought forward. When the liquor from the first two boilings is sufficiently concentrated, it is allowed to cool, and filtered. Thus the flocculent coloring matter is separated, and the acid solution is now fit for precipitation. The filtered cold solution is treated by caustic soda, and the precipitated quinin is drained, washed, and pressed. It is now treated with dilute sulphuric acid, and crystallized into a very thick paste. When cold these crystals are pressed, washed, and again pressed. This removes the coloring matter and the chief part of the sulphate of cinchonin. The pressed cakes of sulphate are finally dissolved in a large quantity of water and recrystallized. The crystals

thus obtained from the hospital sulphate of quinin. The liquid which drains away from the second crystallization removes the small quantity of cinchonin which may not have been got rid of by the first crystallization. If the sulphate is required perfectly white it is redissolved, treated with *pure* animal charcoal, and again crystallized.

The patentee believes that in the ordinary method of making sulphate of quinin *impure* animal charcoal is absolutely necessary, though there is of course the risk of contaminating the product with the salts of charcoal.

Second Operation, with Alcohol.—The blood-red soda-boilings of the bark mentioned in the first operation are treated with hydrochloric acid, in order to retain in solution the alkaloids which have been extracted by the alkaline boilings. The ordinary view that quinin is insoluble in alkalies is pronounced erroneous by the patentee, who states, that in acting upon large quantities of bark the amount retained in solution is very considerable. The caustic alkalies exert less solvent power than the carbonates, and caustic soda least of all. After the red alkaline liquor has been acidulated with hydrochloric acid, it is concentrated and precipitated with lime. The precipitate, a mixture of quinin and lime, is washed, dried, and powdered, and finally extracted with hot alcohol. On distilling off the alcohol, the crude alkaloids are left behind. These are then treated with dilute sulphuric acid, exactly as in the former process, a larger quantity of water being required for removing the coloring matter and the sulphate of cinchonin. After two more crystallizations the sulphate is obtained perfectly pure.

The first operation yields from eighty to ninety per cent., and the second from ten to twenty per cent. of the required product.

USES.—Quinin is now very extensively employed in medicine as a tonic and febrifuge. For these purposes it is used in combination with sulphuric, citric, or valeric acid. The double citrate of iron and quinin is likewise very often prescribed.

ADULTERATIONS.—The consumption of this important remedy having greatly increased, whilst the superior varieties of cinchona bark are becoming yearly more scarce and costly, it is naturally subject to a great variety of adulterations. Amongst these may be enumerated chalk, sulphate of baryta, gypsum, boracic acid, gums, sugar, sugar of milk, starch, stearin, margarin, salicin, and phloridzin. Besides these intentional impurities, cinchonin and quinidin may be present if the preparation has not been conducted with due care. Phosphate of lime is also occasionally found, derived from the animal charcoal used in decoloring the alkaloid.

Mineral impurities may be detected by incinerating a portion of the sample in a platinum capsule. Pure quinin leaves no residue. Or a portion of the suspected quinin may be treated with alcohol at a gentle heat. Quinin dissolves, whilst any mineral matter which may be present, as well as gum, starch, stearin, will remain untouched. If a portion is burned upon platinum foil, sugar and margaric acid may be detected by their peculiar smoke and smell.

Sugar may likewise be detected by dissolving a known weight of the sample in water, and adding baryta, which precipitates both the quinin and sulphuric acid, if present. Any excess of baryta is now removed by a current of carbonic acid gas, and the liquid filtered and concentrated, when sugar, if present, is at once known by its taste. Gums and sugars may also be detected as follows:—Dissolve a weighed amount of the sample in water, and add a solution of pure carbonate of potassa, which precipitates both quinin and cinchonin. The precipitate may be filtered off, carefully dried, and weighed. Sugar and gum remain in solution. The liquid is now evaporated to dryness at a gentle heat, and the residue treated with weak spirit of wine, which dissolves the sugar, leaving gum intact. Filter off the clear liquid, and dissolve any residue in hot water. The aqueous solution is then tested with the sesquisulphate of iron, which precipitates gum as a yellowish jelly. If the sample is boiled in water, and the solution allowed to cool, starch may be detected by adding an aqueous solution of iodine, when the well-known blue or black tinge will appear. Starch, gum, and sugar may also be recognized on placing a little of the suspected sample in a porcelain capsule, and moistening with concentrated sulphuric acid. Quinin is merely dissolved, whilst starch, gum, and sugar are blackened. Ammoniacal salts are detected by titrating a portion of the sample with liquor potassæ, when an ammoniacal odor is evolved. If phloridzin is present, the sample turns a greenish-yellow in contact with sulphuric acid, and is discolored by the vapor of ammonia. If salicin be present to the extent of ten per cent. and upwards, the sample will turn a deep blood-red on the addition of concentrated sulphuric acid. In smaller proportions it may be detected by dissolving the sample in about six times its weight of concentrated oil of vitriol, and then adding twice the amount of water, when the salicin is precipitated, and may be filtered off and tested with sulphuric acid. If cinchonin be present the sample is dissolved, mixed with ammonia in excess, and well shaken up with ether. Quinin is dissolved, whilst cinchonin remains untouched, and may be separated by filtration.

The ordinary organic impurities may be detected by the following simple experiment:—A very small quantity is heated upon platinum foil, or in its absence, upon a silver spoon to fusion. Free quinin has then the appearance of oil of sweet almond; the pure sulphate a pale ruby red, the citrate a pale lemon or a deep yellow, if excess of acid be present. The valerianate remains unchanged in color. If adulterated, the residue will have neither polish nor transparency, and will be black and porous. The detection of the remaining cinchona alkaloids, if present in the salts of quinin, is more difficult. When submitted to optical tests, quinin and cinchonidin, according to BOIRCHARDAT and PASTEUR, are powerfully lævogyrate; quinidin and cinchonin pre-eminently dextrogyrate; and quinicin and cinchonin slightly dextrogyrate, upon plane-polarized light.

The ordinary tests for quinin, as mentioned above, distinguish between that alkaloid and quinidin on the one hand, and cinchonin, cinchonidin, and cinchonin on the other.

Oxalate of ammonia, when added to a solution of these alkaloids gives, after some hours, a crystalline precipitate of oxalate of quinin—if the liquid contain not less than one part of alkaloid in eight hundred of water—and a white precipitate in strong solutions of cinchonin. It does not precipitate cinchonidin or quinidin.

If hydriodic acid or iodide of potassium be added to neutral solutions, the following distinctions appear on crystallization:—The hydriodate of quinin appears as lemon-yellow prisms; the corresponding salt of cinchonidin in long thick colorless prisms; the hydriodate of quinidin in short hemihedral prisms; and that of cinchonidin in silky colorless prismatic needles.

RESINS.—*Resines*, French; *Harze*, German.—These are proximate principles found in most vegetals, and in almost every part of them; in some of them the quantity is very insignificant, whilst in others the resin is found in such abundance, as to render its extraction for industrial or medicinal purposes a profitable business, and it is to the latter class that the following particulars and descriptions apply. They are obtained chiefly in two ways; either by spontaneous exudation from the plants, or by extraction by heat and solvents. In the first case the discharge of the resin takes place, in the liquid state, from accidental punctures in the bark of the tree or shrub containing it, and also from artificial incisions penetrating the bark nearly to the hard wood. The substance which issues from these apertures is not a pure resin, but a mixture of it with volatile oil and other matters. In summer or the warm season the exudation flows freely, and the volatile oil being partly driven off spontaneously and partly resinified, the residue acquires considerable hardness. Should any of the volatile body remain, however, it is driven off on boiling the crude matter in water, and thus the resin is obtained free from all volatile oils.

When the coldness of the season prevents the flowing of the resinous body, the method adopted for its extraction is somewhat as follows:—The ligneous matter impregnated with the resin is reduced by rasping or grinding as fine as possible, and the powder boiled with strong alcohol. Many other matters besides the resin are thus extracted, and, on adding water to the spiritous extract, partly precipitate with it. By a fractional distillation of the menstruum most of the alcohol is recovered; and during the ebullition the finely-divided particles of resin collect and agglomerate in the aqueous fluid.

Resins possess the following general properties:—They are soluble in alcohol, insoluble in water, and melt by the application of heat, but do not volatilize without partial decomposition. They have rarely a crystalline structure, but, like gums, they seldom affect any particular form. They are almost all translucent, not often colorless, but generally brown, occasionally red or green. Any remarkable taste or smell which they sometimes possess, may be ascribed to foreign matter, commonly an essential oil. Their specific gravity varies from 0.92 to 1.2 Their consistence is also very variable. The greater part are hard, with a vitreous fracture, and so brittle as to be readily pulverized in the cold. Some of them are soft, a circum-

stance probably dependent upon the presence of a heterogeneous substance. The hard resins do not conduct electricity, and they become negatively electrical by friction. When heated they melt more or less easily into a thick viscid liquid, and concentrate, on cooling, into a smooth shining mass, of a vitreous fracture, which occasionally flies off into pieces like Prince Rupert's Drops; especially after being quickly cooled, and scratched with a sharp point. They take fire by contact with an ignited body, and burn with a bright flame and the diffusion of much fuliginous smoke. When distilled by themselves in close vessels, they afford carbonic acid and carbides of hydrogen, empyreumatic oil of a less disagreeable smell than that emitted by other such oils, a little acidulous water, and a very scanty shining charcoal.

The solution of resins in either hot or cold alcohol reddens tincture of litmus, but not sirup of violet; it is decomposed by water, and a milkiness ensues, out of which the particles of the resin gradually agglomerate. In this state it contains water, so as to be soft and easily kneaded between the fingers; but it becomes hard and brittle again when freed by fusion from the water. The resins dissolve in ether and the volatile oils, and, with the aid of heat, combine with the unctuous oils. They may be united by fusion with sulphur, and with a little phosphorus. Chlorine bleaches several colored resins if they be diffused in a milky state through water. The sulphide of carbon dissolves them. Concentrated mineral acids decompose resins under the influence of heat, the agents being likewise reduced. Strong sulphuric acid dissolves them in the cold; but on the addition of water, they again separate without decomposition. When heat is applied the sulphuric acid is broken up into sulphurous acid; at the same time carbonic acid results from the resin, and a carbonaceous residue with the artificial tannin of HATCHELL remains. Nitric acid aided by heat effects several transformations in resin, according to its state of concentration and the period during which its action is continued. Some resins yield, to this treatment, oxalic acid, and invariably artificial tannin may be obtained.

Most of them dissolve in solutions of the fixed alkalies, whether hot or cold, as also in ammonia, and form definite salts—resinates—some of which are quite neutral. These resinates are soluble in water, and form a considerable portion of the cheaper kinds of soap, being themselves possessed of detergent qualities. Resinates of the alkaline earths, and of the heavy metallic oxides, may be prepared from those of the alkalies by double decomposition; but they are insoluble, and generally strong acids liberate the resin from them unchanged.

Every resin is a natural mixture of several others, which sometimes admit of easy separation by different solvents, such as alcohol, ether, essential oils, alkaline solutions, *et cetera*. For instance, when certain acid resins are dissolved in alcohol, and an alcoholic solution of acetate of copper is added, it happens sometimes that only a part of the resin is precipitated. The deposit, which can be readily separated from the liquid, is found occasionally to be but partially dissolved by

other menstrua, and consequently admits of being separated into several definite substances. Again, many resins on being treated with a solution of potassa, soda, or ammonia, do not entirely dissolve; and inferring from this that the undissolved portion has not the same properties as that dissolved, the conclusion follows that two or more distinct principles were contained in it. The soft resins, which retain a certain portion of volatile oil, constitute what are called balsams, a full description of which will be found in Vol. I., page 224, *et sequitur*.

According to DUMAS the resins may be arranged in five classes, namely:—

1. Those which yield a volatile oil on being distilled with water, and leave an acid resin, or rather several resins possessed of acid properties, in the retort. To this class belong the several turpentine resins, balsam of copaiba, *et cetera*.

2. Those which yield a volatile oil when distilled with water and one or more acid resins, as in the foregoing; but in addition, a neutral one, generally capable of being crystallized. Animi, elemi, and caranna resins, mastic, vegetal, or palm wax, and several others, are of this order.

3. Resins which do not furnish a volatile oil on being distilled with water. Such are copal, amber, lac, betulin, and the like.

4. Resinous matters containing substances soluble in water of the nature of gum. Many of the members of this group have been already described as gum-resins, under GUMS, to which the reader is referred.

5. Balsams or compounds which contain, besides a volatile oil and an acid resin, cinnamic or benzoic acids, or some substances capable of producing them. It will be unnecessary to follow the description of the subjects coming under this class here, as they have been already described at some length.—See BALSAMS.

The Editor will now glance cursorily at each variety of resin in its alphabetical order, space not permitting of more.

AMBER.—*Succin*, French; *Bernstein*, German; *Succinum*, *Electrum*, Latin.—This interesting substance is frequently included among minerals, with which, however, it can no more be classed than the resin copal found in the sands of Africa. It is a substance of vegetal origin, resembling copal and other resins in appearance, and in some of its physical and chemical properties, and, like them, is employed for varnishes. The variation of its properties from those of ordinary resins is not, perhaps, greater than is to be found among the different members of the class, and may be in part attributed to a slight and gradual alteration effected during the time of its exposure to the various natural agents. From some of its chemical and physical properties and its occurrence in or near coal or lignite, it is usually supposed to be a resin derived from trees of the same geological age with the upper, secondary, or tertiary strata; but from the formation of succinic acid from fat, as well as from amber, one might suppose it to have been a species of wax, or to have a fatty nature. Its balsamic or resinous origin is more probable than the latter view. According to the traditions of the ancient Celtic nations, amber signifies tears shed by

APOLLO on leaving heaven for the famed Hyperborean island—Erin—and the account is thus happily recorded by BRYANT:—

The Celtic sages a tradition held,
That every drop of amber was a tear
Shed by APOLLO when he flew from heaven;
For sorely did he weep, and, sorrowing, passed
Through many a doleful region, till he reached
The sacred Hyperboreans.

Amber is most abundantly found on the Prussian coast of the Baltic, Courland, Livonia, Pomerania, and in Denmark, where it is often washed up on the shore by the waves, after the autumnal storms; or it is dragged up by a net, or obtained by mining. In the latter case a stratum of sand, then of loam, are pierced, neither containing amber; but below the latter occurs a bed of lignite, in and near which it is obtained. From the cones found near it, one may attribute the amber to the balsam of certain extinct species of coniferæ, which has hardened by the loss of its volatile oil. It frequently contains insects of various genera and species; among them several genera of spiders, no species of which is now in existence. Some genera of these insects are still found in South America and New Holland, but the species are extinct; and but a single living insect found in America has been observed in amber, namely—*lepisma saccharinum*. It is sometimes, but rarely, found on the Scandinavian coast; other localities are Hasen Island, Greenland, near London in sand, and Paris in clay, in Italy, on the Sicilian coast, in Spain, Siberia, China, and the United States, where it occurs in the red clay formation subjacent to the green sand, and sometimes in the green sand itself.

Thus it occurs frequently associated with lignite on Martha's Vineyard; from Amboy to below Camden, New Jersey; in the clays and sands of the deep cut on the Delaware and Chesapeake Canal, and in the green sand in Delaware; further at Cape Table, Maryland. It is said that Prussia draws an annual revenue of seventeen thousand rixdollars from this substance.

It is found of variable sizes; a specimen in the royal collection at Berlin weighs eighteen pounds. It is sometimes colorless, though usually some shade of yellow, light and brownish yellow, reddish-orange, brownish-black; it is transparent, translucent, opaque, sometimes milk-white and opaque, different hues and degrees of transparency occurring in the same piece; it has a resinous lustre, is rather brittle, has a conchoidal fracture, and a soft-feeling shining surface; it receives a good polish, and hence is carved into ornaments.

Specific gravity 1.065–1.075. By friction on woollen cloth it becomes strongly negatively electric.

Heated in the air it fuses at about 549°, evolving an agreeable aromatic odor, and burns with a clear flame. By fusion it is decomposed and its properties altered, giving off volatile matter and leaving a clear brownish translucent resin, which is almost insoluble in alcohol, partially soluble in ether, and most perfectly in fixed and volatile oils, with a brownish-yellow color. Slowly heated in linseed oil to boiling, it is soft and flexible, without fusing or decomposing, and, unless cooled slowly in the oil, is as brittle as glass; opaque spots are thus often rendered translucent.

Amber is wholly insoluble in water; absolute alcohol and ether become yellow in contact with it; when used on the substance powdered they extract succinic acid and resin.

It is soluble, with a brown color, in strong sulphuric acid from which water precipitates the greater part of a yellow color, which retains a little of the acid; by boiling with the same acid tannin and charcoal are produced. Nitric acid changes it to a yellow resin, which gradually dissolves in the acid. Finely powdered, and boiled with solution of caustic or carbonated alkali, much succinic acid is removed; and pure water extracts a resinote of the alkali from the residue, leaving amber bitumen.

By destructive distillation in a closed vessel an acid liquor containing acetic and succinic acids passes over; some crystals of succinic acid are then deposited in the neck of the retort, after which an empyreumatic oil is disengaged, at first thin and yellowish, but subsequently brown and thick; finally, a light-yellow wax-like sublimate appears in the neck of the retort, to which BERZELIUS has given the title of *crystallized pyrétine*, and GMELIN amber-camphor. The proximate constituents of amber are a volatile oil, succinic acid, two resins soluble in alcohol and ether, and a bituminous insoluble substance which constitutes the chief bulk of it; its ultimate analysis showed it to consist of carbon, hydrogen, and oxygen in the following proportions:—

	Centesimally.	
	Drassier.	Uro.
Carbon,	80.59	70.68
Hydrogen,	7.31	11.62
Oxygen,	6.73	7.77
Ash,	3.27	9.93
Loss,	2.10	
	100.00	100.00

USES.—Fine amber is used for making trinkets and ornamental objects; but its estimation is much greater in this respect in Oriental nations than with Europeans. The portion designed for ornamental work is split on a leaden plate on a lathe, and then smoothened to a shape on a Swedish whetstone; it is then polished with chalk and water or vegetal oil, and finished by rubbing with flannel. In these processes the amber is apt to become highly electrical and very hot, so much so as to produce nervous tremors in the wrists and arms of the workmen from the electricity. The artists guard against these effects, however, by working the pieces in rotation, so that the heat may not increase to an injurious degree, and the amber remains only feebly excited. The coarser kinds of amber are employed in chemical and pharmaceutical operations, and also for the manufacture of varnishes.

ANIME.—A resin not unlike copal, and of which there are two varieties, the American and the Oriental. The American anime is said to flow from incisions in the *hymenaea courbaril*, a tree growing in Brazil, Virginia, and the West Indies. The purer resin occurs in pale yellow pieces, with a vitreous fracture and dusty surface; softens in the mouth, tastes like mastic, and has an agreeable odor, especially when heated; specific gravity 1.03; combustible, and gives a lively flame. Warm oil of olives or lavender dissolves it;

it is wholly soluble in boiling alcohol, the solution reddening litmus, although the acid is scarcely extracted by water. Cold alcohol separates it into two resins; the soluble—54.3 per cent.—resembles the resin itself; the difficultly soluble resin—42.8 per cent.—precipitates from a boiling alcoholic solution, drying to a tasteless mass, slightly odorous and lighter than water. It also contains about 2.4 per cent. of a volatile oil, which passes off by heating *per se*, or with water. A brown variety does not soften in the mouth.

The Oriental anime, which has a specific gravity of 1.0272, appears to be a mixture of two resins, one pale-yellow, brittle, not softening in the mouth; the other reddish-yellow, softer; it does not contain the difficult soluble resin, and its alcoholic solution has a less acid reaction. It is not decomposed by nitric acid, even at the heat of fusion.

Anime was formerly employed in pharmacy, but is now chiefly used for scenting pastilles, and for varnishes; but it is rather a bad material for the latter, as it is dried with difficulty, and leaves the coating soft and pasty. For these reasons it is never used *per se*, but in admixture with other more suitable resins.

Botany Bay Resin, said to be the produce of *acarois resinifera*, is of a yellow hue, brittle, and of a slightly astringent taste. It exhales a fragrant odor when heated, and dissolves in alcohol and ether. It resembles tolu balsam in containing cinnamic, and a small quantity of benzoic acid.

COLOPHONY.—*Common Rosin*.—This is the residue remaining on the distillation of common turpentine; it retains more or less water, and is known as white and yellow resin, being in this state translucent, and often slightly viscid. When deprived of water by fusion, it is termed brown or black resin, colophony, rosin, or fiddler's rosin.

Rosin is a brittle, tasteless, and almost inodorous substance, of a smooth shining fracture; its specific gravity is 1.080. It softens at 160°, but does not enter into fusion under 275°. According to the analysis of BLANCHET and SELL, this substance, in its pure state, may be represented as composed of $C_{40}H_{30}O_4$; but UNVERDORFEN has shown that colophony includes two distinct acid resins, together with a minute portion of an indifferent one. These acid resins he designates pinic acid, and silvic acid, the former greatly preponderating. As respects the composition of these acids, it appears that they are isomeric, and therefore have the same formula as that above ascribed to pure colophony, a conclusion sanctioned by ROSÉ and TROMMSDORFF, but not by LÖWIG.

Rosin forms an important ingredient in the composition of yellow soap, and is a partial substitute for fixed oil or fat; it is not analogous to the latter in chemical constitution, nor can it, like those bodies, form with an alkali a proper soap by itself. Colophony contains no glycerin, nor any equivalent for that substance.

The formation of yellow soap from rosin depends on the direct combination of the resin acids with soda. No glycerin is eliminated, there being no proper saponification. The compounds formed, however, by the union of soda with rosin are not separable from their

aqueous solutions by chloride of sodium, like true soda soaps, nor do their concentrated solutions become mucilaginous or gelatinous on cooling; nevertheless they produce a lather, and, when added to soap in limited proportion, increase its detergency. Rosin is also used to some extent in perfumery.

This resin is largely employed in manufacturing industry for the purpose of extracting the various oily bodies it produces by destructive distillation, and which oils are largely consumed in the arts, as well alone as for adulterating dearer kinds. The bleaching of common colophony has long engaged attention, but success did not attend the various efforts. Latterly, however, Messrs. HUNT and POCHIN's patent seems to have accomplished the task of converting the common black resin, worth four to five shillings per hundredweight, into a white almost transparent compact article, which is said to be highly beneficial to soap and varnish makers, and worth as much as fifteen shillings per hundredweight.

Their process may be here advantageously although cursorily described. It consists in distilling resins and resinous substances without decomposition, or only partially so, by which they are freed from various mechanical impurities, and at the same time almost deprived of their color. The ordinary rosin of commerce, *et cetera*, are taken and introduced into an iron or other suitable vessel; they are then melted, and steam is passed, during the entire period of the operation, through the fluid mass, until the whole, or nearly the whole, has been distilled. The rosin is condensed in a suitable receiver, kept as cold as it can be by the application of water, and exsiccated; it is then adapted for the purposes for which it is required. During the distillation the temperature rises from about 390° to 600°, at which it is maintained until all such portions of the contents of the still as are capable of being volatilized have passed into the receiver. Instead of steam, carbonic acid, or a mixture of carbonic acid and nitrogen, or hydrogen gas or carbides of hydrogen, are introduced to decolor the resin.

COPAL, said formerly to have been derived from *rhus copallinum* and the *eleocarpus copalifer*, seems by late accounts to be obtained from various species of *hymenæa trachylobium* and *vonapa*. Several varieties of this resin are known in commerce, which are apparently the product of different trees, natives of Africa, America, the East Indies, and New Zealand. Levant copal is considered the best, and is met with in moderate-sized round masses, hard, transparent, colorless, or but slightly lemon yellow. *It is, of all resins, that which makes the finest varnishes.* Two kinds of copal resin are known; one hard or true, and the other tender or fictitious copal. The true variety, as above stated, is met with in large pieces, colorless, or of a slight yellow shade, exteriorly opaque, but limpid in the interior. In some cases its tint approaches to a brown. Insects are occasionally found inclosed in it, but more rarely the debris of plants.

It has so much resemblance to amber that it might be supposed to have a fossil origin; at all events it has probably been long exposed to the action of the air before being collected. It is very hard, and breaks

with a conchoidal fracture. Exposed to heat it softens, but does not permit its being drawn into threads; when the temperature is more elevated it melts, and at the same time undergoes decomposition, and distributes on boiling a vapor having the peculiar odor of the wood of the aloe tree. Its specific gravity varies from 1.045 to 1.139. In the natural state copal is only slightly soluble in absolute alcohol; on boiling it, however, it tumefies, and forms a viscous elastic mass; with ether it acts in a similar way, but ultimately dissolves. When it is desired to dissolve it in alcohol *per se*, the best method is to suspend it in the vapor of the boiling liquid, and it gradually falls drop by drop and is perfectly dissolved; with oil of turpentine, under similar treatment, the result is the same. To avoid the loss of spirit and other inconveniences which attend this process, many trials have been made. One of these, though singular, is said to be effective; it is to grind the resin and expose it to the air for a period of ten or twelve months, after which it is readily taken up by spirit of wine. It may be dissolved in absolute alcohol by first acting on it with ammonia, which softens it into a gelatinous mass, and then adding the spirit in small portions, with the aid of heat. It may likewise be dissolved in alcohol after being softened with ether.

The ordinary practice is, however, to take advantage of the property which certain essential oils have of softening the resin, and thereby rendering it more readily soluble. A quantity of the copal is taken and moistened with oil of rosemary or of lavender; after standing for a time some pieces begin to soften, while others are unaffected; the former are selected for spirit varnish, and the latter are put by for varnish to be made with fixed oils. The first portion is then ground, moistened a second time with either of the essential oils named, and after a short time it swells up to a pasty mass, which on addition of the necessary quantity of spirit of wine dissolves. Spirit of turpentine behaves in like manner. The same menstrua, provided a little camphor be first dissolved in them, readily take up the resin; but the varnish thus formed, as also that prepared by means of oil of rosemary, is soft and devoid of the durability which the real spirit varnishes made with the resin possess. But the common copal varnish is made by melting it cautiously, and adding oil of turpentine heated to a certain point.

According to UNVERDORPEN and FILHOL, who have more recently examined Indian copal, it contains no less than five definite compounds of a resinous nature, four of which possess acid and one neutral properties. Thus, in treating powdered copal with a spirit containing sixty-seven per cent. of alcohol, and adding to the extract thus obtained an alcoholic solution of acetate of copper, a precipitate of bluish flocculi appears, which on being dried and affused with cold ether takes up resin A; the alcoholic liquid retains resin B in solution. Further, on treating the residue with absolute alcohol, a third resin, C, is dissolved together with portions of the two preceding ones; and, finally, by treating what remains from the last menstruum with potassa, a fourth resin, D, separates, and a neutral substance, E, remains.

The analysis of copal, according to FILHOL, is as follows:—

	Bombay copal.	Madagascar copal.	Calcutta copal.
Carbon,.....	79.70	79.80	80.66
Hydrogen,..	9.90	10.78	10.57
Oxygen,....	10.40	9.42	8.77
	100.00	100.00	100.00

The composition of the resin alters, however, on being exposed to the air for some time in a finely-powdered state, or when reduced to an impalpable powder by abrasion under water, oxygen being absorbed, as the following analyses illustrate:—

	Copal exposed to the air in fine powder.	Copal reduced to an impalpable powder under water.
Carbon,.....	77.0	71.4
Hydrogen,.....	10.0	9.2
Oxygen,.....	13.0	19.4
	100.0	100.0

Tender or fictitious copal is found in commerce mixed sometimes with a little Indian copal, but it is brought from the Brazils without any admixture. That from India is vitreous, translucent, and nearly as transparent as glass, but age communicates to it a shade of yellow on the surface. Its ordinary form is in tears; it possesses a weak, agreeable odor, is very friable, and preserves this property even in the varnish made with it, on which account it is not so much esteemed. Heat renders it soft and elastic, so that it can be drawn out into threads as fine as silk. Alcohol partly dissolves it, the residue appearing like gluten. Ether takes up nearly the whole substance.

FILHOL has analyzed this resin and found it gave—

Carbon,.....	85.3
Hydrogen,.....	11.5
Oxygen,.....	3.2
	100.0

Dammara Resin is a white resin brought from the East Indies, and is said to be the produce of the *pinus dammara*; it contains a resin soluble, and one insoluble in alcohol.

Dragon's Blood, which is a deep-red resin imported from the East Indies, has been fully described, although erroneously, under BALSAMS, in vol. i., page 227.

ELEM.—It appears that the source from which this resin is obtained is very doubtful. It is generally described as constituting a member of the *Amyrideæ*, which is allied to the class to which the orange-tree belongs, owing to LINNÆUS confounding apparently two distinct plants under one name—the *amyris elemifera*—namely, the *icica icicariba* and the *amyris plumieri* of DE CANDOLLE; the former a Brazilian tree which yields, according to PISON, a resin similar to the so-called *gum-elemi*, and the latter a native of the Antilles, which likewise produces a resin. PEREIRA, in tracing the source and origin of this resin, found that it was imported entirely from Amsterdam and Hamburg, and concluded that it was the product of a Dutch settlement. He is inclined to believe that which formerly came from Ethiopia by way of the Levant was derived from the *canarium zephyrinum* or *canari*

barat of RUMPHIUS, who says that it yields a resin so like elemi that it might be taken for it. PEREIRA mentions three kinds of elemi—elemi in flag leaves, elemi in lumps, and Brazilian elemi. The first is imported into England from Holland in triangular masses of one to two pounds weight, enveloped in palm leaves. The elemi in lumps is a little paler in color than the Brazilian. MARTIUS states that the first variety is the product of the *amyris zeylanica*; though PEREIRA doubts the assertion, on the ground that if it were a product of Ceylon it would be imported direct hither, which is not the case. The only doubt which he seems to throw upon the Brazilian elemi being derived from the *icica icicariba*, which may be taken for the *amyris elemifera* of LINNÆUS, rests upon the certainty of its being a Brazilian product.

In extracting the Brazilian elemi, an incision is made into the stem of the tree, whence the juice exudes, and the resin is gathered in twenty-four hours afterwards. It is imported in cases containing two or three hundred pounds each. It is soft and unctuous, but becomes hard and brittle by cold and age. It is semitransparent, of a yellowish-white color, mixed with greenish points; its odor is strong, agreeable, analogous to that of fennel. This is owing to a volatile oil, which may be obtained from it by dry distillation.

The description most extensively dealt in, is that which is brought to this country from Singapore in a soft, strong-smelling mass, in cases of about two hundredweight. It is the produce of Manilla, and the Editor is credibly informed that it is not imported from any part West of Singapore. In addition to this, the Brazil sort is occasionally seen in the market.

The proximate principles of elemi are a transparent resin having acid properties, soluble in cold alcohol; a second resin taken up by boiling alcohol, but deposited from the solution on cooling in a crystalline state; a volatile colorless oil, which, according to DEVILLE, resembles much the essence of turpentine, and of citron in composition, as in its reactions; and a bitter extractive. The annexed per centages were found by BONASTRE:—

Volatile oil,.....	12.5
Resins soluble in both hot and cold alcohol,...	60.0
Resins soluble in hot, but not in cold alcohol	24.0
—elemi,.....	
Bitter extractive,.....	2.0
Impurities,.....	1.5
	100.0

The resin *a*, readily soluble in cold alcohol, consists, according to JOHNSTON, of $C_{40}H_{32}O_4$, while the resin *b*, sparingly soluble in cold alcohol, is composed of $C_{40}H_{32}O$. Specific gravity, 1.08 BONASTRE; SCHUBART gives it 1.055.

Elemi is occasionally used as a topical remedy in the form of an ointment, more particularly in ulcerous complaints of an old and indolent nature. It is extensively employed for varnishes.

GUAIACUM.—This substance, which is commonly, though very erroneously, denominated gum-guaiaicum, is the produce of the *guaiacum officinale*, a lofty tree, native of St. Domingo and Jamaica. It occurs in tears naturally exuding from the stem; and in lumps ob-

tained partly from incisions into the trunk of the tree, and partly by the action of heat upon billets of the wood. This resin is of a dark-green dingy color, transparent when in thin laminae, and of a brilliant resinous fracture. It has a slight balsamic odor. Its powder is at first pale grey, but gradually deepens, and becomes green by exposure: it acquires a beautiful but transient blue tint when moistened with spirit of nitrous ether. According to the Edinburgh Pharmacopœia, the characters of guaiacum resin are as follows:—Fresh fracture red, slowly passing to green; the tincture slowly strikes a lively blue color on the inner surface of the paring of a raw potato. The specific gravity of guaiacum varies between 1.20 and 1.23. It is soluble to the extent of about ninety per cent. in absolute alcohol. The insoluble portion, though sometimes described as resin, has more of the characters of altered extractive. When subjected to dry distillation, guaiacum fuses at about 570°, and an oily matter, together with water, passes over, which has been examined by SOBRERO, and by PELLETIER. When chewed, guaiacum softens under the teeth, but has scarcely any taste, though it leaves a burning sensation in the throat.

Physiological Effects.—Guaiacum resin is an acrid stimulant, formerly very much used in medicine, and even now to a great extent.

Under the use of small and repeated doses of guaiacum various constitutional diseases sometimes gradually subside, and a healthy condition of the system is brought about with no other sensible effect of the remedy than perhaps the production of some dyspeptic symptoms, and a slight tendency to increased secretion. One designates this inexplicable, though not less certain, influence over the system by the term *alterative*. When guaiacum is given in *moderately large doses*, or to plethoric, easily excited individuals, one observes the combined operation of an acrid and stimulant. In very large doses guaiacum causes heat and burning in the throat and stomach, vomiting, purging, pyrexia, and headache. In its operation on the system guaiacum is allied to the balsams.

JALAP.—The resinous portion of jalap is the most important. Jalap resin is obtained by mixing the alcoholic tincture of jalap, prepared by percolation or digestion with water. The precipitated resin is to be washed with warm water, and then dissolved in alcohol. By evaporation the tincture yields the resin. PLANCHÉ has proposed another process. By digestion with animal charcoal, the alcoholic solution of the resin is rendered nearly colorless, and by evaporation yields an almost colorless resin. Jalap resin is soluble in alcohol, but insoluble in water. Triturated with milk it does not form an emulsion, but its particles unite into a solid mass. By this it may be distinguished from scammony resin.

Physiological Effects.—Jalap resin is a local irritant. It acts as a powerful and drastic purgative. To scammony it is closely allied, not only by its effects, but also by botanical affinities and chemical properties. It is much less irritant to the intestinal mucous membrane than gamboge; and, therefore, is a much safer purgative.

Adulteration.—Commercial resin of jalap is rarely,

if ever, obtained in a state of purity. Guaiacum resin is the substance most frequently found mixed with it. Two methods have been pointed out for detecting this fraud—one by means of ether, the other by nitrous gas. Ether dissolves guaiacum very well, but does not dissolve resin of jalap. With nitrous gas the process consists in dissolving a small quantity of the suspected resin in spirit of wine, soaking a piece of white paper in this liquid, and exposing the paper to the action of nitrous gas. If the alcoholic solution of resin of jalap contain guaiacum, the paper should assume a blue tint; if no guaiacum be present, the color will remain unaltered.

MASTIC is the produce of the *pistacia lentiscus*, native in the South of Europe, the North of Africa, and the Levant, particularly the Island of Chios. It occurs in small spheroidal translucent tears, of a pale yellow hue, vitreous fracture, agreeable odor, and mild aromatic taste. When chewed, it becomes tough and somewhat viscid; it fuses at about 250°, and begins to be decomposed; it contains a very minute quantity of volatile oil. Mastic is a valuable ingredient in certain varnishes, and is frequently used for the purpose of stopping decayed teeth. It is not employed in medicine. Its produce is commonly known under the name of *pounce*.

SANDARACH, or Juniper resin, is the produce of *thuja articulata*, which grows in Barbary. It is imported from Magadore, and largely used as an ingredient in varnishes. It usually occurs in small yellow brittle drops, easily fusible, and soluble in alcohol.

SCAMMONY RESIN.—The substance known in pharmacy under the name of *scammony*, is an exudation from incision of the root of the *convolvulus scammonia*, and appears first as a milky juice, which afterwards dries. It is often very considerably adulterated. Several varieties of this drug come into the market, but the most select is imported from Smyrna, and occasionally from Trieste, under the name of *virgin* or *lachryma scammony*. It is of a dark-greenish grey color, moderately hard, and of a somewhat resinous fracture. It should not effervesce with hydrochloric acid, nor should its cold filtered decoction be blued by iodine. One hundred grains, when incinerated with nitrate of ammonia, should not yield more than about three grains of ashes: ether should abstract from it at least seventy-eight per cent. of resinous matter. The odor of scammony, especially when breathed upon or moistened, is peculiar; and when a little water is rubbed upon its surface it should easily lactify.

THE RESIN OF SCAMMONY, obtained by evaporating its ethereal solution, is transparent, and of a brown tint, but may be decolorized by animal charcoal. Its alcoholic solution is feebly acid, and water throws down from it the resin in the state of hydrate. According to JOHNSTON, it is remarkable as containing more oxygen than any other resin hitherto analyzed. It is a powerful cathartic.

LAC.—*Laque*, French; *Gummilack*, German.—This resin is produced by the female of a small insect—the *coccus lacca*, or *coccus ficus*—which feeds and fecundates upon the banyan or religious tree of the Hindoos, and several allied plants, such as the *ficus indicus*, *ficus*

religiosa, the *rhamnus jujuba*, the *croton lacciferum*, and the *butea frondosa*.

In November or December the young brood makes its escape from the eggs lying beneath the dead body of the mother; they crawl about a little way, and fasten themselves to the bark of the shrubs. About this period the branches swarm to such a degree with the vermin that they seem covered with a red dust, in which case they are apt to be dried up and exhausted of their juice. Many of them, however, adhering to the feet of birds, become their prey, and are carried off by them to other trees. They soon produce small nipple-like incrustations upon the twigs, their bodies being apparently glued by means of a transparent liquid, which goes on increasing to the end of March, so as to form a cellular texture. At this time the animal resembles a small oval bag, without life, of the size of the cochineal. At the commencement a beautiful red liquor only is perceived, afterwards eggs make their appearance. In October or November, when the red liquor becomes exhausted, twenty or thirty young ones bore a hole through the back of their mother and come forth. The empty cells remain upon the branches; they are composed of the milky juice of the plant which serves as nourishment to the insects, and which is afterwards transformed into the red tinctorial matter which is found mixed with the resin; but its quantity is greater in the body of the insect than in the eggs, and more particularly in the red liquor secreted for feeding the young. After the escape of the insect the cells contain much less coloring body, and, consequently, the collection of resin ought to take place before that time by breaking off the twigs and drying them in the sun. In the East Indies this operation is performed twice in the year—the first time in March, and the second in October.—*Ure*.

The dried branches and twigs are called *stick-lac*, which serves the double purpose of dyeing, varnish-making, and sealing wax.

There are several varieties of stick-lac. According to quality that of Siam is considered the best, the Assam stick-lac ranking next, and the third quality is produced in Bengal. The analyses of the stick, seed, and shell lac are here collated:—

	John Stick-lac.	
An odorous resin,.....	66	65
Resin insoluble in ether,.....	16	75
“ laccin,.....		
Coloring matter,.....	3	75
Laccic acid,.....	0	62
Extractive,.....	3	92
Skins of insects,.....	2	08
Wax,.....	1	67
Salts,.....	1	04
Sand,.....	0	62
Loss,.....	2	90
	100	00

	Hatchett.		
	Stick-lac.	Seed-lac.	Shell-lac.
Resin,.....	68.0	88.5	90.9
Coloring matter,....	10.0	2.5	0.5
Wax,.....	6.0	4.5	4.0
Gluten,.....	5.5	2.0	2.8
Foreign bodies,.....	6.5	0.0	0.0
Loss,.....	4.0	2.5	1.8
	100.0	100.0	100.0

Lac as brought to Europe is in various forms, such as grains, lumps, and thin scales; the former is called *seed-lac*, and is the residue after the resinous matter scraped off the stick-lac, ground and boiled in water to remove the greater part of the coloring matter, and dried in the sun; the second is called *lump-lac*, and is merely the former melted into lumps; and the third, which is named *shell-lac*, is of the same nature as the seed and lump-lac, only purer. It is usually prepared in India by heating the seed-lac in bags over a fire, and by squeezing and pressing, causing the liquefied resin to flow out and fall upon the smooth surface of the stems of the banyan-tree; the coatings thus formed on cooling harden and constitute shell-lac.

It will be seen from the preceding tables that the proportion of resin is much larger in shell-lac than in any of the other commercial forms of the resins. The better quality of the article is of a light-brown hue passing into orange, and sometimes to a deep ruby color, whence the names *orange* and *ruby* shell-lac; the inferior kinds are much less transparent, darker in color like glue, and in thicker plates.

By exposure in thin shreds to the sun's rays, or in a finely-divided state to chlorine water, or by reducing it to a fine powder, suspending in water and passing hydrochloric acid vapor into the menstruum, the dark-colored varieties are bleached. When this is done, however, the resin loses many of those qualities that so admirably recommend it for some kinds of varnishes, but it answers well for making sealing-wax.

Lac resin is very difficultly soluble in alcohol, though, like copal, it may be completely taken up by this solvent. Like most of the other resins, it has a strong affinity for bases, with which it forms definite compounds. Dilute hydrochloric acid and acetic acid dissolve the resin freely, but not the strong sulphuric acid. Borax solutions with the aid of heat also take it up. The portion soluble in alcohol has a specific gravity of 1.139. UNVERDORPEN found it to be a compound of several resins, namely—

1. Resin soluble both in alcohol and ether. 2. Resin soluble in alcohol, insoluble in ether. 3. Resin but very slightly soluble in cold alcohol. 4. Crystallizable resin. 5. Resin soluble both in alcohol and ether, but not in petroleum uncrystallizable. Besides these, a saponifiable fat wax and coloring matter have been detected in shell-lac.

SILVER.—*Argent*, French; *Silber*, German; *Argentum*, Latin.—This is one of the precious metals, and is characterized by its perfectly pure white color. Its combining weight is 108; its symbol, Ag. Melted, its density is 10.47; hardened under the hammer, it becomes 10.54. Its specific heat is 0.057. In malleability it is only inferior to gold, and may be beaten into leaves of less than one-hundred-thousandth of an inch in thickness, and drawn into very fine wires. It has also considerable tenacity, a wire of one-hundredth of an inch in diameter supporting a weight of twenty-three pounds. It is harder than gold, but softer than copper, and when pure it is so soft as to be cut by a knife. The addition of a small quantity of copper increases its hardness.

Silver melts at a full red heat, corresponding to

1870°; but in consequence of its pure white color, and the high lustre which it is capable of receiving, its reflecting power for light and heat is greater than that of any other metal, and, therefore, when perfectly polished, it does not melt in the focus of a mirror capable of fusing platinum. For the same reasons, its radiating power is so low that a silver vessel retains the heat of a liquid contained in it longer than a vessel of any other metal.

HISTORICAL NOTICE.—The discovery of silver appears to have been coeval with that of gold, and dates back to the earliest times of human history. In the book of Genesis it is stated that ABRAHAM, who lived about two thousand years before the Christian era, was rich in cattle, and in silver, and in gold; and on the death of his wife he purchased a field for a burying-place, the payment for which was made with four hundred shekels of silver, which he delivered not in coin, but *by weight, according to the currency of the merchants*. JOSEPH, the great grandson of ABRAHAM, was sold by his brethren to a caravan of Arabian merchants for twenty pieces of silver; and when he was established in Egypt as minister of the king of that country, his brothers brought *silver in their sacks' mouth* to purchase corn during a season of scarcity. Afterwards, when making himself known to his family, JOSEPH presented to his younger brother, BENJAMIN, three hundred pieces of silver. The author of the book of Job, who is certainly a very ancient writer, not only speaks of *the dust of gold*, but says, *Surely there is a vein for the silver, and a place for the gold where they find it*; so that he seems to have been well acquainted with the fact that silver was found in veins, and gold commonly in small particles. The vast amount of the precious metals accumulated by DAVID and SOLOMON has been mentioned in the article on GOLD, and in the first book of Kings it is stated that all the vessels of the house of the forest of Lebanon were of pure gold; *none were of silver, for that metal was nothing accounted of in the days of SOLOMON*, and, in short, *the king made silver to be as stones in Jerusalem*.

The accounts given by the profane writers of antiquity are equally surprising, and some of them altogether incredible. In POLYBIUS, for example, is found a description of Ecbatana, at a period subsequent to the capture of that place by ALEXANDER, in which it is stated that the beams, the roofs, and the pillars which supported the porticos and peristyles of the palace, were all covered with plates, some of silver and some of gold. The tiles, likewise, were all of silver. Though the place had been three times plundered before ANTIOCHUS arrived, there were still remaining in the temple of Ena some pillars cased with gold, and a large quantity of silver tiles, laid together in a heap. CRÆSUS, king of Lydia, who lived about five hundred and forty years before Christ, and whose wealth has become proverbial, is stated by HERODOTUS and DIODORUS to have made presents to the temple of Delphi amounting to four thousand talents of silver and two hundred and seventy talents of gold, or near three millions in value of British money.

The principal sources from which the ancients obtained their gold have been mentioned in the article

on that metal, and probably much of their silver was obtained from the same localities. PLINY speaks of a people named the Dardaneans, who inhabited a country the richest of all India in gold mines, and the Selians, he says, have the most abundant mines of silver. The chief sources of the wealth of the ancient kings of Egypt were the mines of the neighboring countries of Nubia and Ethiopia, which produced not only copper in abundance, but also gold and silver, before iron was known in Africa. According to XENOPHON, the Athenians worked the silver mines of their own country—Attica—from an unknown age, as well as the gold mines in their foreign possessions in Thrace, and in the island of Thasus. Epirus also had silver mines, which continued to be worked in the time of STRABO; but it appears probable that, for a long time, the only ore that was used was that found near the surface. The Colophonians were the most celebrated among the Greeks for their skill in smelting gold, but none of them were equally expert in smelting silver; for, according to STRABO, their successors were enabled to separate the silver from the residual earths with a profit, although even the latter were much inferior in skill to modern metallurgists.

But the country most productive of the precious metals, and especially of silver, in very remote ages, was the Spanish peninsula, which many authorities assume to have been the Tarshish of the sacred writings, to which a commercial expedition was sent by SOLOMON. It is certain that Spain was visited and colonized by the Phœnicians at a very early period, and that continual intercourse was maintained between the colonists and the mother country, as well as with the future descendants of the same race, the sons of Tyre and Sidon, who founded Carthage. The story of the discovery of the mineral wealth of the country, as related by DIODORUS, resembles many of the fables which in ancient times were dignified with the name of history. He states that the Pyrenean mountains were covered with thick woods, which were set on fire either by the shepherds or by lightning, and continued burning so long that the heat melted the minerals, in consequence of which the silver, with which the soil abounded, ran down into the valleys like a stream of water! He adds, that as the inhabitants were unacquainted with its value, they readily exchanged it with some Phœnician traders, who accidentally visited their shores, for some trifling articles of ornament. The traders loaded their vessels with the precious metal till they could carry no more, and then cut their leaden anchors from the bows, and replaced them with others of silver. These statements are extravagant; but there is no doubt that in ancient times a vast amount of silver was successively extracted from Spain by the Phœnicians, the Carthaginians, and the Romans, and exported to all parts of the world in exchange for merchandise.

Gold, iron, and lead were procured in the South, and some tin in the North of Spain; but the gold was probably of small amount, and silver was the chief mineral wealth of the country. Of this mineral PLINY says it was found in all the Roman provinces, but the best in Spain, and that in a barren soil, even in the

mountains; and wherever one vein was discovered, another was found not far from it. He mentions, as a very singular fact, that the mines begun by HANNIBAL still existed in his time, and retained their original names. One, which was still called Bebulu, from the discoverer, had formerly supplied HANNIBAL with three hundred pounds weight of silver daily. This, he adds, was effected by means of passages under the mountain a mile and a half in length, in which the laborers, standing in water, worked night and day by lamp-light to draw off the water, which at length accumulated to such an extent as to form a large river. JACOB, in his *History of the Precious Metals*—an elaborate work, to which the Editor is chiefly indebted for the facts condensed into this historical notice—states that the situation of the mine mentioned by PLINY is at present well known to have been at Guadalcanal, in the modern province of Cordova, at the foot of the Sierra Morena; and, judging from what has been surveyed of it in more recent times, the water, which was imperfectly drained by the costly subterranean tunnel noticed by PLINY, has long since overflowed the whole interior of the mine; but whether it was exhausted of its treasure and abandoned on that account, or whether it was destroyed by the influx of the water, cannot now be ascertained. It is interesting to remark that HANNIBAL chiefly derived from the silver wealth of Spain the sinews of war, which enabled him to shake to its foundations the Roman empire; and, for many years, he greatly over-worked the mines of that country in his eagerness to accumulate and hoard immense treasures, with a view to the accomplishment of the one great object on which he had set his whole heart.

During several centuries of profound darkness which succeeded the overthrow of the Roman empire, mining operations appear to have been suspended throughout Europe, and the dates at which they were generally resumed are not precisely known. The chief sources of mineral wealth in the middle ages were the Austrian mines, or at least those which existed in countries that are now included within that empire; and, of these, it is considered probable that the mines of Chemnitz and Kremnitz in Hungary were those first worked. FERBER dates the opening of Chemnitz in 745, and that of Kremnitz in 770; but AGRICOLA, who states that they had previously been worked by the Romans, dates their reopening nearly a century earlier. The silver in these mines is chiefly found in lead, in a proportion varying from two to twenty ounces of silver in a hundred pounds of the baser metal. In Bohemia there are celebrated mines of silver at Joachimsthal, in the circle of Saatz, but at what period the workings in them commenced does not appear. In some of these mines the galleries have been carried to the extent of five thousand six hundred fathoms, and some of the shafts are three hundred and fifty fathoms in perpendicular depth. At Altenberg, also, the metals were found in beds of gneiss, in which were mingled felspar and granite; but the mines of Schellgadin are at present the most important. These were also originally worked by the Romans, and the earliest records of their resumption date back to 1378. In the

Tyrol, near Brixen, are silver mines, which, during the excitement in the sixteenth century occasioned by the discovery of the mineral treasures of America, obtained the name of El Dorado. In the year 1523 they produced three thousand eight hundred pounds of silver, but subsequently they decreased in value, and have long been discontinued.

The mines of Saxony, says JACOB, were first discovered in the tenth century, when the whole district in which they are situated was covered with wood, and without inhabitants. Some carriers from Halle, on their way to Bohemia, observing metallic substances in the tracks made by the wheels, took them up and sent them to Goslar to be examined, when they were found to consist of lead with a considerable quantity of silver. This led to the establishment of mining operations, which have continued from the year 1169 to the present day. For some years in the fourteenth century the mines of Schneeberg are said to have yielded so large a portion of silver, that the tithes on it amounted in thirty years to three hundred and twenty-four thousand quintals; but these latter mines have long been exhausted.

The mines in the Hartz forest in Germany, which, at the time of this discovery, formed a portion of Saxony, are now partly in the dominion of Hanover, and partly in that of Brunswick. There are various conflicting opinions respecting the discovery of the mineral wealth of the Hartz. The most probable accounts fix it in the tenth century, and the tradition is that a hunter of the name of Ramm, when engaged in the chase, had fastened his horse to a tree, when the animal, by pawing with his feet, scraped away the soil, and thereby discovered some minerals. Specimens of these were sent to the Emperor ORTHO, who immediately despatched expert miners to examine the district. The result was that mines were established, which still continue to be worked, and the oldest is named Rammelsberg, from the discoverer. JACOB estimates the whole Hartz, including the dominions of Hanover and Brunswick, with a small part belonging to Prussia, to have yielded, for some years prior to 1830, about sixty ounces of gold, and three hundred thousand ounces of silver annually.

From the times when the rich mines of Spain were last worked by the Romans, they seem to have been greatly neglected. CARDENNE, however, asserts that the mines of gold and silver which existed in that country were a great source of wealth to the Arabs. The mine of Zalamea, to the South of the river Guadiana in Andalusia, appears to have been worked in the middle ages. It is said to have contained silver without any mixture of lead, though near it was another mine yielding only lead; but the most important mines of Spain, and those which have attracted the greatest attention, from the earliest ages down to recent times, are the quicksilver mines at Almaden, and the silver mine at Guadalcanal. Of the latter Mr. BURR observes, that very minute and authentic records were preserved during the period it was worked in the sixteenth century, on account of the government. In these it is stated to have produced four hundred thousand two hundred and twenty-three

marcs of silver in the first few years after its discovery, and while worked by the state. After this period it passed into the hands of the Fucares, who are said to have obtained immense treasure from the mine previous to its being abandoned, and filling with water. It is only within the last twenty years, adds the same authority, that Spain has again become a silver-producing country, several very rich mines of that metal having been discovered since the recent revival of mining, which dates back only from 1825. In 1839 the celebrated mines of the Sierra Almagrera in the province of Almeria, were discovered, and they have ever since poured a large amount of silver annually into circulation. In 1843 another great discovery of silver was made—the mines of Hiendelencina in the province of Guadalajara, which have since been very productive; and, passing over recent and minor discoveries, Mr. BURR states that within the last few years the introduction of Mr. PATTISON's desilvering process—a process fully explained in the article LEAD—has been very general in the provinces of Murcia and Almeria. A large quantity of silver is thus annually obtained from the slightly argentiferous lead ores of the Sierra de Gador, and of Cartagena, not formerly extracted, but which now contributes to swell the production of this metal in Spain.

The silver mines of Norway and Sweden were long famous, but have latterly become less productive. The mine of Sahl, or Sala, is said to have been worked five hundred years ago. The silver mines of Kongsberg in Norway were scarcely known before 1623. In some years between 1710 and 1767 they yielded a large profit, but in others they were attended with heavy loss, and have frequently been suspended for long periods.

Although in ancient times Britain was celebrated only for its tin, and yielded but small quantities of the precious metals, yet not only does proof exist that gold was found to some extent, but STRABO states that silver mines were worked in this island, and TACITUS represents AGRICOLA, in his oration before the battle of the Grampian mountains, as reminding his soldiers of the riches in gold and silver which were to reward their valor. It is probable that these riches existed only in the historian's imagination—so far at least as they were to be found in a form available to the metallurgical skill which then existed. In modern times silver has been found in the British islands only in small quantities, except in connection with lead; and before the introduction of Mr. PATTISON's process, the trouble of its separation from that metal more than counter-balanced the profit. There are records, however, of silver mines in Cardiganshire, and also in the county of Tipperary in Ireland, both of which are said to have been worked to some extent during the reign of ELIZABETH. It is stated also that Sir JOHN ERSKINE was a proprietor of silver mines at Alva, near Stirling, which ceased to be worked in 1729, having been carried on for six years previously, under the direction of one PEEK, an Englishman; and in the reign of MARY STUART some silver mines were worked near Linlithgow. The produce must have been very trifling, and the profitable mining of either of the precious metals

was virtually a thing unknown in this country until the introduction of Mr. PATTISON's process rendered it advantageous to extract silver from lead; and as this metal is produced to a greater extent in Great Britain than in any other country in the world, the result is that, by virtue of the process above-mentioned, it is now actually entitled to no mean rank as a silver-producing country. The lead of some of the English mines, especially those of Cornwall, and also of the Isle of Man, contains considerable quantities of silver; and the reader will be surprised to learn that one of the highest authorities on this subject, Mr. ROBERT HUNT, has estimated that in 1852 the United Kingdom furnished no fewer than eight hundred thousand ounces of silver, worth, at five shillings an ounce, about two hundred thousand pounds, obtained from lead alone.

But the greatest impetus given to the supply of silver in what may be termed the modern era, arose from the discovery of America by COLUMBUS in 1492. It is true that up to the invasion of Mexico by CORTEZ, in 1519, gold alone had been found in America; or if any silver was procured, it seems to have been in small quantity. Thirty or forty years after that event, mines were in full work at Tasco, Zaltepeque, and Pachuca, but the use of mercury was not yet understood. The smelting of the ore was performed in small portable furnaces, or cylindrical tubes of clay, very broad and pierced with a great number of holes. In these the Indians placed layers of silver ore, galena, and charcoal, and a draught was created by the current of air which passed through the holes. Twenty years after the conquest of Mexico by CORTEZ, PIZARRO achieved that of Peru, and numerous mines yielding both gold and silver were soon opened in that country, but none equal in importance to the celebrated mines of the Cerro de Potosi, which were discovered accidentally in 1545. According to HERRERA, the discovery was made by an Indian hunter, DIEGO HUALCA, who, in pulling up a shrub, observed filaments of pure silver about the roots. On examination the mass was found to be enormous, and a very great part of the population was drawn to the spot and employed in extracting the metal. A city soon sprung up, though in a district of unusual sterility. The mountain was perforated on all sides, and the produce in a few of the first years exceeded anything that had been previously recorded in the mining history of the world.

The sensation created throughout Europe by the news of the discovery of the silver treasures of Potosi, can only be compared to the similar effect produced in recent times by the discovery of the auriferous deposits of California and Australia, which has been fully described in the article GOLD. The wealth of the new El Dorado was, however, grossly exaggerated. From reliable data it has been estimated, that between the year 1557, when the process of amalgamation was introduced, and the year 1578, the annual product of the Potosi mines did not exceed four hundred and forty thousand pounds sterling, which sinks into absolute insignificance compared with the vast amount of treasure now annually exported from California and Australia, without including the newly discovered and still comparatively unexplored deposits on the

banks of the Fraser River. On the whole, the greatest produce of gold and silver, even at that period, was from the Mexican mines, some of the richest of which were already in full activity, although the amount which they yielded was at that time much less than in the course of the two following centuries—the seventeenth and eighteenth—when quicksilver became more abundant, and was more extensively employed in the process of amalgamation. The chief increase of the precious metals between the years 1500 and 1600, was in silver from Mexico, where the production of Zacatecas, Guanajuato, and the other mining districts, had then greatly advanced. In the seventeenth century the silver mines of Yauricocha or Pasco, in the northern part of Peru, were first opened, and yielded a large amount of that metal. It is thus that though Potosi, which had at first produced the greatest quantity of silver, had declined, the product of the other parts of Peru so much increased as more than to compensate for that deficiency; and this increase, especially of silver, was greatly facilitated by the extension of the mines of mercury at Huancavelica.

The product of the precious metals from the American mines continued steadily to increase till 1809, when the convulsions commenced which terminated in the separation of the Spanish vice-royalties from the yoke of the mother country, and the erection of Mexico, Peru, and Chili into independent republics. During these troubles, which continued from 1809 to 1821, the produce of the mines greatly decreased, but has since been gradually augmenting.

The aggregate and relative amounts of silver obtained from different parts of the world, will be stated at the end of the article under the head of Statistics.

SOURCES.—As silver is of great use in the arts, not only for purposes of coinage, but also for services of plate for which it is peculiarly adapted, inasmuch as it is seldom attacked in the slightest degree by any of the substances used for food, so it occurs in great abundance in nature, and is largely disseminated both in the native state and alloyed with various other metals, occurring particularly in lead ores, as noticed under the article LEAD.

Native Silver is characterized by most of the properties of pure silver, but is always alloyed with a small quantity of other metals. It is generally dull at the surface, but exhibits, on being scratched, the pure white color characteristic of the metal. From its slight impurities, it is also less malleable and ductile than silver perfectly pure. It occurs sometimes crystallized in cubes and octahedrons; sometimes in thin leaves or in dendritical or arborescent shapes, resulting from minute crystals implanted upon each other; frequently also it is found in amorphous masses. It is met with chiefly in the primitive formations, as in granite and gneiss; more rarely in the argillaceous schists and grauwacke of the transition rocks, accompanied by quartz, carbonate and fluat of lime, sulphate of barytes, carbonate of iron, galena, *et cetera*. The principal localities in which it occurs native are—Kongsberg in Norway; Schlangenberg in Siberia; Freiberg, Schneeberg and Johanngeorgenstadt in Saxony; Joachimsthal, Przibram, and Ratiborzitz in Bohemia; Schemnitz in

Hungary; Kapnik and Felsőbanya in Transylvania; Andreasberg in the Hartz, Allemont in France; and, lastly, Mexico and Peru in America. In some of these localities it has been found occasionally in considerable masses. Thus, at Kongsberg, pieces have been extracted weighing from fifty to six hundred pounds; in America, at the end of the last century, lumps of two hundred to eight hundred pounds were obtained; and on one occasion a block of solid silver was discovered in the mine of Johanngeorgenstadt, which is said to have weighed nine or ten thousand pounds.

SULPHIDE OF SILVER.—*Glaserz* or *Silberglanz*, German—contains eighty-five to eighty-seven per cent of metallic silver. It is of a blackish dark-grey color, dull externally, but showing a metallic lustre when cut. It crystallizes in cubes or octahedrons, but is generally met with in the amorphous state. It is slightly malleable, almost as soft as lead, and is easily cut with a knife. It fuses readily in the flame of a blow-pipe, and even in a simple jet of gas, disengaging a slightly sulphurous odor, and ends by being reduced on the charcoal to metallic silver. It is met with in nature almost always combined with other sulphides, as those of copper and lead. This mineral is one of the richest and most abundant ores of silver; it forms a large proportion of that annually produced by the various foreign mines, as those of Saxony, Bohemia, and Hungary, and is particularly abundant in the mines of Guanajuato and Zacatecas in Mexico. Its composition, according to KLAPROTH, is—

	From Himmelfurst.	From Joachimsthal
Silver,	86.50	86.39
Sulphur,	13.50	13.61
	100.00	100.00

RED SILVER.—*Rothgültigerz*, German.—There are three species of this mineral:—1. *The antimonial sulphide of silver*, or a double sulphide of silver and antimony—an ore of a dark-red or reddish-black color, very nearly opaque, has a metallic lustre, and usually crystallizes in hexahedral prisms. Its constituents are—silver, from 56 to 62; antimony, from 16 to 20; sulphur, 11 to 14; and oxygen from 8 to 10. It is met with in almost all silver mines, but principally at Andreasberg in the Hartz, Freiberg in Saxony, Kongsberg in Norway, Schemnitz and Kremnitz in Hungary. 2. *Praistite*, or the double sulphide of silver and arsenic, which is of a clear red color, transparent, with a brilliant lustre, and contains sixty-four per cent of metallic silver. 3. *Myargyrite*, which differs from the antimonial sulphide only in containing one-third of the proportion of sulphide of silver.

BRITTLE SULPHIDE OF SILVER.—*Spradglaserz*, German—presents two varieties essentially distinct—

1. *Polybasite*, a combination of sulphide of silver, sulphide of copper, and sulphide of antimony or arsenic; has a semi-metallic lustre and an iron-grey color; seen by transmitted light, in thin scales, it presents a blood-red color; it contains 60.5 to 72.25 per cent of silver, and is found chiefly in the Saxon mines, and also in Mexico and Peru. 2. *Brittle Sulphide of Silver*, properly so called—German, *Schwarzgültigerz*—which is a combination of sulphide of silver with the sulphide of anti-

mony or arsenic; lustre slightly metallic; color iron-grey, and black when reduced to powder; is found associated with the preceding, as also in Hungary, Transylvania, *et cetera*. According to the investigations of ROSE and KLAPROTH, its composition is as follows—

	From Freyberg By Klaproth.	From Schemnitz By Rose.
Silver,.....	66.50	68.34
Copper and Arsenic,.....	00.50	0.64
Iron,.....	5.00	0.00
Antimony,.....	10.00	14.60
Sulphur,.....	12.00	16.42
Loss,.....	6.00	—
	100.00	100.00

Grey argentiferous Copper—*weissgültigerz*, German—a combination of sulphides of silver, copper, lead, and antimony; has a semi-metallic lustre, and a color intermediate between that of lead and steel. That which is found in the mines of Freiberg contains thirty to thirty-two per cent. of silver. The *graugültigerz* is a variety of grey copper much poorer in silver than the preceding.

Plumbo-argentiferous sulphide of bismuth—*wismuthbleierz*, German—is a brittle, leaden-grey mineral; it is a triple sulphide of bismuth, lead, and silver; contains fifteen per cent. of metallic silver. It is found at Schapbach in the Black Forest, but is a rare mineral.

Antimonial Silver—*speisglanz silber*, German—is a semi-metallic substance of a silver-white color, containing about seventy-seven parts of silver and twenty-three of antimony; it is found at Wolfach in the Black Forest, and in some of the Hartz mines, sometimes crystallized in rectangular prisms, but oftener in concrete masses.

Chloride of Silver.—*silberhornerz*, German, horn-silver—is semi-ductile and sufficiently soft to be cut with a knife; color, pearl-grey inclining to blue, and becoming brown in the air; has a vitreous lustre; is usually translucent; crystallizes in cubes. When pure it consists of silver 75.3, chlorine 24.7, and its composition is therefore represented by the formula Ag Cl .

This mineral, says PHILLIPS, which was formerly supposed to be of rare occurrence, constitutes one of the richest and most abundant ores of Chili, where it is frequently associated with native silver, apparently resulting from its decomposition. It also occurs in massive amorphous fragments in connection with sulphide of silver, but still more frequently in small cubical crystals disseminated in the ferruginous rock known in Chili and Peru under the names of *pacos* and *colorados*. Specimens of this mineral, although of comparatively rare occurrence in the European mines, have been obtained from Norway, Siberia, Saxony, the Hartz, and Cornwall.

Iodide of Silver is a rare mineral of a pale lemon-yellow color, with sometimes a tint of green. It was discovered by M. VAUQUELIN in the Mexican mines, but, from its rarity, is of no importance as an ore of silver. It is composed of silver 77.4, iodine 22.6.

Bromide of Silver was discovered by M. BERTHIER in the Mexican minerals, where it has since been found so abundantly in the district of Plataros, near Zaccatecas, that the ores there raised have received the name of *plata verde*, from the green color which it imparts to

them. According to BERTHIER, it is composed of silver 57.70, bromine 12.50.

Native Amalgam, or *argentale mercury*, has a very bright silver-white color, and is so soft as to be easily cut with a knife. It occurs both in distinct crystals and in irregular amorphous masses. It crystallizes in the regular octahedron or dodecahedron. This mineral is found in a great many different localities, but the finest specimens have been procured from Moschellandsberg in Bavaria. Its specific gravity is 14.1, and, according to KLAPROTH, it contains thirty-six per cent. of silver and sixty-four of mercury.

Another species of this substance, says PHILLIPS, forms one of the principal sources of silver in the rich mines of Arqueros, in the province of Coquimbo, Chili. From its malleability and general appearance this product was for a long time thought to be metallic silver. According to the analysis of Professor DOMEYKO, of the mining school of Coquimbo, this amalgam consists of silver 86.63, mercury 13.37, from which it appears to be composed of six equivalents of silver united to one of mercury, and its composition may therefore be represented by the formula $\text{Ag}_6 \text{Hg}$.

Argentiferous Galena.—The sulphide of lead, or galena, is almost always associated with a small quantity of silver in the state of sulphide, and this is the source of the silver obtained in the British Islands. It is regarded as extremely rich when it contains 0.005 of silver, and in many cases it may be extracted with advantage when only a tenth part of that proportion is present.

In general, and whatever may be their nature, minerals are regarded as rich which contain 0.005 of metallic silver.

PURE SILVER.—The silver of commerce is never perfectly pure, being always mixed with a certain proportion of copper and traces of other metals. A small quantity may be obtained pure by dissolving a piece of money or of plate in nitric acid, and adding a solution of chloride of sodium; a double decomposition occurs; the silver is thrown down in the form of an insoluble chloride, while the copper and any other metals that may be present remain in solution. One hundred parts of this chloride are, when separated and dried, mixed with seventy parts of chalk and four or five of carbon, and this mixture is introduced into a crucible and raised to a white heat. Carbonic oxide is disengaged, and chloride of calcium and metallic silver remain in the crucible.

To obtain the silver in a state of great purity, the chloride obtained by the double decomposition in the first instance ought to be repeatedly washed by decantation with boiling water, to be certain of dissolving the other metallic chlorides. Instead of chalk, the operation succeeds perfectly by mixing equal parts of carbonate of potassa or soda with three or four per cent. of charcoal in powder. But as the mixture fuses, the disengagement of gas produces, in this case, a tumescence which may project the matter out of the crucible. For this reason GAY-LUSSAC preferred the use of carbonate of lime, with which the reaction may be effected without fusion, reserving the temperature capable of melting the mixture for the time when, the

reaction being finished, no more gas can be disengaged. When the contents subside, the crucible is filled up with more of the mixture; and when the reaction is finished, the temperature is raised to a white heat; the chloride of calcium and the silver are melted, and the latter forms, on cooling, a button at the bottom of the crucible. The chloride of calcium, which lies above it, always contains a certain quantity of chloride of silver; and to separate the silver from the chloride recourse is had to the humid process. The chloride is first purified by washing, and then subjected to the action of a little sulphuric acid, and a plate of zinc purified by distillation. The reduction is effected rapidly, and the silver forms a grey, spongy, mass, which often floats on the top, because it is penetrated by hydrogen gas proceeding from the decomposition of the water. By stirring with a glass rod, after withdrawing the zinc plate, the hydrogen is separated from the spongy mass, which then falls to the bottom. The liquid is then decanted off, and its place supplied by water and a little sulphuric acid. This new treatment is necessary, for the spongy substance is a combination of silver with zinc, and not pure silver. Accordingly bubbles of hydrogen gas, proceeding from the solution of the zinc, are soon found to be disengaged abundantly. When this ceases, the powder is washed by decantation with boiling distilled water till the liquid is no longer rendered turbid by chloride of barium. In this way the silver is obtained pure, in a state of minute division.

Chemical Properties.—At ordinary temperatures silver is not acted upon by oxygen, but it is tarnished if exposed to an atmosphere containing very minute portions of sulphide of hydrogen, which is always present, to a greater or less extent, in the air of chambers heated by coal fires. When melted, however, in open vessels, it possesses the remarkable property of absorbing about twenty-two times its own bulk of oxygen, which in solidifying it disengages, producing, probably, that kind of metallic vegetation which takes place on the surface of the silver button when suddenly cooled in the cupel. It is not known whether there is chemical combination or merely mechanical absorption in this case; but BARRUEL considers the latter hypothesis by no means probable. The effects of this singular phenomenon, which has been already alluded to in Vol. II., page 284, in connection with the refining of gold, are best shown when the mass of metal is considerable, as, for example, about fifty or sixty pounds. They were carefully studied by GAY-LUSSAC and LUCAS, and are altogether so remarkable that a somewhat more minute account of them may not be unacceptable to the reader. After maintaining about the quantity of metal above-mentioned for a long time in a state of fusion, it is left to cool spontaneously, and begins to solidify at the surface. This process commences towards the edges, and advances towards the centre. The crust thus formed soon cracks, and very fluid silver escapes through the fissures, spreading itself over the surface in a thin layer. This first stage of the phenomenon appears due, not to a disengagement of gas, but rather to the expansion which results from a commencement of crystallization. Soon afterwards, as

the cooling proceeds, the gas in escaping begins to raise the solidified crust at several points, and produces a singular formation of miniature volcanic craters, through which a current of oxygen is disengaged, while lavas of melted silver stream over their edges. In the middle of each little crater the liquid mass is seen boiling violently. In proportion as the disengagement of gas proceeds, the height of these craters increases, in consequence of the solidification of the metal which flows over their sides; the greater part of them get partially choked up, whilst the gas escapes with a constantly increasing force, dragging along with it drops of melted silver, which it projects to a distance, and producing at each eruption small explosions, which succeed each other at very short intervals. The cones of eruption may ultimately attain a height of one and a half to two inches, with a diameter at the base of two to three inches; and for a quantity of fifty pounds of silver, the total duration of the *rochage*, as the process is termed in France, varies from thirty to forty-five minutes.

This phenomenon does not occur when the silver is alloyed with a small proportion of copper, gold, or lead; even one per cent. of copper prevents the absorption of oxygen on which it depends. That this is the cause of the phenomenon may be demonstrated on a smaller scale by heating to a white red in a crucible a considerable quantity of silver, and projecting upon it a little nitrate of potassa, which, by its decomposition, produces an atmosphere of oxygen. The crucible is then to be covered, and the heat continued for some time, after which the lid is removed and the vessel plunged into a tub of water, placing over it an inverted bell-glass filled with the same liquid; the oxygen which is disengaged is collected in the bell-glass, and may be measured. This experiment, says BARRUEL, is not without danger, for the oxygen may be disengaged all of a sudden, and thus produce a violent explosion.

When silver is subjected to a very high temperature, either by means of a burning lens, the flame of the oxyhydrogen blowpipe, or a powerful voltaic battery, it rapidly volatilizes, and burns with a greenish flame. In a state of fusion it may be crystallized, and in this case it assumes the cubical form.

Silver does not absorb the oxygen of the air when it is fused with the alkalis, and for this reason silver crucibles are used in laboratories for making analyses of silicates by means of the caustic alkalis, which would attack platinum ones. Chlorine, bromine, and iodine combine very well with silver, and of these three bodies iodine is that which has the greatest affinity for it. Of the acids, it is acted on most powerfully by nitric acid, which dissolves it in the cold; concentrated sulphuric acid requires heat to dissolve it. Hydrochloric acid attacks it only with difficulty, by leaving it a long time to digest; however, if the metal is in a very divided state, and the liquid be heated to ebullition, the action even of this acid is pretty rapid.

Silver readily combines with sulphur, and hence the fact already stated—the facility with which it is tarnished by contact with air containing even a very small proportion of sulphide of hydrogen. In this case its discoloration arises from the formation of a brown film of sulphide of silver. To clean articles so tar-

nished, the simplest method is to plunge them for some time into a solution of manganate of potassa—*chameleon mineral*—which is obtained by heating to redness a mixture of equal parts of potassa and binocide of manganese. In this operation the manganate is decomposed, and reacts on the sulphur of the sulphide of silver, which it oxidises and then dissolves. Oxygenated water, if convenient, may also be employed for the same purpose.

METALLURGY OF SILVER.—With reference to their metallurgical treatment, the minerals of silver are divided into four classes:—

1. Argentine ores, properly so called, and worked for the silver alone;

2. Ores of lead and silver;

3. Ores of copper and silver;

4. Ores of lead, copper, and silver.

The separation of silver from its ores is effected either by the method of amalgamation, or by a series of successive smeltings, which concentrate the silver in a certain quantity of lead, and the silver is afterwards separated by cupellation. The first of these processes consists essentially in bringing the silver ores, which have been previously pulverized and subjected to a special preparation, into intimate contact with metallic mercury; the silver is dissolved in the mercury, and the amalgam, being separated from the other matters by washing, is subjected to distillation; a residue is thus obtained. The advantage which this process presents over all others, is its great simplicity; but as any associated metals which may be present, such as copper and lead, are thereby lost, this method is usually employed only for ores which contain an insignificant proportion of these or other foreign metals. In the other processes the product obtained by successive roastings and smeltings is a quantity of *argentiferous lead* or *copper*, from which the silver remains to be separated. In the case of lead it is separated, as already stated, by cupellation; for copper, the mass must first be submitted to eliquation—an operation which consists in melting or *sweating out* the silver from the copper, and then cupelling with lead.

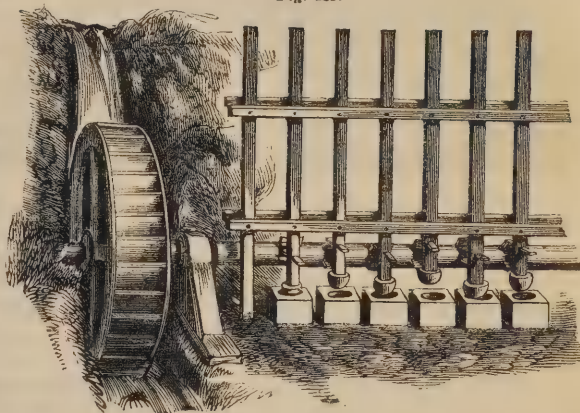
I. ORES WORKED FOR THE SILVER ALONE.—It has been stated that ores of this class, which do not contain an important proportion of other metals, are subjected to a process which consists essentially in forming an amalgam of the silver with mercury, and then subjecting the amalgam to distillation. This is the essential part of the process. Much of its success, however, depends on the manner in which it is conducted, and especially on certain preliminary operations which are required to bring the ore to that state of minute division in which it is most favourably circumstanced for causing the whole of the silver that is contained in it to combine with the mercury. There are two processes by amalgamation, the American or Mexican and the Saxon, which differ considerably from each other in this respect.

American process by amalgamation.—This method, invented in Mexico by BARTHOLOMEO DE MEDINA in

1557, is still practised in that country in all its primitive simplicity; and, perhaps, when the cheapness of labor, the poverty of the ores, the scarcity of fuel, and the deficiency even of water-power are considered, it could not be profitably superseded by any other. It will be found that its principal characteristics depend on these circumstances.

The ore, on being extracted from the mine, is placed in the hands of the *pepenadores*, men and women who break all the larger pieces with hammers, and after rejecting those in which their experience teaches them that no metallic particles are contained, and setting aside those which are very rich to be treated by the smelting process, they subject the rest to a process of crushing and pulverization, with a view to its direct treatment by amalgamation. The ores destined for this treatment are submitted in the first place to the action of the *ingenios* or stamping mills, which are either driven by mules, or, when water-power is at hand, by means of a small breast-wheel—Fig. 485. The long horizontal shaft fixed on the axis of the wheel is armed with five or six cams, placed at diffe-

Fig. 485.



rent situations round the shaft, so as to act in succession on the projecting teeth of the upright pestles or stampers, each of which weighs two hundred pounds, and works in a corresponding oblong mortar of stone or wood. It is estimated that a battery of eight of these stampers, is capable of reducing to powder three thousand five hundred pounds of ore in twenty-four hours.

The powder thus obtained not being sufficiently fine for the purpose of amalgamation, it is transferred from the stamps or *morteros* to be reduced to an impalpable slime or mud in the crushing mills or *arrastres*, represented in Fig. 486, into each of which a little water is introduced. These mills are commonly worked by mules, which turn a vertical shaft armed with two cross-bars. The grinding stones, as well as the sides and bottom of the mill itself, are composed of granite, four blocks of which revolve in each crushing mill, one attached to each of the arms. They are usually placed in a covered shed or gallery, as shown in the figure, which represents the *arrastres* of the *hacienda* or metallurgic works of Salgado, near Guanajuato. These

contain thirty-six dry stampers, also worked by mules, and forty-two crushing mills in which water is used. Each of the latter reduces to a fine impalpable metal-

liferous mud six hundred pounds of powder in twenty-four hours. The mules are changed every six hours. This operation is considered of great importance, for

Fig 486.



the subsequent amalgamation is so much the more complete, and the loss in mercury less considerable, in proportion as the ore is reduced to a more minute state of division.

The ore thus ground into a fine paste is termed

Fig. 487.



lama, and is conveyed into pits of three to six feet in depth, where it is allowed to dry in the sun till it acquires a certain consistence. It is then carried to the *patio* or amalgamation floor—Fig. 487—which is a flat space open to the sky, and surrounded by a stone wall. At Zaccatecas the *patio* is rectangular, three hundred and twelve feet in length by two hundred and forty in breadth, and capable of containing twenty-four flat circular heaps of *lama*, each about fifty feet in

diameter and seven inches deep, arranged in four rows. These heaps are termed *tortas*. A small space is usually reserved at one corner for the purpose of performing assays on the ore, with the view of determining beforehand the proportion of mercury that may be necessary to incorporate with each heap.

At Zaccatecas the *tortas* are formed in the following manner:—In the first instance a space of the requisite size is marked out and inclosed by a number of rough planks, which are propped in their places by large stones. About one hundred and fifty bushels of crude or impure sea-salt are then introduced into this inclosed space, and over this about six hundred metrical quintals of the *lama* or ore in a state of fine paste. The salt and *lama* are then well mixed by turning with shovels and treading with mules, after which the mixture is left at rest during the remainder of the day. On the morrow, after about an hour's further treading with mules, the *magistral*, or roasted and pulverized copper ore—a mineral containing ten per cent. sulphate of copper, and as much sulphate of iron—is added in greater or less quantity, according to the richness of the argentiferous ore and the season of the year; in summer, for example, and with the richer ores, about seven hundred and fifty pounds to the *torta*, and in winter only half that quantity; for it is stated as a singular fact that in summer the mixture cools and requires more warmth, while in winter it acquires of itself additional heat. The larger proportion is for minerals containing 0.0015 of metallic silver. When the operation proceeds too rapidly, arising from the presence of too much *magistral*, which would occasion

a greater loss in mercury, the remedy is to add a certain quantity of lime, which serves to cool the lama.

When the magistral has been introduced, the treading out is continued for five or six hours by means of six mules. When the whole has been well mixed, the process of amalgamation is commenced by adding a certain quantity of quicksilver, which is sprinkled over the heap by straining it through a bag of coarse cloth. The treading by mules is then continued, and the whole is turned over for some hours with wooden shovels. This operation is repeated for several days, until the amalgamator ascertains by examination that all of the mercury is taken up. He then adds a second and sometimes a third charge, repeating on each occasion the same treatment. When the last charge has been added, the mixture is again thoroughly trodden, and the mass is then removed by the laborers on handbarrows to the *lavaderos*, where the amalgam is separated from the earthy matters by washing.

To judge of the progress of the amalgamation from time to time, the amalgamator uses a small black earthenware basin, flat and round, or somewhat similar in form to that represented in Vol. II., Fig. 221, page 272. In this dish he puts a little of the lama or paste which is under the process of amalgamation, and holding the dish inclined and half-immersed in the water, he gives it a rotatory movement in a plane perpendicular to its axis, so that there is formed in the submerged part of the basin a circular current of water which retains the sand in the centre, while the heavy or metallic grains arrange themselves around the circumference according to their specific gravities, and there the amalgam is observed in small spangles. Usually eight parts of mercury are added for one part by weight of silver contained in the ore. Thus, at Zaccatecas, for an ore which is presumed to contain 0.001625 of silver—and this is the average proportion—there is added to the torta, which is estimated to contain about two hundred pounds of silver, on the first occasion nine hundred pounds of mercury; on the second, three hundred pounds; and on the third and last, four hundred and twenty pounds, making a total of one thousand six hundred and twenty pounds of quicksilver. The entire duration of the amalgamation is twelve to fifteen days in summer, and twenty to twenty-five in winter. This is less than a third of the time required at some other Mexican mines, which evidently arises from the small elevation given to the tortas, and the consequent exposure of a large surface to the action of the solar rays.

The next operation is the washing of the amalgamated ore, for the purpose of removing the earthy matters, and of thereby obtaining the amalgam or mixture of silver and mercury in a separate form. This operation is performed in *lavaderos*, or washing vats, which are circular in form, and solidly built in masonry, each about eight feet deep and nine in diameter. A horizontal toothed wheel, mounted on a shaft worked by mules, communicates, through the intervention of another toothed wheel, a movement of rotation to a vertical shaft placed in the middle of the vat, and armed at its lower part with four agitators consisting of cross

beams, from which rise long wooden teeth to the height of five feet. A small stream of water continually flows into the vats from a tank on a higher level. Under the action of the agitators the lighter earthy matter is kept afloat, while the heavier amalgam sinks to the bottom, and from time to time the former is allowed to flow out into a second similar apparatus, where it is subjected to a second washing, and then allowed to run away. An entire torta of amalgamated ore may thus be passed through one vat in twelve hours.

The liquid amalgam obtained in this manner is then strained through a leathern bag, the bottom of which is formed of strong canvass or thick flannel. The uncombined mercury is thus squeezed out, carrying along with it a small quantity of silver, which is not lost, as the same mercury is employed in the next amalgamating operation, while there remains in the bag a mass of semi-solid amalgam, which is submitted to distillation to obtain the silver. For this purpose it is moulded into wedge-shaped masses, each about thirty pounds in weight, which are arranged in a circle in what is called the *burning house*, to the number of eleven, on a solid plate of cast-iron having a hole in its centre. Over this row of wedges several others are built, and the whole pile is covered with a large iron bell called a *capellina*, which is lowered down upon it by means of pulleys, and carefully luted at the bottom to the iron plate with a mixture of ashes, crude salt, and lama. A loose wall of fire-bricks is then built round the capellina, leaving an interval about a foot in width, which is kept filled with burning charcoal all night; and after the heat has been applied about twenty hours the bricks and ashes are removed and the capellina hoisted up. The silver is then found in a solid mass, the mercury having passed off in vapor through a pipe fixed to the opening or hole in the ground plate, by which it is conveyed into a cistern filled with water, and there almost all condensed. The silver, which remains on the plate in solid pieces, is weighed, and is then usually remelted in reverberatory furnaces, and cast into ingots or bars, each about eighty or ninety pounds in weight. Latterly, at some establishments cylindrical retorts of cast-iron have been introduced for distilling the amalgam. The loss in mercury is usually about one and a half per cent. of the weight of silver obtained.

The rationale of the process of amalgamation, as above described, may be explained as follows:—In America the silver exists in the ores, partly in the native state, partly as a chloride, and partly as a simple or multiple sulphide. The copper pyrites which is added reacts on the chloride of sodium employed, producing sulphate of soda and bichloride of copper; the latter acts as an energetic chloridizing agent on the sulphide of silver in the ore, which it changes into chloride of silver, passing at the same time itself into the state of protochloride. The chloride of silver is in its turn reduced by a part of the mercury added, forming with that part protochloride of mercury, and with the other an amalgam of silver. It is the protochloride of mercury so formed that is carried away by the waters in the process of washing, and constitutes almost the whole of the loss in mercury. The

chloride employed serves not only to transform the sulphate of copper into deutochloride, but likewise to dissolve the chloride of silver, and thus to facilitate considerably its reduction by the mercury.

On an average the American ores are very poor, and do not contain more than 0.00150 to 0.00160 of silver. It is their immense quantity, and not their superior richness, that explains the large production of the silver mines of America. The most celebrated are those of Pasco, Cerro de Bambon, Chota, and Huantajaya in Peru; Zaccatecas, Guanaxuato, Valenciana, and Veta-grande in Mexico. Pasco produces annually one hundred thousand to one hundred and fifty thousand pounds of silver; Huantajaya fifty thousand pounds; Zaccatecas three hundred thousand pounds; Guanaxuato two hundred thousand pounds; Valenciana one hundred and fifty thousand pounds. It is estimated that five-sevenths of the silver produced in America is obtained by amalgamation, and only two-sevenths by smelting the ores.

Saxon Process by Amalgamation.—It was only at the end of the last century that the method of treating silver ores by amalgamation was introduced into Europe. Here the circumstances are different to those in Mexico and Peru; fuel is cheaper, mechanical moving power is abundant; manual labor is more expensive; it is therefore important to replace the latter as far as possible by the former two, and this principle will explain the chief points in which the European process differs from the American. These points of difference will appear from the following account of the method by amalgamation, which is practised at the Halsbrücke works, near Freiberg, in Saxony, the most complete establishment of the kind in Europe.

In these works no ores which contain more than seven per cent. of lead, or ore of copper, are submitted to amalgamation, because beyond that point the lead entering into the amalgam would render it very impure, while making the operation itself more difficult, and the copper would be entirely lost. The most usual constituents of the ores are sulphur, silver, antimonial silver, bismuth, sulphides of arsenic, of copper, iron, lead, zinc, *et cetera*, with several earthy minerals. Ores of different qualities are sorted together in such a way that the mixture may contain an average of about four ounces of silver per one hundred pounds of ore. It is necessary, also, that they shall contain a certain proportion of sulphur, to decompose sufficient chloride of sodium in the roasting to cause as much chlorine to be disengaged as shall convert the whole of the silver into a chloride. Accordingly, ores poor in sulphur are mixed with those that are richer, and generally about thirty per cent. of iron pyrites is added. When the whole has been well pulverized in a stamping mill, about one-tenth of its weight of salt is added, and the mixture is then roasted in a reverberatory furnace, the floor of which is elliptical, and is about six feet in length by eight in breadth; the height of the vault in the centre is about eighteen inches. The furnace is charged with three and a half to four hundredweights of the prepared ground ore, which is first dried at a low heat with incessant turning over; the fire is then gradually raised. At first vapor of water is disengaged, then

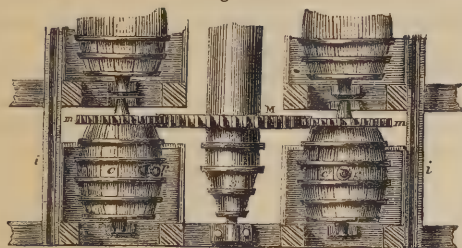
dense white fumes of arsenious acid and oxide of antimony, which deposit themselves in the condensing chambers above; after this the ignition of the iron pyrites becomes obvious by the appearance of a bluish flame and a strong odor of sulphurous acid. When this smell has passed away the chlorination is commenced by raising the temperature to a bright red, and maintaining it at that point till no more gas is disengaged; this requires about three-quarters of an hour, so that a charge is passed through the furnace every four hours. During the first part of the operation, or the roasting properly so called, the arsenic and antimony are separated, and the sulphides of iron and copper are converted into a basic sulphate of sesquioxide of iron and subsulphate of copper. These sulphates, in the second part of the process, or the chlorination, react in their turn on the chloride of sodium, producing sulphate of soda, protochlorides of iron and copper, and chlorine, which combines in the nascent state with the silver contained in the ore, thereby converting it into a chloride. Here it is the chloride of iron which principally acts as the chloridizing agent, whereas in the American process it is the chloride of copper. At the Halsbrücke works there are fourteen roasting furnaces, in each of which about five tons of ore are operated upon weekly; and the condensing chambers or soot vaults yield in the aggregate, during the same time, from four to five tons of ore-dust, containing about sixteen pounds, or 0.00125 to 0.00150 of silver. This dust is treated separately in the same manner as the crude or unroasted ore. The fuel of the first fire is pit-coal; of the finishing one fir-wood. Of the former one hundred and fifteen cubic feet, and of the latter two hundred and ninety, are upon an average consumed for every five tons of ore. The service of a roasting furnace requires two workmen per twenty-four hours of work.

The roasted ore is thrown on a grating inclined at an angle of 45°, and having sixteen apertures to the square inch. That which passes through falls on a sieve or riddle about eight feet long by eighteen inches in width; it is inclined at an angle of 6°, and, in the upper part, has eighty apertures to the square inch, but only fifty in the lower. Three degrees of fineness are thus obtained—the *coarse*, which remains on the grating and the riddle; the *fine*, which passes through the upper part of the riddle; and the *middling*, which passes to the lower part. On the average the proportions obtained are twenty-nine parts of fine, one of middling, and one and a half of coarse or large grains. The latter is broken with a hand-hammer; it is then crushed, along with the middling size, under granite millstones, and afterwards subjected to a second roasting with two per cent. of chloride of sodium; but in this case the operation lasts only two hours instead of four as formerly. The fine is ground in a dry state between granite millstones. The top stones or runners make one hundred and twenty to one hundred and forty turns per minute; they are radiated like those of meal mills; the grooves have a depth of about one-fifth of an inch, and require to be dressed or renewed every three or four days. When they are first put up they are about two and a half feet in diameter, with a thick-

ness of about twenty inches; and when this thickness is reduced one-half, they are used for the lower or bed stones. It is estimated that from two to three horsepower is required for each mill. There are in all ten pair of stones, and each of them grinds per hour from one hundred to one hundred and fifty pounds of roasted ore, besides which there remains on the bolter twelve to fifteen per cent. of coarse material, which must be passed a second time between the stones. The service of two pair of stones requires two workmen per twenty-four hours of work.

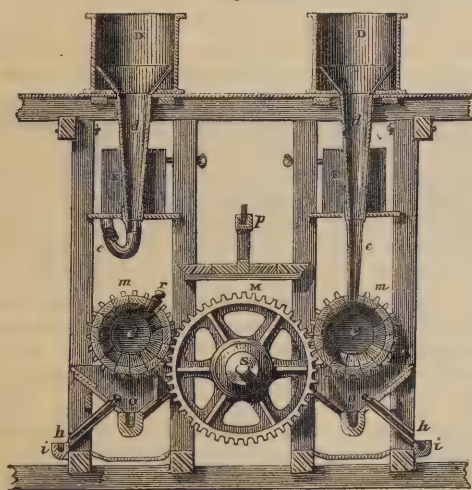
The amalgamation is performed in casks firmly hooped with iron, and each about two feet ten inches

Fig. 488.



long by two feet eight inches in internal diameter. There are twenty of them, arranged in four rows, and turning on horizontal axes. Figs. 488 and 489 will give an idea of this arrangement. Attached to the end of each cask, *c, c*, is a toothed wheel, *m m*, which engages another toothed wheel, *M*, mounted on a shaft,

Fig. 489.



s, which is driven by water-power. Each of the casks has an opening, *r r*, about four inches in diameter, and securely closed by an iron or wooden screw stopple during the amalgamation. The roasted ore is charged into hoppers, *D, D*, which are prolonged downwards by conical tubes, *d, d*, and leather hose, *e e*. The latter are introduced, during the charging of the casks, into the openings, *r r*, and then turned upward as one of them is shown in the figure. Above each cask is a vessel, *E*, for containing the exact amount of water

required for each charge, and these are also fitted with flexible tubes and stopcocks for allowing the water to pass as required. The bearings of the wheels, *m m*, mounted at one end of each of the barrels, and through which they receive their movement from the wheel, *M*, are supported on slides which move to and fro upon the bars, *f*, and the wheels can therefore be disengaged at pleasure. The charge is commenced by introducing into the barrels the water from the vessels, *E*, each of which contains thirty-three gallons, and the whole of this is transferred into the barrels; the roasted ore, to the amount of ten hundred-weights for each, is then introduced, and lastly there is added from eighty to one hundred pounds of iron in pieces about one and a half inch square by three-eighths thick. The stopples are then screwed in, and the casks are thrown into gear, and made to revolve slowly for about an hour and a half at the rate of fourteen to fifteen turns in the minute. During this stage, the chloride of silver dissolved in the alkaline chloride is decomposed by the fragments of iron, producing chloride of iron and metallic silver. It is very important that the roasting should have been carried far enough to decompose all the chloride of copper; for if not so, the latter would be equally reduced by the iron to the metallic state, and would subsequently pass into the amalgam, rendering it very impure. At the end of an hour and a half the barrels are stopped, and five hundred and fifty pounds of mercury introduced into each, by means of pipes connected with the tube *g*, which communicates with a large graduated iron reservoir. The barrels are then put in motion again, with a speed of twenty to twenty-two revolutions per minute, and this is continued for nineteen hours without intermission, except for a short period at the end of every four hours to examine whether the paste has the proper consistence, and to judge of the progress of the operation. The reaction is facilitated by the elevation of temperature which is observable in the contents of the barrels, and which is greater in proportion as the velocity of rotation is more considerable. The higher the temperature the more completely will the residues be exhausted, but the greater will be the loss, in the subsequent washings, of very minutely-divided mercury, which it will then be impossible to recover. There is therefore a proper medium, which has been determined by experience to correspond to about 90°.

The amalgamation being now considered as terminated, the barrels are nearly filled with water, and are made to revolve during two hours with a speed of eight or nine turns per minute, to collect the amalgam. The motion is then stopped, and the process of discharging them is proceeded with. For this purpose the conical bungs, by which they were hermetically sealed during the amalgamation, are removed, and a leathern tube fitted with an iron stopcock is inserted into each aperture; the barrels are then reversed, so that the apertures are turned downward, and the amalgam is made to fall along the sluice, *h*, into the gutter, *i*, which conducts it to a general reservoir. The barrels are then turned up to adjust to them hollow stoppers fitted with wire-grating; and in reversing them again the slimy residue falls into the canal, *o*, which

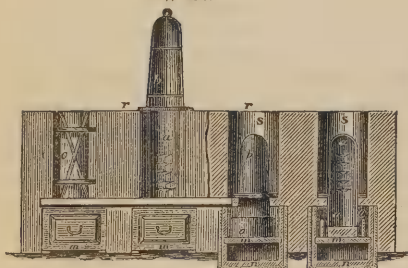
conducts them to the washing vats, while the pieces of iron retained by the grating remain in the barrels. Altogether each operation lasts twenty-four hours. About two pounds of iron are consumed in each barrel at one operation, and about thirty pounds are added every fifteen days.

The amalgam obtained is strained by hand labor through a flannel bag of a conical form; the mercury which passes through contains at the utmost 0.00004 of silver, and is passed back into the amalgamation barrels. The solid amalgam, which remains in the bag, contains, according to KERSTEN'S analysis:—

Mercury, ..	84.20
Silver,	11.00
Copper,	3.50
Antimony, zinc, and lead,	1.00
Sulphur,	traces.
Loss,	0.30
	100.00

Distilling the Amalgam.—The mercury is separated from the silver by distillation. For this purpose the amalgam is placed in flat iron dishes, under a bell-apparatus. Fig. 490 represents the four bells employed at the Halsbrücké establishment; *m, m, m, m* are wooden drawers, sliding in grooves upon the bases *q q*; and each of which contains an open box or basin, *o o*, of cast-iron. In these basins are placed vertical iron rods, *a a*, resembling candelabra, resting upon three

Fig. 490.



feet, and each supporting five flat iron dishes, formed with holes in the centre, whereby they are fitted upon the iron rods, three inches apart, each plate being successively larger than the one above it. About sixty pounds of amalgam are put into each dish, and the whole is covered with a cast-iron bell, *b b*, which is raised and lowered by means of pulleys. When the bells have been let down into their place, the aperture through which they descend is covered with an iron plate, *r*, and the open space, *s s*, which forms the stove, is closed in front with a door, *c*, the edges of which are carefully luted. The boxes, *m*, and basins, *o*, are filled with water, which must be continually renewed through pipes in the sides of the boxes, so that the iron basins may always be kept partially immersed, and as cool as possible. The fuel is then placed in the vacant spaces, *s s*, round the upper part of the bells; and the doors, *c*, being closed and luted, the fire is fed gradually, first with turf and then with charcoal, in such way that it does not attain its maximum heat until about eight hours have elapsed, after which the fire is allowed to decline gradually. The

management of the fire is a point of the greatest importance, and requires the most careful attention, for if the temperature be not raised very cautiously, there is much risk of the bell breaking, and also of a part of the silver being carried over mechanically by the mercury in volatilizing; on the other hand, if the temperature be not sufficiently elevated, there will remain in the silver a greater or less amount of the mercury, which will be completely lost in the refining.

Each distilling operation lasts twelve hours, and the product is about forty-five pounds of plate or *teller* silver from each bell. The teller silver contains only about seventy-five per cent. of fine silver, the remainder being chiefly copper; it is melted in an open iron crucible, and cast into ingots—a process by which some of the impurities are removed, and the ingots contain about eighty per cent. of fine silver.

The earthy residuum of the twenty barrels in which the amalgamation was performed is run into five circular tanks, each about five feet in depth, with a diameter of five feet at the top and three at the bottom; these are filled up with water, and in the side of each there are four orifices, arranged one over the other, at a distance of about five inches from each other. In the middle of each tank is a vertical axis, carrying horizontal arms, which are made to revolve during twenty to twenty-two hours at the rate of twelve to fourteen turns per minute; and while this agitating process is going on, the supernatant liquid, containing the lighter earthy impurities, is allowed to flow out, twice by the highest orifice, twice by the second, and once by the third or lowest, taking care to fill up the tanks with water after each partial discharge. The amalgam itself is drawn out by the lowest orifice only once a-week; it is very impure, and after being fused yields an alloy which contains only twenty-five to sixty-five per cent. of fine silver. This product might be refined by fusing it with a little saltpetre and borax, but it is sent by preference to the Mint, where it is alloyed with the fine silver which is obtained from the cupellation of lead. The amount of the residues, which are finally rejected as useless, rises to eighty per cent. of the weight of the crude ore, and their contents in fine silver varies from 0.00008 to 0.00016. The waters which proceed from the washing of the amalgamation barrels are purified by deposition, and then concentrated and crystallized in leaden pans; the product is a quantity of impure sulphate of soda, which is februated by a second crystallization. The mother-water, or that portion of the liquid which refuses to crystallize, is concentrated by milk of lime; and the product thus obtained, which is termed in German *dünge salz*, is employed in the country with much advantage as a manure; it is composed, according to M. LAMPADIUS, of—

Hydrated gypsum,	68.7
Chloride of sodium,	7.4
Carbonate of potassa,	5.3
Hydrates of manganese and iron,	12.9
Clay, sand, and loss,	5.7
	100.0

The total loss in silver varies from five to nine per cent. of the quantity contained in the ore; the loss in

The following table exhibits the effect of PATTISON'S process on one thousand parts of workable lead containing different proportions of silver:—

Workable lead submitted to one crystallization.		Rich lead.		Lead middling rich, to be recrystallized with the workable lead.	Poor lead.		Proportion between the content in silver of the rich lead and that of the poor lead.
Weight.	Content in silver.	Weight.	Content in silver.	Weight.	Weight.	Content in silver.	
1000	0.001606	136	0.003800	125	739	0.001200	3.17
1000	0.001230	136	0.003203	125	739	0.000862	3.70
1000	0.000862	162	0.002150	125	713	0.000568	3.78
1000	0.000598	169	0.001606	125	706	0.000357	4.49
1000	0.000568	169	0.001454	125	693	0.000341	4.26
1000	0.000341	234	0.000814	125	641	0.000170	4.80
1000	0.000234	250	0.000598	125	625	0.000088	6.79
1000	0.000088	259	0.000218	125	616	0.000033	6.61
1000	0.000030	100	0.000130	125	650	0.000020	6.50

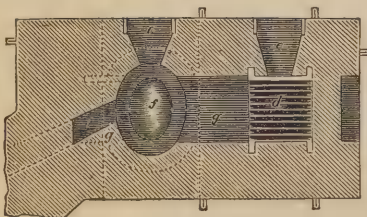
It will be seen that the concentration of the silver by this process is all the more complete, in proportion as the lead subjected to the operation is poorer in that precious metal; hence, it is particularly applicable to the leads of England and Spain, but not to rich leads. Neither can it be applied with advantage to leads which are both poor and impure, because by cupellation the advantage is gained of separating the impurities in the abstrichs, so that litharges are obtained which are commercially valuable in themselves, or which, if subjected to reduction, yield a lead of superior quality.

The silver obtained from the cupelling furnace represented in Figs. 492 and 493, as well as the rich lead concentrated by PATTISON'S process, still requires further purification, and for this purpose it is subjected in both cases to cupellation on a small scale, with a cupel or test made of bone-ash. Figs. 494 and 495

Fig. 494.



Fig. 495.



represent the refining furnace employed for this purpose at Friedrichshütte; *c* is the fire-door; *d* the grate; *e*, door for charging the rich lead into the cupel; *f*, elliptical cupel of bone-ash, the longer axis of which is about sixteen inches, and the smaller axis ten inches; this cupel is movable, and rests upon two iron bars, *g g*, over which are tiles, *h h*, for adjusting the surface

of the cupel at any desired level; *i*, flue leading to a chimney about eighteen feet in height. About one hundred and ten to one hundred and thirty pounds of rich lead or impure silver constitute one charge of the cupel; and the silver obtained from a previous cupellation on the large scale, yields about ninety-four per cent. of fine silver.

III. ORES OF COPPER AND SILVER.—In smelting argentiferous copper ores, the principal object in view is to obtain the baser metal in that state in which it is termed *black copper*; and when this metal contains not less than 0.003 of silver it is deemed sufficiently rich to be submitted to the process of liquation or sweating. This process has been briefly described in the article COPPER, Vol. I., pages 522 and 523; but some additional details will now be necessary. In the first place, the black copper is fused with a certain quantity of poor lead, and the alloy so formed is cast into cakes or discs; these are then submitted to a carefully graduated heat, which causes the lead to melt or sweat out, carrying along with it the greater portion of the silver, which has a stronger affinity for that metal than for the copper. This is the process termed liquation or eliquation. It has been found by experience that, with a view to diminish as much as possible the loss in copper and in lead, the most suitable proportion between the quantities of lead and copper in the prepared discs, is that of eleven parts of the former metal to three of the latter; and that, to extract the silver sufficiently, it is necessary to employ at least four hundred and eighty parts of lead for one part of silver contained in the black copper.

When the black copper is only slightly argentiferous, the poor lead, which has served for a first liquation, is not sufficiently rich to bear advantageously the expenses of cupellation; in that case it is used a second time for extracting the silver from a fresh quantity of black copper. By this means the content of silver in the alloy is nearly doubled, and then it is suitable for being submitted to cupellation.

Lastly, when the black copper is very rich, the process is commenced by subjecting it to a first liquation with workable lead, the products of which are a rich lead for cupelling, and a middling rich black copper; the latter is then submitted to a second liquation with poor lead, which yields cupreous residues very poor in silver, to be treated for rosette copper, and moderately

rich workable lead, which is passed back into the rich liquation process.

The content in silver of the black argentiferous coppers of Mansfeld, which are treated at the liquation works of Hettstœdt, where both the lead and fuel are very high in price, averages 0·00520. The fusing and casting of the liquation discs is performed in a cupola furnace. Each campaign lasts thirty hours, during which time two hundred discs are cast, each weighing about three hundred and eighty pounds, and measuring about two feet in diameter by three inches in thickness. For one thousand pounds of black copper, the proportion of poor lead added is four thousand four hundred pounds. The liquation furnace, with the discs arranged in their place, is represented in Figs. 333 and 334, Vol. I., at the pages above referred to. When the lead, carrying most of the silver along with it, has been melted out, the deformed discs which remain are termed *carcas*. When the heat has been well regulated, all the lead which separates by liquation contains a uniform admixture of copper to the amount of between two and three per cent.

The *carcas*—German, *kienstœcke*—still contain twenty-five per cent. of lead, and, to free them from this, they are subjected to a new liquation, which is termed in French, *ressuage*; German, *darren*. For this purpose the *carcas* are accumulated to the extent of fifteen to twenty thousand pounds weight, in a vaulted chamber, on a series of low parallel walls, between which a wood fire is kept up. In the walls of the chamber are a number of draught holes communicating with a chimney. In front this oven is closed by an iron door lined with clay, but leaving an opening at the bottom for the purpose of introducing the fuel and allowing air to enter. A red heat is kept up during fourteen to fifteen hours; the lead which was still retained by the *carcas* soon begins to run, and becomes in great part oxidised. It falls into the galleries in the middle of the fuel, which have a gentle slope, so that both the lead and its oxide, more or less charged with copper, flow into a basin of water which is placed on the floor of a chamber in front of the oven. The fire is allowed to go out when the scoriæ assume a strong red tinge, which denotes the presence of copper. The residues, which are termed *torrefied carcas*, are then withdrawn, while still at a red heat, and thrown into water to separate the scaly crust of oxide with which they are covered, and which is afterwards separated more completely by means of a pointed hammer. As a general rule, one hundred pounds of *carcas* yield sixty to eighty pounds of torrefied *carcas*, and twenty-five to forty of scoriæ and oxidised debris.

The torrefied *carcas* are refined for rosette copper; they still contain ten per cent. of lead, and yield seventy to seventy-five per cent. of rosette copper.

The scoriæ and refuse of all the preceding operations are fused with the litharges and the residues from the cupellation of the workable lead obtained in the process of liquation; the product is a cupreous lead, which is cast into cakes or discs, and these in their turn are subjected to the series of operations which have just been described. The lead proceeding from the new liquation is, however, poor in silver, and is therefore enriched

by using it for the liquation of the black copper before passing it into the cupel.

In this series of operations, there is lost about ten to twelve per cent. of the lead employed, that is to say, forty to fifty per cent. of the weight of the black copper, or at least sixty to eighty pounds for every pound of cupel silver obtained. The loss in silver usually exceeds twenty-five per cent., regarding that silver as lost which remains in the copper. The loss in copper is five to six per cent. The *carcas* are very difficult to refine, and never yield copper of the first quality.

These results show how imperfect is this method; and hence, in the great metallurgical centres, the method now preferred is to separate the silver from the copper, either by the amalgamation of the matts or by that of the black copper. These operations are effected in a manner analogous to the Saxon amalgamation process, which has been already described, so that it will be only necessary to indicate briefly the special circumstances resulting from the nature of the materials submitted to the operation.

The amalgamation of the argentiferous black copper is practised at Schmölnitz in Hungary; it contains 0·0040 of silver. The principal difficulty to be overcome is the pulverization of the black copper: to effect this, it is heated to redness on the sole of a reverberatory furnace, and at this temperature it is placed under the pestles of a stamping machine. The matter thus crushed and broken is passed through a sieve; the finer portion is ground to a flour under iron mill-stones, the coarse is reheated and passed again under the stampers. The reduction of the chloride of silver is performed by means of copper balls, so as not to precipitate the copper from the chloride and thus render the amalgam impure, but then the loss in mercury is considerable; in certain cases it would be advantageous to saturate the liquor with lime, and to replace the copper balls by iron, which would diminish the loss in mercury. The residues of the amalgamation are remelted for black copper; their content in silver does not exceed 0·00008, and the loss in that metal is only five per cent.; the loss in mercury is 2·5 lbs per thousand lbs of black copper, or from 0·30 to 0·35 of the weight of the silver. The expenses of amalgamation do not rise to one-fourth part of those attending liquation, and the copper obtained from the smelting of the residues is of superior quality.

The amalgamation of the argentiferous matts of copper is practised at Mansfeld. The matt subjected to amalgamation at that establishment contains about fifty per cent. of copper, and 0·0025 of silver. After pulverizing the matt, it is submitted in a reverberatory furnace to a preparatory roasting, to expel the excess of sulphur; it is afterwards reduced to a thin paste with a dilute solution of sea-salt and twelve per cent. of slacked lime, which serves to saturate the sulphuric acid. The paste thus obtained is dried, ground, then roasted a second time; this is, properly speaking, the chloridation. The reduction of the chloride of silver is effected by means of iron. The residues of amalgamation are mixed, still in a moist state, with twelve to thirteen per cent. of clay, and moulded into small bricks, which are dried in a kiln, and reduced in a

furnace to black copper by adding, to form the smelting bed, twelve to thirteen per cent. of quartz, 1.5 to 2.5 per cent. of fluor spar, and thirty-two to forty per cent. of the slag from the smelting of the crude ore. The loss is eleven to twelve per cent. of the silver contained in the matts, about three-fourths of this amount remaining in the black copper, which contains 0.00046; the loss in mercury is 0.8 of a pound per thousand pounds of matt, or 1.6 pounds per thousand pounds of black copper, that is to say, about 0.35 of the weight of the silver extracted. The loss in copper is less than by liquation, and the metal is of excellent quality.

Instead of employing the different processes which have just been described, the ores of argentiferous copper might be treated in the humid way, in a manner analogous to that which is practised at Linz on the banks of the Rhine, and at Stadtberg in Westphalia, for the treatment of carbonated copper ores too poor to be treated by the ordinary processes. This method consists in treating these ores with sulphuric acid. It is impossible to submit to the direct action of this acid either calcareous or pyritous ores—the former, because a sulphate of lime would be formed which would cover or surround the copper with a paste, so as to be acted upon with difficulty; the latter, because it would scarcely dissolve in the acid. It would be necessary therefore, in these cases, to separate the gangues by smelting the crude ores, which would give them in the form of matts; and these might be roasted with a small quantity of saltpetre in furnaces, or retorts embedded in masonry, and supplied with an artificial blast. A little small wood would be sufficient to commence the heating, as the combustion of the sulphur would afterwards develop the heat necessary for the roasting. The gases proceeding from the retorts should be made to arrive, along with a current of steam produced by a separate boiler, under and around cases filled with roasted and pulverized matts; by the reaction of the steam and the gases from the retorts, sulphuric acid would be formed, which would dissolve the roasted matts; the latter might be exposed beforehand, in heaps, to the simultaneous action of the atmospheric agents and water, to transform the undecomposed sulphides into soluble sulphates, which might be removed by washing. In like manner, if the roasting of the matts did not furnish a sufficient quantity of sulphuric acid, an additional quantity might be procured by subjecting iron pyrites to the same process. A liquor would thus be obtained, containing the iron, copper, and silver of the matts; and of these the silver might be precipitated at once by metallic copper, then the copper by iron. It might be desirable, for the purpose of diminishing the consumption of copper, to almost neutralize the liquor in the first place by means of lime, and then to separate the sulphate of lime by decantation, which would be attended with no other inconvenience than impairing a little the purity of the precipitates. The silver precipitate might be purified by fusing it with a little nitre and borax; the copper could be refined for rosette copper; and lastly, the sulphate of iron, or green vitriol, might be crystallized for the market, or if dried and then slightly torrefied, it might be used for the manufacture of fuming sulphuric acid.

As regards the argentiferous black copper, it might be dissolved directly in the sulphuric acid, and the silver afterwards precipitated by metallic copper, as is practised in the mints.

IV. ORES OF LEAD, COPPER, AND SILVER.—The treatment of these ores is perhaps the most complex metallurgical operation that exists, and therefore it will be necessary to enter into some detail on the subject. Ores containing lead, copper, and silver, are divided into two great classes, according as the lead or the copper predominates. In the former case they are treated as lead ores; and, besides the workable lead, matts are obtained containing silver, copper, and lead, which are subjected to repeated fusions with substances containing more lead. Each fusion gives workable lead, which is cupelled, and the last matts are melted by themselves for black copper, which is afterwards submitted to liquation or amalgamation, to separate the silver which it still contains.

The ores which contain only a small quantity of lead are carefully assorted, and divided into at least two classes, the rich and the poor ores. The latter, according to their nature, are submitted to a *crude smelting*, with or without the addition of pyrites either crude or partially roasted, serving in the latter case as a flux, or using other fluxes if necessary, exactly as in the treatment of copper ores. The earthy gangues are thus separated, and poor matts are obtained, which are roasted once or oftener, and are then concentrated by fusion along with additional ores of the same richness. The products of this operation are scoriæ which are passed back into the crude smelting, and *rich matts*. These matts, after several roastings, are fused with plumbiferous substances and ores rich in silver, especially such as contain lead. The products are workable lead, which is cupelled, and matts which are subjected to a new fusion with plumbiferous matters; lastly, cupreous matts are obtained, yielding argentiferous black copper, which is treated in the manner already described. The fusion of the matts along with lead should be performed at a lower temperature than the crude smelting, in order to diminish as much as possible the loss in lead; this is the process followed at Freiberg in Saxony.

Where substances containing lead are rare or difficult to procure, the fusion of the matts with that metal is replaced by a *fusion of concentration*, and the silver is separated from the new matts by *imbibition*. For this purpose the poor lead is melted separately a little before the tapping of the matt, and is stirred with a fire-iron at the instant when the matts flow into the crucible; the lead then decomposes a part of the sulphide of silver, and passes into the matt, while the reduced silver combines with the rest of the lead and produces workable lead. If this workable lead be not sufficiently rich for cupellation, it serves anew for what is called a rich imbibition; this process constitutes the old Hungarian method. The new matt is treated over again in the same manner, and finally cupreous matts are obtained, which are fused by themselves, and yield argentiferous black copper.

Fig. 496 exhibits in plan, and Fig. 497 in vertical section, following the line A B, the Frankenscharn

works, near Clausthal in the Hartz, for the treatment of argentiferous and cupreous galenas; *a, b, c, d,*

Fig. 496.



e, f, g, denote furnaces for smelting the ores; *h,* low furnaces like the English slag-hearths for working the last matts; *k,* slag-hearths for reducing the litharge; *m,* the liquation area; *n, p,* cupellation furnaces; *xy,* a floor on which the materials for charging the furnaces

Fig. 497.



are deposited and prepared; *c,* the stamping apparatus; *D,* stream of water which impels the machinery.

Eight parts of ore in the rough state, as taken from the mine, yield one part of schlich, fit for smelting; the content of the schlich in lead is sixty to seventy per cent.; the gangue is quartzose and argillaceous. From ten to twelve thousand pounds of schlich are smelted every twenty-four hours. The furnace is attended by relays of three workmen, and a campaign lasts nine or ten weeks. The products are workable lead, which is cupelled, and matts which contain 0.001 of silver and 0.34 to 0.40 of lead. The last matts obtained are roasted several times, and are then smelted, yielding argentiferous black copper, which is submitted to liquation.

COMBINATIONS OF SILVER.—There are three oxides of silver—a suboxide, a protoxide, and a binoxide. Of these the protoxide alone forms permanent and definite saline combinations.

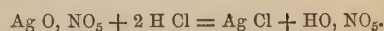
The *Suboxide of Silver*— Ag_2O —was first obtained by FARADAY, by exposing an ammoniacal solution of the protoxide to the action of air. It separates in the form of a black film.

Protoxide of Silver— AgO —is obtained by adding solution of caustic potassa, or lime, or baryta-water, to the solution of nitrate of silver. The precipitate, when washed, is of a brownish-grey color, anhydrous, tasteless, but soluble, according to GRAHAM, to a small extent in pure water, free from saline matter, and has, when in solution, an alkaline reaction. It is completely reduced to the metallic state by the action of a red heat, or even by the prolonged action of the solar light. In the latter case, however, the black powder which results is possibly the suboxide. By digesting it with caustic ammonia it forms an extremely detonating compound, known as *fulminating silver*, and which, according to GAY-LUSSAC and SERULLAS, is probably an azotide of

silver. This compound, which must not be confounded with the *fulminate of silver*—to be described presently—has hitherto received no application, on account of the extreme danger which attends its preparation and management. It sometimes explodes even while still wet, and should, therefore, be prepared only in small quantities, and handled with the greatest possible caution.

Peroxide of Silver— AgO_2 —was obtained by RITTER by electrifying a weak solution of silver. It deposits in acicular crystals at the positive pole, but is readily converted into the protoxide, and is of no use in the arts.

Chloride of Silver—*horn-silver*— AgCl —is procured by adding a solution of chlorine, of hydrochloric acid, or of chloride of sodium, to nitrate of silver, or to any of the soluble salts of silver, with the exception of the hyposulphite. Thus—



It falls in the form of a curdy precipitate of a white color, but which, by exposure to light, becomes purplish-brown, and ultimately black. In sunshine the change is extremely rapid, more especially if any organic matter be present. It is perfectly insoluble in water, so that the minutest portion of hydrochloric acid, or of a chloride in solution, may be detected by adding to the liquid a drop or two of nitrate of silver. It is sparingly dissolved by concentrated hydrochloric acid, and thrown down upon dilution. It is insoluble in nitric acid and in cold sulphuric acid; but, when boiled in sulphuric acid, it is slowly decomposed. When dry chloride of silver is heated to dull redness in a silver crucible, it fuses, and on cooling concretes into a grey semitransparent substance, which is known as *horn silver*, or *luna cornea*. The presence of moisture is necessary to the blackening effect of light upon the chloride, as when dried in the dark and subsequently exposed to light under an inverted glass over sulphuric acid, no discoloration is produced.

Iodide of Silver— AgI —is precipitated upon adding hydriodic acid, or a soluble iodide, to a solution of nitrate of silver. It is of a dingy yellow color, insoluble in water, and decomposed when heated with potassa. Like the chloride, it is discolored by light, and hence its use in DAGUERRE'S photographic process—the plate of silvered copper intended to receive the image in the camera being prepared by exposing it in a box containing iodine. The iodide is distinguished from the chloride, not only by its yellow color, but also by its being insoluble in ammonia, which constitutes its special characteristic.

Bromide of Silver— AgBr —is an insoluble yellowish substance, formed in the same manner as the iodide, and having analogous properties.

Nitrate of Silver— AgO NO_3 —constitutes the most important salt of this metal. It is obtained by dissolving silver in nitric acid diluted with three parts of water; nitric oxide is disengaged, and if the silver contain copper, the solution will have a bluish tinge; if gold, that metal will remain undissolved in the form of a black powder. The solution of nitrate of silver should be perfectly clear and colorless. It is caustic, and tinges

animal substances of a deep yellow, which, by exposure to light, becomes a deep purple or black stain. It is the essential ingredient in many of the washes employed for dyeing the hair, and in the composition of the so-called *indelible* inks for marking linen; but in point of fact, cyanide of potassium will remove the black stain produced by any of the preparations of silver. The crystals are colorless, transparent, anhydrous tables, soluble in an equal weight of cold, and in half their weight of boiling water. Alcohol also dissolves about one-fourth of its weight of this salt at its boiling point, but deposits nearly the whole as it cools. When heated in a silver crucible, the nitrate fuses into a grey mass, and, if cast into small cylinders, forms the *lapis infernalis* or *lunar caustic* of the surgeons. Ivory, marble, and several other bodies may be stained black, or even silvered, by soaking them in a solution of nitrate of silver, and fully exposing them to the action of the sun's rays. A plate of copper, introduced into a solution of this salt, occasions a brilliant precipitation of crystalline silver, and the copper is oxidised and dissolved by the acid. The introduction of mercury into the solution causes a beautiful crystalline deposit of silver, known as the *arbor Dianæ*. To obtain this crystallization in its most perfect state, the solution should contain a little mercury; and the mercury put into it should be already combined with one-sixth its weight of silver.

Several recipes for indelible or marking inks, formed with nitrate of silver, are given in Vol. II., page 381.

Fulminate of Silver— 2 Ag O , $\text{Cy}_2 \text{ O}_2$.—This curious and dangerous compound is prepared as follows:—One hundred grains of fused and finely-powdered nitrate of silver are added to an ounce of warm alcohol, and the mixture stirred in a sufficiently large glass basin. An ounce of fuming nitric acid is then added, and presently a violent effervescence ensues, and a powder falls. As soon as this appears white, cold water is added, and the powder is immediately to be collected upon a filter, washed, and carefully dried at a temperature of 100° . In collecting and handling this powder, the utmost caution is requisite. It should be made in small quantities only, and touched with nothing hard; for it has sometimes exploded upon the contact of a glass rod even under water. The feather of a common quill serves to collect it; and it should be kept in a wide-mouthed vessel covered by paper, and by no means in a stoppered or even a corked phial, as serious accidents have arisen from its unexpected explosion. In short, one cannot be too careful in meddling with it, and its use for fulminating balls and other purposes of amusement is highly dangerous. It detonates in the quantity of a grain, or even half a grain, with great violence, when heated or touched by any hard body. The nature of this substance has been investigated by LIEBIG and GAY-LUSSAC, who have shown that it is a compound of two equivalents of oxide of silver with one of fulminic acid.—*Brande*.

Sulphide of Silver— Ag S —may be obtained by heating finely-divided silver, or plates of silver, with sulphur. It is a grey crystallizable compound, considerably more fusible and much softer than silver. It is the presence generally of sulphide of hydrogen which occasions the

tarnish upon silver, and which, though only superficial, is a great obstacle to many applications that might otherwise be made of this valuable metal.

Sulphate of Silver— Ag O , SO_3 —is deposited when sulphate of soda is mixed with nitrate of silver. It is also formed by boiling silver with its weight of sulphuric acid. It forms a white saline mass, easily fusible. Upon the large scale, small portions of gold may be most economically separated from large quantities of silver, by heating the finely-granulated alloy in sulphuric acid. The gold remains in the form of a black powder, and the sulphate of silver may be decomposed by the action of metallic copper. The silver is precipitated in a pulverulent state, and, with a little borax or other vitrifiable flux, is fused, and cast into ingots. The sulphate of copper is obtained in the crystallized state by evaporating the residuary liquid.

Hyposulphite of Silver— Ag O , $\text{S}_2 \text{ O}_2$ —is formed by digesting carbonate of silver in hyposulphurous acid. It crystallizes in permanent prismatic crystals, soluble in two parts of cold water. Hyposulphite of silver is formed by dropping a weak solution of nitrate of silver into a very dilute solution of hyposulphite of soda. A white cloud is at first produced, which redissolves on agitation. On adding more of the precipitant, the cloud reappears, and aggregates into a grey precipitate, which is the hyposulphite. The solubility of argentine compounds in hyposulphites has led to an important application of the latter in photography, for the purpose of fixing the designs by the removal of all adhering or unchanged salt of silver.

Carbonate of Silver is precipitated in the form of a white insoluble powder, by adding carbonate of potassa to nitrate of silver. It blackens by exposure to light, and is easily decomposed by heat. Carbonate of ammonia only throws down a portion of the nitrate, and forms a triple *ammonio-carbonate* of silver.

The other salts of silver are of too little importance to call for special notice.

ALLOYS OF SILVER.—Silver unites difficultly with *iron*. Upon fusing silver with that metal, the alloy separates into silver retaining about one-thirtieth of iron, and iron retaining about one-eightieth of silver. The latter has a peculiar hard and crystalline texture.

When silver and *steel* are fused together, an alloy is formed which appears perfect while in fusion, but globules of silver exude from it in cooling, which shows the weak affinity of the metals. At a very high temperature the greater part of the silver volatilizes; but a portion, equal to about one in five hundred, remains, constituting a perfect alloy known as *silver-steel*, and which is admirably adapted to the formation of cutting instruments.

Lead and silver form a very brittle dull-colored alloy, from which the lead is easily separated by cupellation. When fused lead, containing silver, is suffered to cool slowly, the lead which first concretes forms granular crystals, and is nearly pure, while almost the whole of the silver is contained in the liquid portion. The separation of the two metals in this way constitutes PATTISON'S process.

With *zinc* silver readily combines, producing a brittle bluish-white granular alloy. When a mixture of eleven

of zinc and one of silver is highly heated in an open crucible, it burns, and the whole of the silver is sublimed with the oxide of zinc.

With *tin* silver forms a white, hard, brittle alloy. *Antimony* also forms a brittle white alloy, the density of which exceeds the mean of its components. The greater part of the antimony volatilizes during protracted fusion; and the whole may be separated in the form of oxide by roasting.

Bismuth and silver may be combined by fusion. The alloy is brittle, yellow-white, and lamellar, exceeding in density the mean of the components. The density of an alloy of equal weights of bismuth and silver is 10·7.

Arsenic, fused with silver, forms an alloy composed of 100 silver and 16 arsenic. It is grey, brittle, granular, and by long fusion great part of the arsenic volatilizes. It may be entirely got rid of by roasting.

With *mercury* silver readily amalgamates. When red-hot silver is thrown into heated mercury, it dissolves; and when eight parts of mercury and one of silver are thus combined, a granular crystalline soft amalgam is obtained, the density of which exceeds the mean. When a solution of this amalgam in liquid mercury is squeezed through chamois leather, the excess of mercury, carrying along with it only a small portion of silver, goes through, and the solid amalgam is left behind.

Standard Silver.—The most important alloy of silver is that which it forms with copper. On account of its softness, silver is seldom employed in the pure state; by the addition of a small proportion of copper, it is rendered harder and more sonorous, while the color of the metal is scarcely impaired. A mixture of seven parts of silver and one of copper still retains a decided white color, although of a less pure tint than that exhibited by virgin silver.

The alloy of silver with copper constitutes plate and coin; the proportions are fixed by the legislature of the country in which the mixture is worked. In this country the same alloy is employed both for the purposes of the mint and the uses of the silversmith; it is composed of 11·1 of silver, and 0·9 of copper, and this mixture is known by the name of *standard silver*. A pound troy, therefore, of the standard silver of this country consists of eleven oz., two dwts. pure silver, and eighteen dwts. of copper. Its density is 10·3; its calculated density, according to the mean of the components, 10·5; so that the metals dilate a little on combining.

To prevent fraud, all silver vessels are required to be stamped by the Goldsmiths' Company, who are empowered by government to search all silversmiths' shops, and seize all articles which have not been impressed with the Hall mark of the company. For the assay of the articles, and the impression of the company's stamp, attesting its quality as standard silver, one shilling and sixpence per ounce on the weight of the object is charged. Of this amount the larger proportion is paid over to the government in the form of a tax, whilst a small sum is retained as a compensation for the trouble incurred in making the assay.

In France three different standards are employed.

The alloy used for the silver currency of the country is composed of nine parts of silver, and one of copper; for plate, a mixture of 9·5 parts of silver to 0·5 of copper is employed, whilst for small articles of silver used for ornaments, an alloy of eight parts of silver to two of copper is allowed.—*Phillips*.

The silver coins of the ancients and many Oriental silver coins are nearly pure; they only contain traces of copper and of gold.

When silver alloyed by copper, such as standard silver, is exposed to a red heat in the air, it becomes black from the formation of a superficial film of oxide of copper. This may be removed by immersion in hot diluted sulphuric acid, and a film of pure silver then remains, of a beautiful whiteness; this is called *blanched*, or *dead silver*. It is usual to employ this process in order to improve the color of objects formed of alloyed silver; the article, when heated nearly to redness, is plunged, while still hot, into water acidulated either with nitric or sulphuric acid; the external oxide of copper is thus entirely removed; and the matted appearance of the pure silver, which now forms the surface, soon gives place to a bright polish by rubbing with a burnisher. The blanks for coin are treated in this way before they are struck; whence the whiteness of new coin, and the darker appearance of the projecting portions occasioned by wear, in consequence of the alloy being uncovered. Articles of plate are often deadened or matted by boiling in bisulphate of potassa, which acts in the same way as the dilute sulphuric or nitric acid.

Silver Solder consists of—

Silver,	667
Copper,	233
Zinc,	100

SILVERING.—Almost all kinds of silvering are now usually performed by electro-chemical deposition, and for full details of the process, the reader is referred to the article *ELECTRO-METALLURGY*, Vol. I., page 800, *et sequitur*. When the term *silvering* is applied to mirrors, it generally means the application of a compound of tin and quicksilver, so that, in that sense, the word is misapplied; but, by Mr. DRAYTON's process, described Vol. II., page 227, a coating of actual silver is deposited upon the plate of glass, and in that case, therefore, the term is strictly applicable.

Silver is hammered out into thin leaves in the same manner as gold; and the account of the process given in the article on that metal, Vol. II., page 288, will therefore suffice for both. When silver-leaf is to be applied to the surfaces of bodies, the methods prescribed for gold-leaf, Vol. II., page 290, are also generally suitable. Among the metals, copper or brass are those on which the silverer most commonly operates, and frequently the white alloy of nickel. Iron is seldom silvered, but the process is essentially the same. The principal steps of the operation are summarily described by Dr. URE as follows:—

1. The *smoothing down* the sharp edges, and polishing the surface of the copper, or other metal, to be silvered.

2. The *annealing*, or making the piece to be silvered

red-hot, and then plunging it in very dilute nitric acid, till it be bright and clean.

3. *Pumicing*, or clearing up the surface with pumice-stone and water.

4. The *warming* to such a degree merely as, when it touches water, it may make a hissing sound; in which state it is dipped in very weak aquafortis, whereby it acquires minute insensible asperities, sufficient to retain the silver leaves that are to be applied.

5. The *hatching*.—When these small asperities are inadequate for giving due solidity to the silvering, the plane surfaces must be hatched all over with a graving tool; but the chased surfaces need not be touched.

7. The *charging*, the workman's term for silvering.—This operation consists in placing the silver leaves on the heated piece, and fixing them to its surface by burnishers of steel, of various forms. The workman begins by applying the leaves double. Should any part darken in the heating, it must be cleared up by the scratch-brush.

The silverer always works two pieces at once, so that he may heat the one, while burnishing the other. After applying two silver leaves, he must heat up the piece to the same degree as at first, and he then fixes on with the burnisher four additional leaves of silver; and he goes on *charging* in the same way four or six leaves at a time, till he has applied, one over another, thirty, forty, fifty, or sixty leaves, according to the desired solidity of the silvering. He then burnishes down with great pressure and address, till he has given the surface a uniform silvery aspect.

Silvering by the precipitated Chloride of Silver.—The white curd obtained by adding a solution of common salt to one of nitrate of silver, is to be well washed and dried. One part of this powder is to be mixed with three parts of good pearlash, one of washed whiting, and one and a half of sea-salt. After clearing the surface of the brass, it is to be rubbed with a bit of soft leather, or cork moistened with water, and dipped in the above powder. After the silvering, it should be thoroughly washed with water, dried, and immediately varnished. Some use a mixture of one part of the silver precipitate with ten of cream of tartar, and this mixture also answers very well. Others give a coating of silver by applying with friction, in the moistened state, a mixture of one part of silver-powder precipitated by copper, two parts of cream of tartar, and as much common salt. The piece must be immediately washed in tepid water, very faintly alkalized; then in slightly warm pure water; and, finally, wiped dry before the fire.

The inferior kinds of coated buttons get their silver coating in the following way:—Two ounces of chloride of silver are mixed up with one ounce of corrosive sublimate, three pounds of common salt, and three pounds of sulphate of zinc with water, into a paste. The buttons being cleaned are smeared over with that mixture, and exposed to a moderate degree of heat, which is eventually raised nearly to redness, so as to expel the mercury from the amalgam, formed by the reaction of the horn-silver and the corrosive sublimate. The horn-silver thus acquires a silvery surface, which is brightened by clearing and burnishing.—*Ure*.

ESTIMATION OF SILVER.—The behavior of various reagents with solutions of silver is given in a tabular form in the article on GOLD, Vol. II., page 269, to which the reader is referred. In general, the *soluble* salts of silver are recognized by furnishing a white precipitate with hydrochloric acid and the soluble chlorides, which blackens by exposure to light, and which is readily soluble in ammonia; and by affording metallic silver upon the immersion of a plate of copper. The salts *insoluble in water* are mostly soluble in ammonia; and when heated on charcoal before the blowpipe, they afford a globule of silver. A yellow precipitate on the addition of phosphate of soda and of the soluble arsenites, a red-brown by arseniates, a crimson by the chromates, and white by ferrocyanide of potassium, are further characteristics of the soluble salts of silver.

Tin and lead are the most rapid precipitants of metallic silver from the nitrate; cadmium, zinc, copper, bismuth, and antimony are more slow in their operation, and mercury still more tardy. Chloride of silver is rapidly reduced by most of the metals which form soluble chlorides, such as zinc, iron, cadmium, cobalt, and arsenic. Zinc, copper, and arsenic rapidly reduce the ammoniacal solution of oxide of silver. Of all the metallic precipitants, zinc and cadmium are the most effective; but when zinc or antimony are used, the separated silver contains those metals.

The solubility of silver in nitric acid, and the complete insolubility of its chloride in acid solutions, render the separation of silver from other metals in most instances an easy operation. When its amount is to be estimated quantitatively, the alloy or pulverized ore is dissolved in nitric acid, and the precipitation of the silver in the form of chloride is effected by the addition of a small excess of hydrochloric acid. In order that a dense precipitate may be obtained, the solution should be heated nearly to the boiling-point previous to the addition of the precipitant. When the whole of the chloride has settled at the bottom of the vessel, the supernatant liquor is carefully drawn off by means of a glass siphon; and the chloride, after being well washed by repeated decantations with water slightly acidulated with nitric acid, is transferred to a thin porcelain capsule, the weight of which has been accurately ascertained and noted down. The chloride, when placed in this capsule, is first carefully dried in a water-bath, and then heated over the flame of a gas-burner or spirit-lamp, until it has become fused, when the crucible and its contents are again weighed. The difference between the first and second weighings gives the amount of the chloride, from which that of the silver can be deduced by the simple proportion:—

As 100 : 75.27 :: K, or the weight of chloride obtained; since every 100 parts of the chloride correspond to 75.27 parts of metallic silver.

ASSAY OF THE ALLOYS AND ORES OF SILVER IN THE DRY WAY.—In this process the object sought is to obtain the silver and other metals that may be present in the form of an alloy with lead, which is afterwards passed to the muffle and cupelled in the ordinary way; in the latter, the method adopted is founded upon the simple process which has just been described.

In assaying the ores of silver, the preliminary operations to which the minerals are subjected, and the form of the cupels and other apparatus employed, have been fully described in connection with the analogous processes followed in the assaying of gold ores; and, therefore, it will be quite unnecessary to repeat them in this place. To obtain an alloy with lead, with a view to cupellation, ores of silver, in which the metals that are present exist in the form of reducible oxides, are commonly fused with a mixture of litharge and finely-powdered charcoal. The proportion of litharge employed for this purpose, says PHILLIPS, must be varied according to circumstances, as the resulting button of alloy should not be too rich, since in that case a portion of the silver is lost in the slag; nor too poor, as the cupellation would then occupy a long time, and a loss through sublimation be entailed. In ordinary cases, if four hundred grains of ore be the quantity operated on, a button of two hundred grains will be a very convenient amount for cupellation; and this may be obtained by the addition of three hundred grains of litharge, and from seven to eight grains of finely-powdered charcoal. The whole is to be well mixed with two hundred grains of carbonate of soda, on a sheet of highly-glazed paper, and afterwards introduced into an earthen crucible, of which it should not fill more than two-thirds the capacity. This is now covered with a thin layer of borax, and fused in an ordinary assay furnace—care being taken to withdraw it from the fire as soon as a liquid and perfectly homogeneous slag has been obtained, as the unreduced litharge would otherwise be liable to cut through the pot and spoil the experiment. When it has sufficiently cooled, the crucible is broken, and the button of alloy obtained is passed to the cupel. When other minerals than oxides or carbonate are to be examined, the addition of charcoal, or any similar reducing agent, becomes in many instances unnecessary, as litharge readily attacks all the sulphides, arsenio-sulphides, *et cetera*, and oxidises nearly the whole of their constituents, with the exception of silver, whilst a proportionate quantity of metallic lead is at the same time set free. The slags formed in this way contain the whole of the excess of litharge added; and the button of alloy produced is subjected to cupellation in the usual manner.—*Phillips*.

In the assay of alloys of silver by cupellation, the directions which are given in Vol. II., page 303, in connection with the assaying of gold, render unnecessary a repetition of all the details of the process, which consists, as there stated, in the oxidation of the lead and other oxidisable metals, and their absorption by the cupel. From the circumstance that the plate and silver money of all European nations are alloyed with copper, the mixtures of these metals are those which most frequently engage the attention of the assayer; and the point to be chiefly attended to is the amount of lead necessary to be added to perform the cupellation efficiently. This amount should be greater, in proportion as the quantity of copper is more considerable; but, in cupelling an alloy of silver and copper, the same amount of lead cannot safely be added as in treating an alloy of copper and gold, as the greater volatility of the silver would cause a consider-

able loss of that metal before the whole of the lead could be absorbed. In this case, therefore, the following table, showing according to D'ARCET, the amount of lead necessary to effect the proper cupellation of various alloys of silver and copper, must be substituted for that given at the page above referred to:—

Standard of silver.	Amount of copper alloyed.	Quantity of lead necessary.	Quantity of lead in relation to that of copper.
1000	0	3-10th*	0 to 0
950	50	3	60 to 1
900	100	7	70 to 1
800	200	10	50 to 1
700	300	12	40 to 1
600	400	14	35 to 1
500	500	16 to 17	32 to 1
400	600	16 to 17	27 to 1
300	700	16 to 17	23 to 1
200	800	16 to 17	20 to 1
100	900	16 to 17	18 to 1
Pure copper 1000	1000	16 to 17	16 to 1

* Even with pure silver it is found necessary to add a little lead on the cupel, as the button would not otherwise assume the rounded form which is required.

In this table the numbers in the third column, which express the quantity of lead necessary to be added in each case, are multiples of the weight of alloy on which the operation is performed. Hence, in the third line, for example, in which the alloy consists of 900 of silver, and 100 of copper, for each grain of alloy taken, seven grains of lead will be necessary; and as each grain of alloy contains only one-tenth of its weight in copper, it follows that the ratio of the lead to the copper is as seventy to one. It will be observed that, even with pure silver, it is found necessary to add a little lead on the cupel, the reason of which is, that the button of silver would not otherwise assume the rounded form required. It will be remarked, also, that here, as in the table given for an alloy of gold and copper, the proportion of lead to be employed for a silver alloy below the standard of 500, remains constantly the same.

Although silver is not appreciably volatilized when melted alone, yet it is so to a certain extent in the presence of lead; and therefore the cupellation should be made at the lowest temperature at which the absorption of the litharge can be effected; and even when every precaution is used, there is always a loss of silver in cupellation, for which allowance must be made in finally calculating the per centage. The table adopted for this purpose at the French mint is given in Vol. II., page 304, to which the reader is referred.

When other metals besides lead and silver are present in an alloy, the cupel usually affords indications, from which it is easy to judge of their nature, and roughly of the amount in which they exist. Mr. PHILLIPS, in his excellent manual of metallurgy, gives the following directions for this purpose:—Pure lead stains the cupel a straw-yellow color, sometimes verging on orange. Copper gives a grey or dark-brown tint, according to its quantity. Iron produces a black stain, which is chiefly formed shortly after the commencement of the operation, and gives rise to a dark ring around the sides of the cupel. Zinc leaves a yellowish stain on the cupel, and produces, during the process of cupellation, a luminous white flame and abundant fumes of the same color, which carry off

with them a considerable amount of silver. Tin produces a grey slag, and antimony leaves a spongy yellow scoria, which causes the circumference of the cupel to effloresce and split off. The two last-named metals render the cupellation of the alloys in which they exist extremely difficult, and necessitate the employment of a large quantity of pure lead, in order to carry off the insoluble oxides formed. When assays of alloys containing silver are frequently to be made by cupellation, it will be found extremely convenient to keep in the laboratory a supply of poor lead, ready weighed out into pieces of fifty and one hundred grains; by this means the standard of the lead being previously known, it becomes easy, by merely counting the number of pieces added, to know exactly what deduction is to be made for the silver in the poor lead at the termination of the cupellation.—*Phillips*.

Humid Method of Assay.—The operation is the same as that described above under estimation of silver, except that instead of collecting and weighing the argentiferous compound, graduated test liquors are employed, and the silver estimated from the volume of such solutions required to precipitate the silver completely. Although the method by cupellation was found to be convenient, where a number of assays were required to be conducted at the same time, and was therefore, until of late years, exclusively adopted at the different mints, yet the results obtained by this method not being perfectly accurate, the French Government in 1829 appointed a commission for inquiring into the subject; and GAY-LUSSAC, who was one of the commissioners, proposed the adoption of the liquid method of assay, which is now generally practised, not only at the Parisian mint, but also at the similar establishments of this and other countries. Not only is greater accuracy obtained, but by successive improvements in the apparatus, the humid process is now conducted with greater facility and despatch.

In this process the standard of the alloy of silver and copper is determined by means of a solution of chloride of sodium, the strength of which has been accurately determined beforehand. Common salt, without any preliminary purification, is employed for this purpose; and the strength of the solution is so regulated, that a decilitre thereof will exactly precipitate one gramme of pure silver. In proceeding to make an assay, one gramme of the alloy to be examined is dissolved in five or six grammes of nitric acid, and to this is added from a graduated burette the standard solution of common salt, until no further precipitate of the chloride of silver takes place. When, in adding the precipitant, the point of saturation seems to be nearly attained, the bottle must be well shaken after the addition of each successive drop of the solution, in order that the liquor may become clear by the precipitation of the chloride of silver formed. When the whole of the silver has thus been thrown down, the exact quantity of the solution of chloride of sodium employed in its precipitation is read off from the graduated scale; and, by the amount used, the per centage of silver present is at once indicated.

When great accuracy is required in making the assay of a silver coin or a piece of plate, the composi-

tion of which is approximatively known beforehand, two distinct solutions of chloride of sodium are employed:—The first, which is termed the *normal solution*, is of such a strength that one decilitre will precipitate exactly one gramme of pure silver; the second, called the *decimal solution*, is only one-tenth of the strength of the first; and, consequently, a litre of it is required to effect the precipitation of one gramme of silver.

To explain the details of the process, let it be supposed that a piece of silver money of the French coinage is to be assayed, and which, in order to be of the legal standard, should contain eight hundred and ninety-seven thousandths of pure silver. Instead of this, suppose the alloy in question to contain only eight hundred and ninety-six thousandths of silver, so that 1.116 gramme of the mixture corresponds to one gramme of pure silver. This quantity is cut off the coin, accurately weighed, and put into a bottle that admits of being perfectly closed by a glass stopple, where it is dissolved in from five to six grammes of pure nitric acid; and as soon as the solution has been completely effected, one decilitre of the normal solution of salt is introduced. If the alloy contain exactly as much silver as was supposed, namely, eight hundred and ninety-six thousandths, the whole of that metal will be precipitated by the quantity of solution added, and the supernatant liquor will contain no traces of chloride of sodium in excess. But if the standard be higher than was supposed, there will still remain a portion of silver in solution; and if it be less, the whole of the silver will have been precipitated, but the liquor will contain an excess of chloride of sodium.

To ascertain which of these effects has been produced, the bottle is carefully closed with its glass stopple and briskly shaken, until the precipitate has subsided, and the solution become clear. A cubic centimetre of the decimal solution, capable of precipitating 0.001 gramme of pure silver, is then introduced. If any silver remain in solution, the liquor becomes cloudy; and after being again shaken, another centimetre of the decimal solution is added. If the liquor still becomes turbid, it is again shaken and allowed to become clear; a third centimetre of the decimal solution is poured in; and so on until no further cloudiness is produced by the addition of the decimal solution. Supposing that five of the cubic centimetres of the decimal solution, successively added, have produced a precipitate, while the addition of the sixth has not affected its transparency; it may be concluded that, after the precipitation of one gramme of pure silver by the decilitre of normal solution, the liquor still contained at least four-thousandths of a gramme of silver. But as a cloudiness was produced by the fifth cubic centimetre of the decimal solution, and none by the sixth, it is evident that the liquor did not contain more than five-thousandths of a gramme of silver; and, therefore, by adding $4\frac{1}{2}$ thousandths, the exact result is certainly attained within one half-thousandth of the truth. The standard of the alloy under examination will therefore be $896 + 4\frac{1}{2} = 900\frac{1}{2}$ thousandths.

When, on the contrary, the first cubic centimetre of the decimal solution produces no precipitate in the solution of silver, which has already received the decilitre

of the normal liquid, it is evident that the standard of the alloy must be inferior to eight hundred ninety-six-thousandths. In this case, its exact composition is ascertained by means of a standard solution of silver in nitric acid, so adjusted that one litre of the liquor shall contain exactly one gramme of pure silver; this is called the *decimal solution of silver*, and is only employed when the alloy under assay proves to be poorer in silver than was imagined at the commencement of the operation. In using it, a cubic centimetre of the solution is dropped from a pipette into the bottle containing the assay; and it occasions a precipitate of salt exactly corresponding to the same volume of the decimal solution of common salt, which was added for the purpose of ascertaining if all the silver was precipitated. The liquor is then cleared by agitation, and another cubic centimetre of the silver solution is added. If this still produces a cloudiness, the bottle is again shaken; and when the whole of the chloride has deposited, a third measure of the solution is introduced; and so on until the silver solution ceases to cause any precipitate. Assuming that the first five cubic centimetres of the silver solution produced a precipitate, and that on the addition of the sixth the liquor remained perfectly clear, it is probable that the fifth cubic centimetre was not entirely decomposed; and it is usual to assume that four and a half cubic centimetres of the silver solution, have been sufficient to decompose the excess of the chloride of sodium left in the liquor after the introduction of the decilitre of the normal solution. In this case, therefore, it is evident that it will be necessary to subtract four and a half thousandths from the presumed title of the alloy, and that its standard will be correctly expressed by $896 - 4\frac{1}{2} = 891\frac{1}{2}$ thousandths.

Such are the details of the process, which is greatly facilitated in the different mints, and generally where numbers of assays of silver and copper alloys have to be made, by the admirable manner in which the apparatus is arranged. The normal solution of common salt is kept in a large vessel, *v*—Fig. 498—made of sheet-copper, carefully tinned on the inside, and supported on a shelf near the ceiling. To prevent evaporation, it is covered by an immovable lid, through which passes a tube, *w*, descending to near the bottom, for the purpose of admitting air to supply the place of the liquid as it is drawn off; and by means of a gauge, *p*, at the side, the quantity of solution contained in the vessel is indicated. From near the bottom of the vessel proceeds a tube, *t*, furnished with a stop-cock, *d*. The pipette, *P*, which contains exactly a decilitre of the liquid, is connected with the tube, *t*, by another tube, *t'*, which contains a thermometer. The metallic connecting piece, by which the tube, *t'*, communicates with the pipette, *P*, is provided with two stopcocks, *rr'*; the stopcock *rr'*, shown also separately in the figure, is so constructed as to allow the air to escape in proportion as the solution enters the pipette. In conducting an assay, the operator closes the extremity of the pipette with the fore-finger of the left hand, and with the right opens the stopcocks, *rr'*. When the pipette is filled with the normal solution of chloride of sodium a little above the mark *m*, the taps, *rr'*, are

closed; and the pipette remains charged with the solution after the finger is removed. On the table below this apparatus is a sliding support, *s*, on which the bottle containing the solution of the alloy in nitric acid is secured by means of a case of copper, *b*, and near it is a small stand containing a sponge, *n*, covered by a piece of fine linen, and arranged at the exact height of the beak of the pipette. The assayer now slides the plate, *p*, in the grooves of the stand, *s*, so that the sponge may come in contact with the end of the pipette; and, by carefully admitting air through the stopcock, *r'*, the liquor is allowed to descend until it exactly reaches the line, *m*, scratched on the glass. The last drop of the solution, which would otherwise remain attached to the beak, is taken off by the sponge; and as the latter becomes saturated, the solution

passes down through the hollow stem on which the sponge is supported into the cylindrical vessel beneath. The operator now draws the slide forward until it is stopped by a peg, which arrests it when the mouth of the bottle, *b*, is immediately under the beak of the pipette; the stopcock, *r'*, is then again opened, and the solution flows into the bottle.

As it generally happens that several assays are being made at the same time, they are put, when weighed out, into as many bottles arranged in a metal frame like a cruet-stand—Fig. 499—each being marked with its own number, and, by the side of each bottle, is a small cup for holding the stopple. After the introduction of the nitric acid, the stand is placed in hot water for the purpose of facilitating the solution. When this is completely effected, the nitrous fumes are removed from the bottles by gently blowing into them through a glass tube; and a decilitre of the normal solution is added to each in the manner which has just been described.

The bottles are then placed in another metal frame *M*—Fig. 500—which is similarly provided with cases or compartments for each, and is suspended from the extremity of a steel spring, *s*, while it is steadied below by an elastic band, *p*, of vulcanized india-rubber.

Fig. 498.

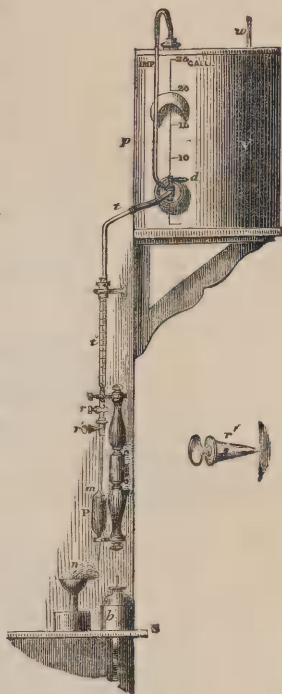
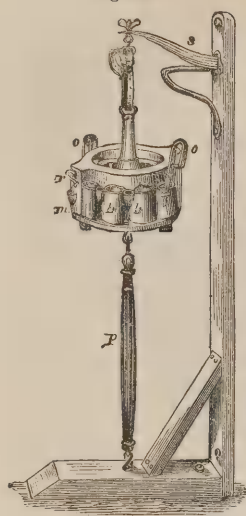


Fig. 499.



The bottles, after being carefully closed by their stopples, and secured in their places by a kind of collar—Fig. 501—which, when thrown up, is supported by a rest *r*, are well shaken by an assistant, who

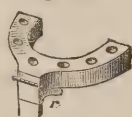
Fig. 500.



takes hold of the handles, *o o*, and briskly agitates the whole apparatus for some minutes. As soon as the liquors have in this way been rendered clear, the bottles are removed from the frame *M*, to a black table, divided into compartments, which are numbered to correspond with the numbers on the bottles. The decimal solution, which is contained in a phial with a pipette passing through its stopple, is now employed for determining the exact standard of the several assays. On the surface of the pipette a line is drawn, so graduated as to enable the operator to measure out exactly one cubic centimetre

of the solution, which he does by applying the forefinger to the upper extremity of the tube; and the latter, while thus closed, being removed from the bottle, is then allowed to drop, by the cautious admission of air, until the liquid has fallen to the level of the line marked on the glass. The top of the tube is again stopped by the finger; and the cubic centimetre of solution is transferred to the first bottle of the series, into which it is allowed to flow by simply removing

Fig. 501.



the finger. In the same manner an equal quantity of solution is added to each of the other assays.

The operator now examines each of the bottles in succession, and makes a mark with a piece of chalk on the black table before those bottles in which he observes that a precipitate has taken place. These are again taken to the agitating apparatus, in which they are briskly shaken until the liquors have again become clear, when they are restored to their places on the black table; and another cubic centimetre of the decimal solution is added to each bottle in which a precipitate was obtained by the last operation. This process is continued until all the bottles cease to give precipitates; and, on counting the number of chalk marks before each, the number of cubic centimetres of the decimal solution which have been added to each is ascertained. From this number must be deducted half a centimetre in each case, to allow for the superfluous quantity which may have been added the last time, a portion only of which has probably been decomposed.

The normal solution of chloride of sodium is prepared at the temperature of 59° Fahrenheit; but as the density of the solution varies with the temperature

of the air, it is necessary to construct a table of corrections to be employed when the assays are conducted at a higher or lower temperature. For this purpose the thermometer contained in the tube, *t'*—Fig. 498—should be consulted, and the correction read off from the prepared tables; but, in most instances, the assayer makes an experiment every morning on the saline solution with one gramme of pure silver, and from the result obtained he is enabled to correct any error arising from change of temperature, as well as from want of due care in the preparation of the normal solution.

The standard solution of chloride of sodium is usually prepared in considerable quantities at a time; it is made by dissolving five hundred grammes of common salt in four litres of water, and filtering. The additional quantity of water that would be required for the normal solution, supposing the chloride to be pure, is now added; and the solution is carefully adjusted to the exact standard by adding a decilitre to a solution of one gramme of pure silver in nitric acid. The liquor is clarified by agitation; and by the addition of successive centimetres of the decimal solution either of silver or chloride of sodium, the exact amount of free silver or chloride, as the case may be, remaining after the addition of the decilitre of normal solution, is accurately ascertained.

The decimal chloride solution is prepared by pouring a cubic decilitre of the normal solution into a bottle of the exact capacity of a litre, and filling it up with pure distilled water.

The decimal solution of silver is prepared by dissolving one gramme of pure silver in nitric acid, to which distilled water is added to make up an exact litre of the liquid.

When the alloy under assay contains either mercury or lead, the results obtained by the humid process are not exact, since these metals are precipitated with the silver, and decompose a portion of the normal solution, which vitiates the conditions of the experiment. The presence of mercury is indicated when a difficulty is experienced in obtaining a transparent solution by agitation; and when that is the case, the assay is not to be relied on. The assay of alloys containing mercury may, however, be made by the humid process, by adding a solution of acetate of soda to the nitric acid liquor containing the silver, previously to the introduction of the normal solution, as the acetate prevents the formation of the chloride of mercury.

The silver assays for the Royal Mint are now conducted by the humid method, and the following is a brief outline of the process as communicated by Dr. W. A. MILLER to Mr. TOMLINSON:—Ten grains of the alloy to be assayed are accurately weighed, and dissolved in one hundred and twenty grains of pure nitric acid. The standard solution of salt is so regulated that a thousand grains thereof will exactly precipitate one grain of pure silver. Now, taking the standard of English silver at nine hundred and twenty-five silver, and seventy-five copper, care is taken to keep an excess of silver in the solution; for if salt be in excess, however small, no amount of shaking will get it clear. Accordingly, the pipette *P*, Fig. 498, is charged with the standard solu-

tion to the mark, *m*, which is equivalent to nine hundred and twenty-three grains, a quantity which is capable of precipitating nine hundred and twenty-three grains of pure silver; the liquor is agitated for about a minute, and then allowed to settle. Ten grains of the decimal solution, capable of precipitating one-hundredth of a grain of silver, are now added: if a cloud be produced, a chalk mark is made against the bottle. The liquor is agitated for a minute, a second dose of the decimal solution is added, and if no precipitate is produced, it is thus shown that of the ten grains of the alloy, 9·235 grains consist of pure silver, the rest being alloy; thus showing a result a little below the standard. The standard solution of silver is formed by dissolving ten grains of pure silver in pure nitric acid and diluting it,

so that one thousand grains thereof shall contain one grain of silver.—*Tomlinson*.

STATISTICS.—In statistical returns of the precious metals, gold and silver are usually associated together, and accordingly the reader is referred to the tables appended to the article on GOLD, Vol. II., pages 308 and 309, for tables which exhibit the aggregate and relative amounts of gold and silver obtained from the different countries of the world, the annual consumption of the precious metals, and the amount of gold, silver, and copper monies coined at the mints of Great Britain, France, and the United States. To the ample information afforded by these tables with reference to the present or recent supplies of the precious metals, it will be sufficient to add the following:—

TABLE OF THE QUANTITIES OF SILVER BROUGHT INTO THE MARKET EVERY YEAR, ON AN AVERAGE, FROM 1790 TO 1802.

Old Continent.	Pounds avoirdupois.	New Continent.	Pounds avoirdupois.
ASIA.			
Siberia,	38,500	Central America,	1,320,000
EUROPE.		South America,	605,000
Hungary,	44,000		
Austrian States,	11,000		
Hartz and Hessa,	11,000		
Saxony,	22,000		
Norway,	22,000		
Sweden,	11,000		
France,			
Spain,			
Total of the Old Continent,	159,500	Total of the New Continent,	1,925,000

Thus, towards the close of the last century, the New Continent furnished twelve times more silver than the Old.

The following is HUMBOLDT's estimate of the annual produce of the mines of the New World at the beginning of the present century:—

ANNUAL PRODUCE OF THE MINES OF AMERICA AT THE COMMENCEMENT OF THE NINETEENTH CENTURY.

Political divisions.	Gold.		Silver.		Value of the gold and silver in dollars.
	Mares of Castile.	Kilogs.	Mares of Castile.	Kilogs.	
Vice-royalty of New Spain,	7,000	1,609	2,338,220	537,512	23,000,000
Vice-royalty of Peru,	3,400	782	611,090	140,478	6,240,000
Captain-generalship of Chili,	12,212	2,807	29,700	6,827	2,060,000
Vice-royalty of Buenos Ayres,	2,200	506	481,830	110,764	4,850,000
Vice-royalty of New Granada,	20,505	4,714	.. ..	.. ..	2,990,000
Brazil,	29,900	6,573	.. ..	.. ..	4,360,000
Total,	75,217	17,291	3,460,840	795,581	43,500,000

Taking the dollar at four shillings, this would give eight millions seven hundred thousand pounds sterling as the total annual produce of the American mines *in gold and silver*. HUMBOLDT further estimated the annual produce of the European mines of Hungary, Saxony, *et cetera*, and those of Northern Asia at the same period, at about one million pounds more.

The production of gold, says McCULLOCH, has very largely increased since 1848, as compared with that of silver; and if this state of things go on, the value of silver, measured in gold, can hardly fail gradually to rise. But it is by no means clear that it will go on.

The supplies of silver are increasing in most parts of the world, particularly in Mexico and Europe. It is to be observed, however, that a comparatively inconsiderable rise in the value of silver, as compared with gold, is sufficient, unless prevented by legislative enactments, to make the latter be used in preference to the former in the currency of those countries in which both metals are legal tender.

In concluding this article, the Editor again begs to acknowledge his obligation to Mr. GEORGE BLAIR of Glasgow, for much valuable matter, and for his kind assistance, at all times cheerfully rendered.

SOAP.—*Savon*, French; *Seife*, German; *Sapo*, Latin.—The article now to be considered is one of the utmost importance, as, with the progress of civilization, it becomes an indispensable necessity to every human being; and as the art of its production is entirely of a chemical nature, the more it is studied under the guidance of chemical principles, the higher in quality and the better suited to its purpose will be the material. The theory which accounts for the union of certain principles of oils with the alkalies in the formation of soaps, is indeed as abstruse as that which relates to some of the most refined instances of affinities. The manufacture of soap is, therefore, strictly scientific; and it behoves those who desire to advance in the art, to study thoroughly the principles involved in it, so that each result may be an advancing lesson for their own profit, while it enables them to repay the benefit they have derived from chemistry, by furnishing, from their experience, new facts for the guidance of others.

Whether the extended use of soap be preceded or succeeded by an improvement in any community—whether it be the precursor or the result of a higher degree of refinement amongst the nations of the earth—the remark of LIEBIG must be acknowledged to be true, that the quantity of soap consumed by a nation would be no inaccurate measure whereby to estimate its wealth and civilization.

Of two countries with an equal amount of population, the wealthiest and most highly civilized will consume the greatest weight of soap. This consumption does not subserve sensual gratification, nor depend upon fashion, but upon the feeling of the beauty, comfort, and welfare attendant upon cleanliness; and a regard to this feeling is coincident with wealth and civilization.

The rich, in the middle ages, concealed a want of cleanliness in their clothes and persons under a profusion of costly scents and essences, while they were equally luxurious in eating and drinking, in apparel and horses. With civilized nations at the present time, a want of cleanliness is equivalent to insupportable misery and misfortune. The remission of the soap duty in Great Britain, which, so long as it remained unrepealed, prevented the adoption of all improvements in the manufacture, has enabled British to compete more successfully with foreign manufacturers; and it may now be hoped that this branch of industry will still further progress, so that an abundant supply of this necessary, and indeed indispensable article of domestic use, may be more easily obtainable by all.

In proof of the injurious influence of the excise duties on this and other branches of manufacture, it may be stated that the process for its production has undergone little or no alteration for the last two or three centuries. Now, however, that the manufacturer is not restricted as to the choice of materials, it remains only for the chemist to supply other and cheaper ones, and to guide the practical man as to the best method of combination; and, doubtless, diligent inquiry will reward those who enter upon the subject in a truly scientific spirit.

The term soap was formerly applied to all compounds consisting of an alkali, an alkaline earth, or a metallic oxide, united to a fatty or oily acid, or other substance of an unctuous or oleaginous nature. This extended meaning of the term is, however, not now recognized; it is now applied to those combinations of grease or oil with the alkalies which, by their peculiar properties and solubility in water, aid the removal of grease and dirt in the processes of washing and scouring. This cleansing influence is due to what is termed a detergency; that is, a power of rendering soluble in water the adhering dirt of the clothes and the skin, to which purpose soap is almost exclusively applied. The alkalies themselves—potassa and soda—possess this property of detergency; and the former, potassa, under the form of wood ashes, was used in the most ancient times by the Hebrews, Egyptians, and Greeks, as an aid to cleansing processes. Free alkali itself, however, possesses a solutive property over fibrous materials, over even human skin, and hence the necessity of combining it in such a manner as to modify this injuriously corrosive action.

The remedy is the substitution of soap, which, by its slight excess of alkali, rendering soluble in and miscible with water all the dirty grease of the clothes and oily exudations from the pores of the skin, is at the same time deterrent itself; for, though composed of oil and alkali in a state of combination, it still possesses the influence of the latter without any of its hurtfulness. Oleate of oxide of lead, formerly called *lead soap*, is insoluble, and constitutes the diachylon plaster of pharmacy. The analogous salts of zinc and lime, formerly termed *zinc soap* and *lime soap*, are also insoluble.

HISTORICAL NOTICE.—Although the word *soap*, or rather *sope*, is occasionally met with in the translation of the sacred records, it must not be supposed that the substance now known by that name was used by the Israelites. The word so rendered, doubtless, refers to the juice of some plant, or more probably to the ashes of a plant; as the substance in question appears to have deterrent properties. The earliest mention of the term *soap*, as applied to the substance now under discussion, occurs in the writings of PLINY, who also describes a process for its preparation differing but little from that pursued at the present day. This writer ascribes its invention to the Greeks, from whom the Romans, and subsequently other nations, derived a knowledge of its manufacture. HOMER makes no mention of soap, and it was doubtless unknown to him. In the excavations at Pompeii a complete soap-boiling establishment was discovered, containing soap still perfect, though it must have been prepared upwards of seventeen hundred years. The Editor was greatly interested inspecting the factory.

The Germans were at a very early period distinguished for their production of superior soap, and hence probably the Latin term *sapo*, from the original German *seipe*, now written *seife*, and from this by a transposition of letters, the English *soap* is derived. Owing, in a great measure, to natural advantages of the country, France is now the great mart for soap, and especially for toilet soaps.

MATERIALS.—The materials used in the manufacture of soap, are the various kinds of oil or fat, resin, and the alkalis, potassa and soda. All oils and fats of whatever kind, vegetal or animal, yield soaps, when treated with alkali, as will be subsequently described. Only a very limited number, however, is used in this manufacture; and these such as may be obtained at a very low price compared with that of the others. In Great Britain palm-oil is probably consumed in greater quantity than any other, and principally in the production of hard soap; for soft soaps, the various kinds of fish-oils, the drying oils from seeds, and tallow are mostly employed.

In France, and on the Continent, olive oil is extensively used in soap-making; and for soft soaps, hemp-seed oil is highly valued.

Tallow, saponified with soda, yields white curd soap; this, formerly much used for domestic purposes, is superseded in great part by the softer, and otherwise superior palm-oil soap. Cocoa-nut oil soap, on account of its property of dissolving pretty readily in salt water, is useful for washing during long sea voyages. Of all soaps, the most emollient are those of palm-oil, castor oil, and of spermaceti; yet these are not nearly so extensively used by the perfumer, or for toilet purposes, as the curd or ordinary tallow soap. Though it is of the utmost importance that the manufacturer should be fully acquainted with the peculiar properties, not only of the oils generally, but of the several individual kinds, still it will not be necessary to repeat here what has already been stated in the article specially devoted to the consideration of that subject.—Vol. II., page 597, *et seq.*

Most of the oils and fats are met with in commerce in a sufficient state of purity for their conversion into soaps without previous preparation.

Palm-oil, however, and occasionally tallow, are exceptions to this rule, and, therefore, the methods most effectual for their purification before being used in the manufacture will be afterwards stated. The destruction of the coloring matter is the object of these processes, and though described with a special view to the decoloration of palm-oil, they are generally equally applicable for tallow and other oils or fats which it may be necessary to purify more completely. The admirable investigations of CHEVREUL relative to the constitution of fatty bodies, and of LIEBIG as to the peculiar behavior of soap with various saline solutions, have greatly simplified the description of the several operations in the soap manufacture; and one can now understand the reason for the several operations, and trace with accuracy the changes that take place throughout.

Nevertheless, much room remains for future investigators in this wide field; and many improvements may still be expected from further research. Tallow, olive, palm, and cocoa-nut oils, oleic acid, and resin are used for the production of hard soaps; fish and seed oils, on the contrary, for soft soaps. The mixture of oleic acid with small quantities of stearic and margaric acids, which is obtained in the separation of stearic acid by pressure, as described under the article CANDLE, affords an excellent soap, the production of which is a secondary

process in stearic-acid manufactories: it is prepared so much the more readily as the fat is already decomposed, and the acid merely requires neutralization with alkali.

Experiments were made by DARCET, LELIÈVRE, and PELLETIER, on the relative value of different kinds of oil and fat in the manufacture of soap. The oils or fats were saponified by means of caustic soda lies, and the products were, therefore, soda soaps. The results of these experiments were as follows:—

Three pounds of olive oil gave a block of soap weighing six pounds ten ounces, which, on exposure to the air for two months, became four pounds fifteen ounces. It was then dry and perfectly solid, of excellent color, resembling that of Marseilles soap. By further exposure in a dry place it became still lighter, owing to loss of water.

Sweet almond-oil soap was found to be next to the olive-oil soap in consistency. This was very white, uniform, and of an agreeable odor. Its weight from three pounds of oil was five and a half pounds; and, after two months' exposure, it lost one pound of water. *Rape-seed oil soap* is of a greyish-yellow hue, is more consistent than that of colza oil, and possesses the peculiar odor of the oil from which it is produced.

Oil of beech-nut soap is of a dirty-grey color, softer than the preceding, and has the smell of the oil. This soap is greasy, pasty, and clammy, and when exposed to the air becomes yellow.

By associating these oils with proportionate quantities of suet or tallow, mixtures will be formed, of which soaps of proper quality and consistence can be made. The soaps made from *poppy oil* are of a dirty grey, without any disagreeable smell; are clammy, and of medium consistence. They become yellow in the air, and, when exposed to cold, become soft at the surface. This oil, when mixed with the greases, yields a soap much resembling in appearance that of olive oil.

Hemp-seed oil soap is of a green color, very pasty, and so soft that the least addition of water renders it liquid. Exposed to the air, it loses its green tint exteriorly, bleaches, and afterwards becomes brown. *Nut-oil soap* is of a yellowish-white color, with but little consistence, is greasy and clammy, and assumes a brown appearance on exposure. *Linseed oil* yields a whitish soap, which, however, becomes yellow by contact with the air. This soap is greasy, pasty, and viscous, of a slight consistence, and powerful odor, and is reduced to a thin paste by a slight addition of water. *Sperm-oil soap* is of a dirty-grey color. It retains the peculiar smell of the oil, becomes reddish-brown and of some firmness, but much less than olive-oil soap.

Soap prepared from *fish oil* is very similar to the last named. *Cod-liver oil soap* differs only in having a more unpleasant smell and less consistency. *Suet or tallow soap* is white and solid, and has a slight odor of the fat. Exposed to the air, it loses water, and becomes brittle. Soap prepared from *lard* is very white, solid, inodorous, and especially valuable for the production of toilet soaps. *Rancid butter* yields a soap which is white, and in properties similar to tallow soap, but retains a rancid smell. *Castor oil* and *spermaceti* soaps are emollient, and especially applicable to toilet pur-

poses. Soap, made from palm oil is little inferior to castor oil or spermaceti soap. Lastly, soaps prepared from drying oils are usually soft and flabby.

The appended table shows the quantity of soap obtained from three pounds of each of the oils mentioned above, saponified with caustic soda solution.

Oil or fat.	Color of the soaps.	Quantity obtained as taken from the frame.	Loss of weight in pounds and ounces.	Time.
Olive oil,	White,	6 lbs. 10 oz.	5 lbs. 0 oz.	2 months.
Sweet almond oil,	White,	5 " 11 "	4 " 6 "	2 months.
Colza oil,	Lemon-yellow,	5 " 14 "	5 " 0 "	15 days.
Rapeseed oil,	White,	6 " 8 "	5 " 0 "	20 days.
Beech-nut oil,	Dirty-grey,	5 " 4 "	4 " 13 "	2 months.
Poppy oil,	Grey,	4 " 8 "	4 " 6 "	45 days.
Hempseed oil,	Green,	5 " 0 "	4 " 14 "	15 days.
Nut oil,	Deep yellow,	4 " 7 "	4 " 6 "	15 days.
Linseed oil,	Yellowish,	5 " 0 "	4 " 12 "	1 month.
Sperm oil,	Dirty-grey,	4 " 12 "	4 " 10 "	15 days.
Fish oil,	Reddish-brown,	4 " 11 "	4 " 8 "	1 month.
Cod-liver oil,	Dirty-grey,	4 " 14 "	4 " 12 "	15 days.
Suet or tallow,	White,	8 " 4 "	6 " 0 "	2 months.
Lard,	White,	8 " 3 "	5 " 0 "	2 months.
Washed rancid butter,	White,	11 " 0 "	7 " 0 "	2 months.

PALM OIL.—The sources, preparation, properties, and composition of this valuable oil, have been fully discussed in a previous article, Vol. II., page 618. It remains here to notice more particularly the treatment to which it is necessary to submit it, to remove the coloring matters, *et cetera*, previous to its employment in the manufacture of soap. Its rapid rise in commercial importance during the last half century exceeds that of nearly every other article imported, as will be seen by the following statistics:—

	Hundredweights.
Imported in 1820,	17,456
" 1830,	213,476
" 1840,	315,503
" 1850,	447,796

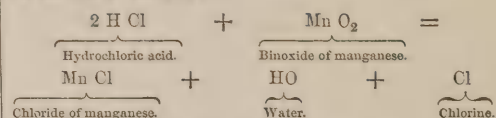
At the present time palm oil is imported to the amount of upwards of twenty-five thousand tons annually.

As it arrives in this country, this oil is tinged of a peculiar and characteristic orange-red color, which renders it unfit for use in this manufacture in its natural state. The coloring matter, it should be observed, is not proper to the pure oil, which, in a state of chemical purity, is perfectly colorless. There is associated with the oil, however, and extracted with it from the palm a peculiar principle, which in the course of time undergoes spontaneous decomposition, assuming at the same time a characteristic color.

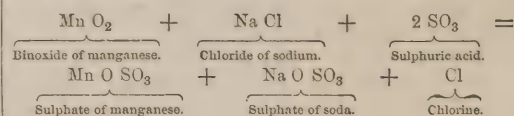
Numerous processes have from time to time been adopted to effect the decoloration of palm oil, nearly all of which depend upon the application of nascent oxygen produced through the decomposition of various compounds, from which it may be liberated with a greater or less degree of facility.

The old method consisted in the employment of nitric acid; but this method, though not objectionable on account of its cost, has the disadvantage of impairing the peculiar violet odor of the oil upon which its value chiefly depends; whilst, at the same time, though the coloring matter is destroyed, the oil is not perfectly bleached, and hence it yields a soap of a greyish-yellow hue. Neither is chlorine well adapted for the purpose, though the coloring matter is readily decomposed by it; for this agent exerts an injurious action on the oil itself, developing a brown tint, and impairing its

consistence. Nevertheless, chlorine has been used to a great extent for depriving palm oil of its color; the materials for generating the chlorine, namely, binoxide of manganese and hydrochloric acid, or, instead of the latter, chloride of sodium and sulphuric acid, being introduced directly into the melted oil. The changes that ensue when hydrochloric acid is employed, may be shown as follows:—



and when, in the place of hydrochloric acid, chloride of sodium and sulphuric acid are used, the reaction may be thus stated:—



As to the precise manner in which chlorine effects the destruction of coloring principles, this is a question upon which there is much difference of opinion. It cannot be questioned, however, that the injurious action of free chlorine on the substance of oils is owing to its powerful affinity for hydrogen, and that by the abstraction of this element more or less completely from the oil, entirely new and probably substitution compounds are produced, which will account for the alteration in the color and consistence of the oil.

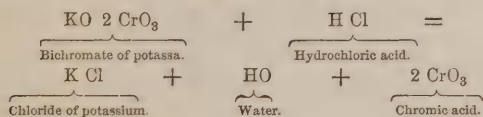
Of all methods of bleaching palm oil, that which effects the decomposition of the coloring matter most completely, is that originally proposed and patented by Mr. WATT, in which the decoloring agent is nascent oxygen produced by the decomposition of chromic acid. The process is commenced by heating the oil by steam in an ordinary boiling cauldron for half an hour; it is then allowed to stand at rest to deposit impurities, and when cooled down to about 130°, it is drawn off from the sediment and condensed steam, and placed in wooden vessels, each capable of containing two or three tons. To each half tun of oil, thus far freed from extraneous matters, the following mixture is added; a saturated aqueous

solution of twelve and a half pounds of bichromate of potassa, four pounds of concentrated sulphuric acid, and about twenty-five pounds of strong hydrochloric acid. These are the proportions recommended by the patentee, but are not always strictly adhered to; many bleachers using to the above quantity of oil, ten pounds of the bichromate, and forty of the hydrochloric acid. After being well agitated with the mixture for a few minutes, the oil becomes of a black color; in a short time, however, this changes to dark green, and soon afterwards to light green; and at the same time a thick froth appears on the surface indicating the termination of the reaction. The oil is now examined by taking out a small portion and allowing it to settle, and if not sufficiently decolorized an additional portion of the bleaching mixture is added.

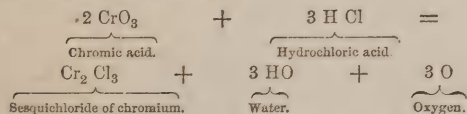
After complete decoloration, which is effected in from ten to fifteen minutes, the oil is permitted to remain undisturbed for about half an hour, so as to allow the deposition of the aqueous solution of chloride of chromium, sulphate of potassa, and other foreign matters; after which the clear oil is drawn off into a wooden vat, mixed with a little fresh water, and again heated for a short time by means of steam.

After being once more allowed to rest to deposit water, *et cetera*, the oil may be siphoned or otherwise drawn off, and is fit for use.

As already mentioned, the decoloration is effected in this process by the agency of nascent oxygen. When the solution of bichromate of potassa and hydrochloric acid are mixed, the acid of the bichromate is liberated, the oxygen of the potassa seizes the hydrogen of the acid forming water, and the chlorine unites with potassium to produce chloride of potassium as represented in the annexed equation:—



After this decomposition, the mixture, containing an excess of hydrochloric acid, is added to the melted oil, and on coming in contact with the organic matter, a further change takes place between the hydrochloric and chromic acids. The latter is reduced to sesquioxide of chromium, and this with hydrochloric acid yields sesquichloride of chromium; water is formed, and oxygen is set free as follows:—



The liberated oxygen is seized by the coloring matter, and the green sesquichloride of chromium, chloride of potassium, *et cetera*, are found in solution in water at the bottom of the vat. The sulphuric acid directed to be added by the patentee, does not appear to be essential to the operation, and is indeed omitted by many bleachers. Oil once bleached by this process may be preserved from acquiring odor, and the soap made from it does not become tinged like that made from oil bleached by other methods.

Another process for bleaching palm oil, depending, like the preceding, on the decoloring power of oxygen at the instant of its liberation, was patented some years ago by Mr. WATSON. In this method manganate of potassa or chameleon mineral is used as the source of oxygen, and after solution in water is added to the melted oil in the proportion of one-twentieth of its weight, the oil being placed in a wooden cask, and mixed with dilute acid. The whole is to be well mixed, and gradually heated to 212°, and maintained at that temperature for an hour. The rest of the process is conducted precisely as directed when bichromate of potassa and hydrochloric acid are employed.

On account of the tendency of the solution of manganate to spontaneous decomposition, the mixture of dilute acid and fat, to which it is to be added, should be at the lowest temperature consistent with its fluidity. Owing to this peculiarity of the manganate, as well as for many other reasons, it is not likely to supersede the employment of bichromate.

When palm oil is to be used in the production of yellow soap, the most economical mode of bleaching is by the process patented by Mr. ARTHUR DUNN. This method, which is also applicable to other oils and fatty matters of a like nature, consists in the exposure of the oil to the combined influence of air and heat. The air is forced beneath the surface of the oil through pipes, by means of a blowing apparatus, and then allowed to rise through the liquid in numerous small streams; the oil being maintained at a temperature between 170° and 230° by steam pipes or other means. A hood communicating with a chimney is placed over the vessel containing the oil, for the purpose of conducting away the unpleasant vapors which are disengaged. This process appears to be an improvement of the method first recommended by Mr. CAMERON through the Society of Arts. This gentleman directed the heated oil to be violently agitated by means of a horizontal fan, revolving at the rate of about six revolutions a minute, and it was stated that by this method four tons of oil may be decolorized in ten hours at one operation, and at the expense of half a ton of coals.

All that is essentially necessary to effect the bleaching is obviously the exposure of the oil to the combined influence of air and heat, and with this view the process of Mr. DUNN seems as complete a method as could be devised. According to PARNELL, the oil should not be maintained at a temperature exceeding 180° during the operation of blowing in the air. He recommends, however, that at the commencement of the process it be heated to 212°, and then suffered to cool a little. This is necessary, inasmuch as the air has but little effect as long as water is present; but when this is completely expelled, the bleaching commences immediately. The oxidising action of the air on the coloring matter of palm oil, as PARNELL observes, seems to be accelerated by combining the influence of light with that of heat. With this end in view, the oil is sometimes placed in a thin layer, on the surface of a large shallow uncovered vat. Several of these vats, each about a foot in depth, may be heated by means of steam passed through serpentine

lead pipes proceeding from a common boiler; one extremity of each tube may terminate in a receiver for the condensed water, and the latter may be returned to the boiler. Each vat is first two-thirds filled with water, and when this is become hot, a sufficient quantity of palm oil is introduced to form when fluid a layer of about two inches in depth, and this should be maintained during the whole process at a temperature as near 212° as possible. To preserve an equal temperature throughout the fluid, the steam may be admitted at opposite ends of the vat, and separated in contrary directions by two distinct serpentine tubes. Both air and light having access, the time required for the decoloration of the oil at a temperature approaching to 212°, is from ten to fifteen hours: the thinner the stratum of oil, the more rapid is the process. The rapidity of the bleaching action is not sensibly lessened by loosely covering the containing vessel, provided the removal of the air over the surface of the oil is not much interfered with; but if exposed to a temperature of 212° in a closed vessel, so that although light and heat have access, the air is excluded, the oil does not then become bleached; hence PAYEN, who made these observations, suggests the propriety of adopting such an expedient as will, while not excluding air, partially prevent the great loss of heat which occurs from the extensive surface of oil presented to the air in the open vessels commonly used in this method of decoloration. The bleached oil, which while fluid retains a fawn-colored tint, is after solidification of a greyish-white color.

RESIN.—Besides oil and alkali common resin or colophony also forms an important ingredient in the production of soap. The sources and method of procuring this substance have been fully discussed in a separate article, and it only remains here to treat of it as a constituent of soap. The kind used is that yielded by the common turpentine, produced by and extracted from the several species of pine.

Though employed in the fabrication of soap as a partial substitute for oleaginous or fatty material, resin does not possess a similar constitution to these matters, and, therefore, does not suffer an analogous alteration in the process of saponification. Resin contains no oxide of glyceryle or any similar body, nor indeed any base whatever. UNVERDORBEN, who made a careful examination of it, found it to be an indefinite mixture of two distinct substances possessing very decided acid properties, and which he termed sylvic and pinic acids, the latter of which is readily soluble in cold alcohol of specific gravity 0.86, and the former nearly insoluble in this liquid. The introduction of too large a proportion of resin into soaps, gives to the latter a very dark color, and also renders them much too soft for application to the purposes for which hard soaps are used. Resin is used only in the production of yellow soap.

ALKALIES.—The alkaline ingredients employed in the soap manufacture are, as already noticed, potassa and soda. Both these articles are met with abundantly in commerce in the state of carbonate, and in this condition purchased by the soap manufacturers.

The crude carbonate of potassa, termed *potash* or

pearlash, is prepared by calcining in an iron pot the residue of the evaporation of a lie obtained by digesting wood ashes in water. Its production has been fully described under the article POTASSIUM. Besides carbonate of potassa, it contains in considerable proportions, chloride of potassium, sulphate of potassa, and other salts. These, however, do not interfere materially with its application to the soap manufacture.

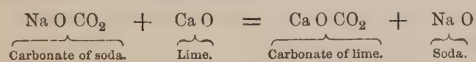
The carbonate of soda of commerce is variously designated, according to the source whence it is obtained. Barilla, a very impure variety, is in appearance a grey or bluish-grey mass, and is imported from Spain and the Levant. It is procured from the plants of the order *Chenopodiaceæ*, which, being cultivated on the coast, are, when ripe, cut down, dried, and burned in heaps; the resulting ash is barilla. Besides carbonate of soda, it contains sulphate of soda, sulphide and chloride of sodium, carbonate of lime, alumina, silica, oxide of iron, and carbonaceous matters which have escaped combustion. The quantity brought to this country is now very small; indeed soap manufacturers generally have abandoned its use. *Kelp*, another very impure carbonate of soda, is prepared in a similar manner to barilla, from the plants of the order *Algaceæ*. It contains the impurities which exist in barilla, and, in addition, an alkaline iodide. Kelp is used to a far greater extent by soap manufacturers than barilla, but its value as a source of soda is very insignificant. The greatest source of soda, both as applied to the production of soap and to all other purposes, is the *white ash* or soda ash of commerce, procured by the decomposition of common salt. The introduction of this material, though it was effected with much difficulty, has been the greatest stimulus the soap manufacture has ever received. Mr. JAMES MUSPRATT of Liverpool, who was the first to carry out LEBLANC's process on a large scale, in the year 1824, was compelled to give away soda by tons to the soap-boilers before he succeeded in convincing them of the extraordinary advantages to be derived from it. As soon, however, as he effected this, and when the soap-boilers discovered how much time and money they saved by using artificial soda, orders came in so rapidly that the Editor's father, to satisfy the demand, had his crude soda discharged red hot into iron carts, and thus conveyed to the soap manufactories.

From that period a constant race was kept up between soap-making and the artificial production of soda. Every improvement in LEBLANC's system was followed by an extension of the soap trade; and it is a curious fact, that the seaport of Liverpool exports annually more soap at present, than did all the ports of Great Britain previous to the conversion by Mr. MUSPRATT, on the large scale, of chloride of sodium into crude carbonate of soda. The manufacture of soap has, on the other hand, been a powerful stimulus to the preparation of soda, and of the important secondary product—chloroxide of calcium, or *bleaching powder*—two substances which are so intimately allied with almost all branches of chemical manufactures. Thus soap occupies one of the most important pages in the history of applied chemistry. The increase in the consumption of this article has led, moreover, to the dis-

covery of new materials for its production, and has opened new channels to commerce.

When the soda prepared from common salt was first introduced into the soap manufacture, for making yellow soap, the fabricators purchased it in the form of *black ash* or *ball soda*. This, at that time designated also British barilla, is the residue of the calcination, in a reverberatory furnace, of a mixture of sulphate of soda, chalk or broken limestone, and small coal; and when lixiviated with cold or luke-warm water, affords a solution of carbonate of soda, containing also a small quantity of caustic soda and sulphide of sodium, together with a portion of undecomposed chloride of sodium and sulphate of soda. The alkaline carbonates now used by soap manufacturers, are white ash or soda ash. This is obtained by lixiviating the above-mentioned black ash in water, drawing the solution from the insoluble matters, and evaporating to dryness. The residue thus obtained may be used for making lie; but, as it usually contains some sulphide, which, in the production of white soap, is a source of inconvenience, it is necessary for some purposes to calcine this residue at a moderate heat, whereby nearly the whole of the alkaline sulphide becomes oxidized and converted into sulphate.

This ash contains carbonate of soda sometimes to the amount of ninety-five or ninety-six per cent. It is, however, essentially necessary in the production of soap, that the alkali should be rendered caustic—that is, set free from combination by the removal of carbonic acid; as, if it be in chemical union with any other body, it has no decomposing power over the oils or fats. Even if combined with the weakest acids, saponification will not ensue; and the greatest care should, therefore, be exercised in this preliminary process—the preparation of the lies. The process for causticizing is the same in principle for the preparation both of soda and potassa lies. It depends upon the greater affinity of lime than of soda or potassa for carbonic acid, and the decomposition is one of the most simple, thus—



The proportions of soda ash and lime employed vary according to the degree of strength of the soda; similarly with regard to the potassa salt. It is, however, always an advantage to have an excess of lime over the alkaline carbonate, as in the contrary case any undecomposed carbonate is totally lost.

A fact deserving of mention in treating of the preparation of lies is, that in the process of causticizing by means of lime, a portion of the soda appears to enter into some form of combination very difficultly soluble. Mr. KYNASTON, a student of the Editor's, lately examining the calcareous deposit, found it to contain, after being well washed, soda to the amount of five or six per cent. When the deposit, after being dried, is heated to a temperature insufficient to expel carbonic acid, and, after being allowed to cool, is again drenched with water, caustic soda is then removed with great ease, and the deposit may be almost completely deprived of soda. Taking these facts into consideration, the Editor is of opinion that it would well repay the soap manufacturer to collect the lime deposit, VOL. II.

and, after thorough desiccation by exposure to the air, to submit it to heat until the carbonic acid is expelled. The lime now again become caustic, may be used advantageously in the preparation of fresh lie, and the process may be repeated until the deposit becomes highly charged with the impurities of the ash, when fresh lime may again be used for a new process.

Another of those progressive steps manufacturers frequently take, leading to the simplification of operations which previously had been tedious, laborious, and wasteful, has been taken in the soda trade, the especial benefits of which are to be derived particularly by the soap-maker and the public generally. This intellectual advancement consists in preparing *directly* the caustic alkali, by the use of which the soap-maker at once dispenses with a considerable plant outlay, economizes space, expedites the operations of his trade, and effects no little amount of saving in labor alone, compared with the present general practice. Besides the foregoing immediate and apparent advantages resulting in favor of the soap-maker, from the employment of caustic soda prepared *directly*, there are others of much greater importance—namely, the economy of alkali, and the readiness with which soap can be made by the use of lies, the strengths of which are immediately under control, and which cannot be obtained economically on the present causticizing system to which soda ash is submitted, unless at considerable trouble; and even then the lies are not pure, owing to the circumstance that strong caustic alkaline solutions divest carbonate of lime of a portion of its carbonic acid.

The article in question, being in the solid state, is most convenient for transit and storage. It is now prepared largely in some alkali works; MUSPRATT BROTHERS, and HUNTLEY, of Flint, North Wales, manufacture it to a very considerable extent, and the trade is likely to be greatly increased; and the Editor is convinced that its employment would be much more economical to the soap manufacturers than the present method of preparation. It requires simply to be dissolved in a given quantity of water, to produce lies ready for use, and of any required strength. In America it is now largely employed for this purpose, but in England rarely, if at all. Its introduction, though a great advantage to the soap producers themselves, will probably be a matter of as much difficulty as was that of the introduction of the so-called artificial soda, at least as regards the English manufacturer. The method of preparation of this caustic soda will be fully described in a subsequent article. It is of such a nature that it cannot be economically or, indeed, conveniently applied, except where artificial soda is produced to a considerable extent. Being perfectly free from sulphide of sodium, it is especially applicable to the production of white soaps.

Testing the Lie.—That the soap-boiler may be in a position to carry out his method accurately, and to proceed with safety, it is necessary during the lixiviation in the ash tubs, and whilst boiling the fat, that he should be able at any moment to ascertain correctly the strength of the lies. For this purpose specific gravity bulbs, or the *hydrometer*, is used. In this country Twaddell's hydrometer is most commonly employed.

The indications of such an instrument are in no kind of connection with the chemical nature of the fluid; and as the graduation is perfectly arbitrary, nothing more can be established by its application than a comparison of the densities of different liquids. As, however, a correspondence has already been established between the degrees of the hydrometer and the specific gravities, and it is also known what proportions of potassa and soda correspond to the specific gravity of different solutions, the hydrometer may be used as a means of ascertaining the amount of alkali present. The degree indicated by Twaddell's hydrometer, multiplied by five and added to one thousand, expresses the specific gravity of the fluid. A lie testing 27.50 Twaddell, for instance, has a density equal to 1.138, which is equivalent to 15 per cent. of potassa or 12.8 per cent. of soda, always supposing the lie to contain no other matters or salts which might also affect the specific gravity. This, however, is never the case with soap-boilers' lie, so that the indications are only approximations with reference to the amount of alkali, or even may be altogether fallacious. Still they are useful in a variety of ways, and are, indeed, indispensable. The practitioner is able with this instrument to follow the diminishing strength of the liquid flowing from the ash tubs or vats, and to form a just estimate of its value, when, at the same time, a test with acid proves the absence of carbonic acid. But even in the process of soap-boiling itself, the test of the lie afforded by the hydrometer, combined with the personal experience of the workman, is a clue by which he is enabled to judge whether the proper strength has been attained; knowing as he does what degree the hydrometer ought to indicate from any particular soda or potassa lie for any particular purpose. The more or less caustic taste of a lie is also a test much depended on by many soap-boilers.

SAPONIFICATION.—Oils and fats themselves are neither soluble in water nor miscible with it; but nearly all are made so by union with alkali. The process of effecting this combination is termed *saponification*, and the compound produced is *soap*—hard soap when its base is soda, but more or less soft when potassa is the alkali present. The properties and composition of the different kinds of oil and fat, as well as their behavior under the influence of various reagents, have been fully discussed in a separate article. It is, however, necessary in considering the theory of saponification, again to notice the constitution of these bodies in its bearing upon their conversion into soap. The fixed oils, as well as the animal fats, are composed for the most part of certain proximate principles, of which stearin, margarin, and olein are the most abundant. Some oils, as for instance palm oil, have constituents peculiar to themselves; but as they are quite analogous to olein, and other bodies above-mentioned, in their chemical constitution, and consequently similar in their relation to alkalies, these will serve as examples.

In animal fats stearin is usually the most abundant constituent; margarin more especially characterizes the vegetal and human fats; olein is present in both, though varying in its nature in different kinds of oil.

Stearin, margarin, and olein, however, are not free

uncombined bodies, but positive compounds, each of its respective acid with a base, termed *oxide of glyceryl*, the hydrate of which is glycerin. Thus, though the base is the same in all, the acid constituent in each of the three is peculiar. The acid in stearin is termed *stearic acid*; that in margarin, *margaric acid*; and that in olein, *oleic acid*. Stearin, margarin, and olein have, therefore, a saline constitution, and may be respectively regarded as a stearate, margarate, and oleate of oxide of glyceryl. When brought into contact with a free alkali, or a metallic oxide in presence of water, these fatty principles undergo decomposition; the alkali, or metallic oxide, being a more powerful base, seizes the oily acid, and a stearate, margarate, or oleate of potassa is formed, as the case may be. These latter compounds, when mixed with a solution of a more powerful acid, such as the mineral acids, or even of the stronger organic acids, as oxalic, tartaric acid, *et cetera*, are decomposed, a salt of the base with the acid employed being produced, while the oily acids are set free, and at the instant of separation combine with a certain proportion of water. The oxide of glyceryl, liberated from the fatty principle by the action of an alkaline solution, also at the moment of separation enters into combination with a definite proportion of water, the product being glycerin, which, owing to its sweet taste, and the source whence it is procured, was originally termed the sweet principle of oils. It will now be more easily understood that the oils or fats, or the principles of which they are composed, are themselves incapable of *direct* combination with the alkalies, or other bases; or, in other words, the mixture of a fat or oil with an alkali, does not occasion the formation of soap. On the addition of water, however, with which the base of the fatty principle may combine, saponification ensues immediately. Previously to the admirable investigation of CHEVREUL, to whom chemists are indebted for a knowledge of the composition of oils and fats, and their peculiar properties and behavior, the presence of water in the process of saponification was supposed to occasion a change proportional to its elements, converting the stearin, margarin, and olein into new bodies, which from their acquired acid properties were termed adipose or saponic acids; the peculiar unsaponifiable body glycerin being left behind as an incidental product. Hence, what are now known to be positive compounds of a fatty acid with the base of glycerin, were considered as altered in ultimate composition by the action of water and alkali. This view is now known to have been fallacious, and it has been conclusively demonstrated that the acids exist ready formed in the fats, and are separated from the base-oxide of glyceryl, in accordance with that law which determines the power of stronger bases over weaker ones.

Thus, therefore, when solution of potassa or soda is boiled with oils, the fatty acids are abstracted, and the eliminated oxide of glyceryl, uniting with water, forms glycerin. And thus it is explained why the fatty acids separated from oil, estimated together with the glycerin, always exceed the weight of the oil or fat submitted to decomposition—the excess being due to the water entering into combination both with the glyceryl base, and with the fatty acids. The following diagram

will render the decomposition that ensues, when an oil is saponified, much more intelligible :—

Substances employed.	Composition.	Products of decomposition.
Fats or oils, namely, stearate, margarate, oleate, <i>et cetera</i> , of oxide of glyceryl.	{ <div> Stearic acid, Margaric acid, Oleic acid, + Oxide of glyceryl, </div>	Stearate, margarate, and oleate of potassa or soda, that is, soap.
Potassa or soda, Water,		
		Hydrated oxide of glyceryl, that is, glycerin.

Soap, therefore, it will be observed, does not result from a direct union of the fatty matter with the alkali; a further proof of which is seen when the soap obtained as above is decomposed by the agency of a stronger acid. It will be found that the acid decomposing the soap, by seizing its alkaline base, leaves the fatty material in a totally different state to that in which it existed when originally added. It is now found to possess acid properties, and to unite much more readily with alkalies; or, in other words, to be more easily saponified. This latter property is accounted for from the fact that, being in an uncombined state, the acids have no base to overcome, as was the case in the first instance. In all saponifiable fats, the same reaction ensues, though the soap produced contains different acids, according to the kind of grease or fat employed. Thus, in the case of palm oil, the soap consists for the most part of *palmitate* of soda or potassa. When spermaceti is used, the soap produced consists of *cetyl-ate* of potassa or soda, and instead of glycerin, an analogous body termed ethal is found in the mother-liquor. By far the greater majority of fats, however, yield when treated with alkalies, soaps containing only stearate, margarate, and oleate of potassa, if a soft soap, and of soda in the case of hard soaps. Resin, though employed in the manufacture of soap in the place of fixed oil or fat, is not to be considered analogous to a fat in its chemical constitution, or to be capable of forming with an alkali a proper soap by itself. Resin contains neither oxide of glyceryl nor oxide of cetyl, nor any equivalent for these substances, but is an indefinite mixture of three distinct bodies possessing well-marked acid properties; and hence named *sylic*, *pinic*, and *colopholic* acids, each of which is capable of entering into combination with alkalies, and of readily dissolving in alkaline solutions, though totally insoluble in pure water.

For the complete saponification of fats or oils, an excess of alkali is requisite, and is so much the more willingly employed, as it can be removed again without difficulty. The production of soap is by no means a momentary process, nor can it be done with the same exactness or rapidity as the decomposition of an ordinary salt. On the contrary, the manufacture consists of a number of stages, and these occupy a considerable length of time from the first mixing of the fat with the alkali, when a sudden emulsion is produced, to the formation of soap ready for use, or even to that point when the whole of the alkali is saturated with fatty acid. Acid salts are first produced with the oily acids, and these hold the remainder of the fat in solution, or in a state of division, until it also is able to combine with alkali, and transform the acid into neutral salts, or into finished soap. This reaction may easily be observed, if the fat is boiled with one-half the required quantity

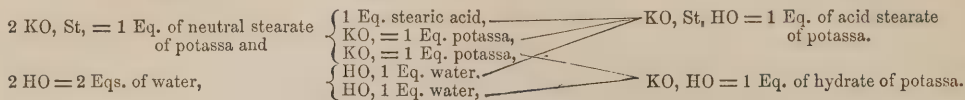
of alkali; the whole of the oil is in such case dissolved, but the solution becomes turbid on cooling, and when water is added, and the mixture again boiled, unsaponified fat separates, showing that this had only been retained in the fluid by the stearate or margarate of the alkali that had been formed.

HARD AND SOFT SOAP.—Soaps are divided into two classes, differing from each other in the material from which they are produced, and are distinguished by the names *hard* and *soft soap*. Hard soaps are made from fats, or vegetal fat oils, and soda; for soft soaps, the oleaginous material is usually a fish oil or vegetal drying oil, and the alkali, potassa. Hard soaps may, however, be made with potassa, provided a solid fat be employed; but soda soaps are invariably harder than potassa soaps, the unctuous material being the same. The hard soaps of animal fats are either white or marbled, and are particularly applicable for washing the finer articles of dress, the soft soaps being more caustic than the solid soda soaps. Of the hard soaps of commerce those made with oils, with the exception of palm-oil, are mixtures of margarate and oleate, with only a small proportion of stearate of soda; those made with animal fats are mixtures of stearate, margarate, and oleate of soda. On the continent, and wherever wood is abundant, potassa is frequently introduced in admixture with soda in the production of hard soaps.

PROPERTIES OF SOAPS.—Potassa and soda soaps are readily soluble in hot water and alcohol; the addition of a quantity of water to the aqueous solution produces a precipitation, the neutral salts of stearic and margaric acids decomposing into free alkali, which remains in solution, and acid stearate and margarate of alkali, which precipitates in the form of pearly, crystalline scales. Potassa soaps are more soluble in water than those containing soda. Stearate of soda may be regarded as the type of hard soaps; in contact with ten times as much water it suffers no striking change, while stearate of potassa under the same circumstances forms a thick paste, or a viscid solution. In these respects the margarates of potassa and soda closely resemble the corresponding stearates. Oleate of soda is soluble in ten parts of water, and oleate of potassa in four parts. The latter forms a jelly with two parts, and possesses such a strong affinity for water, that one hundred parts absorb one hundred and sixty-two when exposed to a humid atmosphere. It follows, therefore, that soaps are soft in proportion to the oleates, and hard in proportion to the stearates and margarates they contain; so that the softness or hardness of soap is not solely dependent upon the base that is employed.

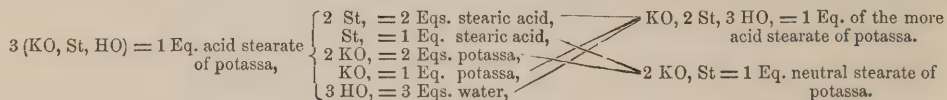
Soap of Commerce—that is, stearate, margarate, or oleate of alkali—is never dissolved by cold water without decomposition. The neutral salts are resolved into alkali, which dissolves, and into an acid salt, which is

precipitated. The same decomposition occurs when hot solutions of soap—particularly of dilute—are cooled. According to CHEVREUL, who particularly investigated this decomposition in the case of stearate of potassa, when a solution of this neutral salt—2 KO, St—is cooled, one-fourth of its potassa remains in solution, and a



Acid stearate of potassa, after being separated from the liquid as above, and treated with a thousand parts

mixture of neutral with acid stearate of potassa is separated. If the same salt is dissolved in five thousand parts of cold water, the acid stearate—KO, St—is alone precipitated in the form of pearly scales, and half of the potassa remains in solution according to the subjoined equations:—



The occurrence of these decompositions, which ensue equally with the margarates and oleates of potassa and soda, as with the stearates, affords an easy explanation of the appearance of the whitish turbidity always produced when soap is dissolved in even the purest water, and show, at the same time, that the alkalinity of soap-suds is solely due to the liberation of caustic potassa or soda; and this it is that affords the possibility of removing fatty impurities in water, which is the sole object of washing with soap.

It is of the utmost importance to the soap-boiler that he be well acquainted with the physical comportment of soaps with solutions of different salts, as, for instance, with chloride of sodium, carbonate of soda, the corresponding potassa salts, chloride of ammonium, and various others. These although not absolutely essential to the formation of soaps are very much concerned in the separation of the foreign matters that render hard soap impure; and are also useful to impart to it the proper amount of water. In practice, a solution of chloride of sodium is always employed for this purpose. The peculiar behavior of soap with a solution of this salt is thus described by LIEBIG:—If a piece of common hard soap be placed in a solution of salt at ordinary temperature, it floats upon the surface without ever being moistened, and if the liquid be heated to boiling, it separates without foam into gelatinous flocculæ, which collect on the surface, and upon cooling unite into a solid mass, from which the solution flows off like water from fat. If the flocculæ be taken out of the hot fluid, they congeal on cooling into an opaque mass, which may be pressed between the fingers into fine laminæ without adhering to them. If the solution is not quite saturated, the soap then takes up a certain quantity of water, and the flocculæ separate through the fluid on boiling. But even when the water contains one four-hundredth part of common salt, ebullition does not produce solution. If the soap is boiled in a dilute and alkaline solution of salt, and suffered to cool, it again collects on the surface of the fluid in a more or less solid state, depending on the greater or less degree of concentration of the solution; that is, on the quantity of water taken up by the soap. By boiling the dilute solution of salt with soap for a considerable time, the

of hot water, is again decomposed into neutral stearate of potassa, and a still more acid stearate, as follows:—

aqueous flocculæ intumesce, and the mixture assumes a foamy appearance, but still they are not dissolved, as the solution separates from them. The flocculæ, however, have become soft and pasty, even after cooling, and their pastiness depends on the quantity of water they have imbibed. By still continued boiling this character again changes, and in proportion as the water evaporating renders the solution more concentrated, the latter again extracts the water from the flocculæ; the liquid, however, continues to foam, but the bubbles are larger. At length a point is attained at which the solution becomes saturated; the larger iridescent bubbles formed just before disappear, and the liquid continues to boil without froth; all the soap collects as a translucent mass on the surface, and now the solution and soap cease to attract water from each other.

If the plastic soap be now removed and cooled, while the solution is pressed out, it becomes so solid as scarcely to receive an impression from the fingers. In this state it is called *grain soap*. The addition of salt, or its solution, to a concentrated alkaline menstruum of soap in water, precipitates the soap in gelatinous flocculæ, and the mixture behaves precisely as solid soap boiled with a dilute solution of salt. Carbonate of and caustic potassa act exactly as salt in separating soap from the alkaline fluid. The application of these facts to the manufacture of soap is obvious. The fat is kept boiling in an alkaline lie until all pasty matters disappear; but the lie should have only a certain strength, so that the soap may be perfectly dissolved in it. Thus tallow may be boiled for days in a caustic potassa solution, of specific gravity 1.25, without being saponified. If the lie be stronger a partial saponification ensues; but being insoluble in the fluid, the soap floats on the surface as a solid mass. By the gradual addition of water with continued boiling, the mass at a certain point becomes thick and clammy, and with more water an emulsion is formed; on continued heating, this becomes perfectly clear and transparent, if a sufficient quantity of alkali be present. In this state it may be drawn out into long threads, which on cooling either remain transparent, or are milky and gelatinous. As long as the hot mass, suffered to drop from a spatula, exhibits a milkiness or opalescence, the boiling is continued, or

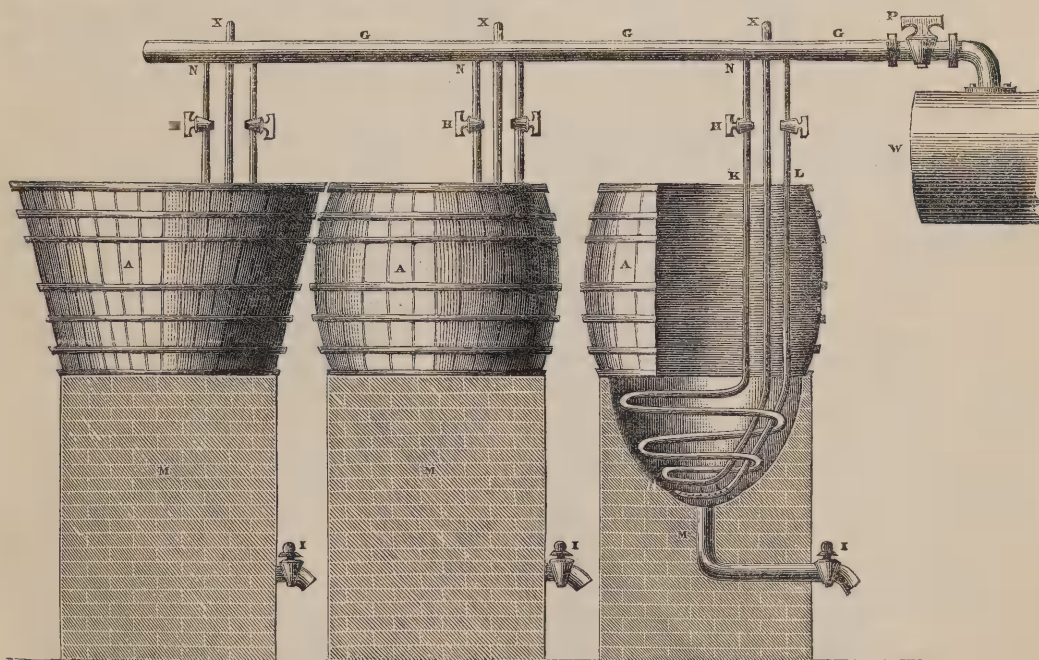
more alkali added. When excess of alkali is present, the milkiness arises either from imperfect saponification, or want of water; the former is known by dissolving a little impure water, which becomes perfectly clear when the whole is saponified.

If the lie contain lime the mixture is also turbid, but the addition of an alkaline carbonate causes the turbidity arising from this cause to disappear instantly. In order to separate the soap from water, free alkali, and glycerin, a large quantity of salt is gradually added to the boiling mass, waiting after each addition till that portion is completely dissolved; the first addition increases the consistency of the mass, while each successive portion renders it more fluid, till it loses its adhesive character, and drops from the spatula in short thick lumps. As soon as the congelation is complete; that is, when gelatinous flocculæ separate from a clear watery liquid, the fire is extinguished, the soap allowed to collect on the surface, and cooled either on the liquid, or ladled out and allowed to get solid. In being separated by means of salt from a very dilute solution, soap suffers an alteration in composition, the soap so thrown down being a bistearate, bimargarate, or binoleate of the alkali, instead of the neutral compound originally in solution; but when the solution is of moderate strength, the soap is separated unaltered in composition. The same results as those obtained by the use of common salt are also produced, although in a less

energetic manner, by chloride of potassium, carbonates of the alkalies, sulphate of soda, acetate of potassa, and chloride of ammonium. Of these, sulphate of soda and chloride of potassium have but a very slight action. Concentrated caustic lies also separate soap from its solution, in the same manner as with common salt; in weak caustic lie, on the contrary, soap is perfectly soluble. On this account soap-boilers, especially at the commencement of the operation, except in the case of cocoa-nut oil, always use weak lies, as the stronger would prevent the necessary amount of contact amongst the ingredients, and very much retard the process of saponification. Not only all foreign matters other than soaps, but also the base of the oils—glycerin—is completely separated from soap by means of caustic or saline solutions, in which it is perfectly soluble. The separation of the small quantities of earthy and metallic soaps, always formed during the process of saponification by means of impure alkalies, requires a distinct operation, termed the *fitting* process, which will be presently alluded to.

The Caldrons.—The boilers or caldrons used in the soap manufacture are formed of cast-iron or wrought-iron plate. Their capacity varies according to the quantity of soap to be produced at each operation. The pan or kettle is fixed in the brickwork, and so built round that the heat acts solely on the bottom. Before the repeal of the soap duty, the waste lies were required

Fig. 502.

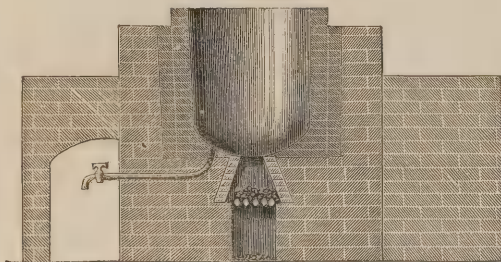


to be pumped out at the top, through the mass of soap. Now it is usual to withdraw these from the bottom, by means of a pipe fixed to the boiler. Fig. 503 is a section of the arrangements. The pans are usually cast with a flange at the upper rim, so that if necessary the boiler may be enlarged by adjusting a hollow cone

of wood, iron bound, and which is termed the *curb*. It may extend as high as desired, and should be surrounded with mason-work as the rest of the pan. In some manufactories the boiling of the soap is accomplished by means of steam, either conducted directly into the materials in the boiler, or when a too high

temperature is not desirable, by applying the steam to the outer surface of the caldron. The application of steam is a method of communicating heat to the caldrons,

Fig. 503.



far preferable to the old method of placing the boiler directly in contact with the fire. Not only is there a great saving of fuel, but less attention, and, consequently, fewer hands are required, while the facility of arresting ebullition at any desired moment is of great importance. In the annexed representation—Fig. 502—are shown three caldrons, A, A, A. The main pipe or feeder, *c*, is attached to the boiler, *w*, which is stationary, and generally placed against the wall immediately above the kettles or caldrons. These latter are partly of iron and partly of wood, the upper portion or *curb* being wood, well hooped round by iron rings, and the lower portion of cast-iron, and so shaped that the worm can lie closely to the sides, and that the blow-pipe can fit upon the bottom. The cock, *i*, is for the withdrawal of the spent lies. The pipe, *l*, serves when necessary to communicate additional heat to the contents of the pan, and is useful also to agitate the mass. In some manufactories the boiling caldrons are made wholly of wood, well fastened by iron clamps.

MANUFACTURE.—Hard Soaps.—The process of soap-making varies in some particulars according to the kind of oil or grease to be saponified, though the general method is the same for all. The lies or solutions of caustic soda having been prepared as previously directed, the whole quantity of unctuous material to be saponified at one operation is usually introduced into the boiler at once, and for every ton, from a hundred and fifty to two hundred gallons of caustic liquor of specific gravity $1.090 = 18^\circ$ Twaddell are added, and the whole is gently heated to ebullition. After boiling for an hour and a half or two hours, the whole forms a viscid emulsion, capable of being drawn out into clear threads. The soap now produced is in solution in the water, and requires to be separated before the spent lie can be withdrawn, and to complete the saponification, a fresh one applied. For this purpose a sufficient quantity of common salt is added, which, dissolving in the liquid, causes the soap—which, as previously observed, is quite insoluble in a strong solution of chloride of sodium—to rise to the surface.

When the soap paste has remained in the boiler a sufficient length of time to have become partially cool, it is ladled out into buckets or pails, conveyed to the frame-room, and poured into the frames to solidify. These frames or *sesses* consist of a pile of rectangular inclosures, measuring internally about forty-five inches

by fifteen inches. They should be very smooth, and so jointed as to fit closely together. When piled one upon the other, to the height of three or four feet, they form a tight square well fitted to receive the boiled soap paste. They are tightly bound together by clamps and screw rods. Cast-iron frames, as a substitute for the above, in the manufacture of yellow soaps, are of late introduction. These latter are formed of five rectangular plates, one for the bottom, two for the ends, and two for the sides, so arranged and fastened together as to form a well or reservoir of the same length and breadth as the wooden frames, and about five feet in height. These frames are put together and taken to pieces much more easily than those of wood, and the good conducting power of the iron considerably accelerates the cooling and solidifying of the soap. If the soap is allowed to solidify in the state in which it is run into the frames, it has a rough granulated texture, and is extremely hard. It is therefore usual to mix a small quantity of water with it in the frame, and afterwards agitate the mixture with a wooden *paddle* or *crutch* until nearly cold. By this means it acquires a finer grain, and is not nearly so hard.

The soap having become cold and dry, and in a state to be removed from the frames, which may be known by gentle pressure of the finger making no impression, the iron screw rods which bind the frames together are removed, and each frame is lifted off the soap, which is left a compact mass of the size of the interior of the frame. This mass is then marked round with a kind of iron toothed *scribe* or *dentier*. This instrument is shown in Fig. 504. The teeth are near or distant from each other accordingly as the blocks

Fig. 504.

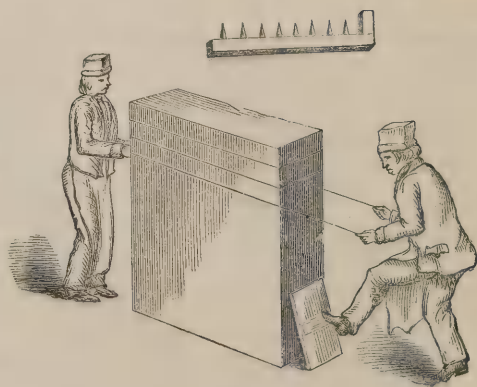


Fig. 505.

are desired of small or large size. The mass is then cut by means of a wire, as shown in Fig. 505, into slabs, and these are again sub-divided into bars. These bars are then removed to the drying-room, and piled upon one another crossways, interstices being left for the circulation of air, to facilitate the drying.

The process of the manufacture of soap, though constant in principle, varies in detail in different countries. The following is the method pursued in the United States, as described by MORRIS:—The strength of

the lie employed differs accordingly as the oil to be saponified is richer in olein or in solid constituent. The operation is commenced by pouring the lie into the boiling caldron to a third of its capacity. This is then heated to ebullition, and the oil is now poured in. The reaction is such that a magma is immediately formed. The proper formation of this magma is considered to be the most delicate and important part of the whole process, and if badly managed, a much greater quantity of lie is required to form the same weight of soap than otherwise would be. After pouring in the oil, the heat is decreased by opening the doors of the furnace, and when the mixture of oil and lie is complete, if necessary a further quantity of weak lie is added gradually, and with constant stirring during the addition, so as to insure thorough contact. The mass should remain homogeneous; the oil should neither rise to the surface nor descend to the bottom. If oil should present itself, it is then necessary to add more strong or weak lie, according to the capacity of the caldron. If the lie is in excess, a further quantity of oil must be added; always stirring briskly upon any addition of new material. The operation requires from eighteen to twenty hours for completion. It may, however, be greatly accelerated by throwing in the scrapings or the waste of soap already made. An excess of soda is recognized by the liquidity and transparency of the paste. If the oil is in excess it rises to the surface. The presence of a large proportion of common salt in the soda, also prevents more or less the proper formation of the magma. When this is the case to any considerable extent, the use of soap scraps is indispensable. The next step in the process is the removal of the large quantity of water which was required for the ample saponification of the fat. This is effected by the addition of lies containing common salt, and afterwards boiling the mixture from fifteen to twenty hours, constantly stirring during ebullition. When the mass opens in different places, the separation is complete. The fire is withdrawn, and the whole is now allowed three or four hours' repose, after which the settled waste lie is drawn off. A further quantity of lie, charged with common salt, is now added, and the mixture is gently boiled; being careful to remove from the sides of the caldron any adhering soap, so that all portions may be in contact with the lie. The mass now acquires more consistence. After some hours' repose, the settled waste lie is again withdrawn. Lie of specific gravity $1.10 = 20^\circ$ Twaddell is poured in, and the mixture is again boiled; by this it acquires a still greater consistence. After continued boiling for about three hours it is allowed to deposit, and the waste lie is again drawn off. This operation is repeated once more, but with strong lies, being careful to stir the paste while being heated, so that the whole may form a homogeneous mass, and allowing only a gentle ebullition. The soap at this stage begins to acquire firmness. The boiling with lie several times successively, serves not only to complete the saponification, but to wash and purify the soap. That it may be perfect, it is necessary to repeat the operation four or five times. As soon as complete, the fire should be withdrawn, and the mass allowed repose to settle and become somewhat cool,

and then ladled out and conveyed in buckets to the frames.

WHITE SOAP—CURD SOAP.—The unctuous material employed in the production of this soap may be tallow or lard, or olive, or well-bleached palm oil, or mixtures of these in almost any proportion. To produce one ton of soap, from ten to fourteen hundredweight of tallow or olive oil are required. The process of saponification is conducted as above described, with but slight variation, attending more particularly to the complete removal of the *alumino-ferruginous* impurities of the lie, which otherwise impart to the soap a coloration more or less intense. Their removal is effected by boiling the soap several times with fresh lies, or by thinning out the soap with a little lie, and applying gentle heat, then covering the caldron carefully and allowing it to settle. The upper strata of soap is afterwards ladled out and run into the cooling frames. The average composition of ordinary white tallow soap is—of alkali one part, of fatty acids about nine parts, and five to eight parts of water. In England by far the greater quantity of curd soap produced is made from tallow or mutton suet and soda only. Some manufacturers, however, substitute for one-fourth of the tallow as much lard or olive oil, and a soap is produced greatly superior in quality, and less liable to change by exposure. Soap made solely of tallow is, besides, inconveniently hard, and very difficult of solution. In France, and on the Continent, when tallow is saponified, olive oil is always added in the proportion of twenty to twenty-five per cent. of the oleaginous material. In England lard is not unfrequently used as the softening agent; and when applied in about the same proportion answers every purpose, while it has the advantage over olive oil, that it does not detract from the whiteness of the soap. The advantages gained by the addition of lard to olive oil or to tallow may be summed up as follows:—The soap remains unaltered for a longer period, does not emit the disagreeable odor of tallow, and the saponification is more perfect, as the excess of olein in the lard or oil compensates for the large amount of stearin in the tallow, thus inducing a more ready and perfect union of the alkali and oily acids. English white or curd soap is largely used by the cloth manufacturers of Yorkshire, and the lace and stocking bleachers of Nottingham. Tallow is not saponified to a very considerable extent on the continent; but in its stead, olive oil mixed with about one-fifth of rape oil is used in the manufacture of hard soaps. This addition of rape oil is always resorted to, because olive oil alone yields a soap as hard and compact, and as difficultly soluble, as soap made wholly of tallow and alkali. This, however, is not the case with rape oil, and other oils of a similar nature—that is, such oils as become thick and viscid by exposure; experience having demonstrated, though the reason is as yet unknown, that the oils which turn viscid the soonest by exposure, yield with soda softer soaps than those made with oils which, like olive oil, remain long limpid under the influence of the air. The admixture of rape oil with olive oil has therefore the effect of modifying the degree of hardness of the soap, just as when lard is saponified in conjunction with tallow.

YELLOW SOAP.—This variety of soap differs from the preceding and other kinds, inasmuch as a considerable quantity of *resin* enters into its constitution. This substance, as previously observed, is capable of entering into combination with the alkalies, to produce a detergent compound soluble in water. Besides the resin, or common fat, or inferior tallow, palm oil is also used to a considerable extent. The usual proportion of palm oil and resin are three and a half parts of the former to one of the latter; sometimes the proportion of resin is still greater, and the soap produced is then soft and dark colored. When the saponification of the oil is nearly complete—that is, at the last charge of the lie—the resin is introduced in a state of coarse powder, and well mixed with the soap by agitation. The mixture is then boiled for some hours; a small quantity of lie being added from time to time, if necessary, to preserve an excess of alkali until the soap is completely formed, when the lie may be withdrawn and one or two waters, or else weak lies, applied successively with agitation for the purpose of washing and purifying the soap. The resinous scum being removed for another operation, the soap is conveyed to the iron frames to solidify. Yellow soap usually contains, to one part of soda, from ten to eleven parts of oily acid and resin, with from twenty-four to fifty per cent. of water. If it contain a large proportion of water, it has just the same appearance as when it contains only a small proportion. When anything like fifty per cent. is present, it has been added while the soap was in the frames, for the purpose of fraud. If tallow or other grease be employed in the manufacture of yellow soap, instead of palm oil, the following is the mode of procedure:—Two thousand pounds of the oil or fat, six hundred pounds of resin, and from a hundred and fifty to a hundred and seventy-five gallons of soda lie of specific gravity 1.075 to $1.150 = 15^{\circ}$ to 30° Twaddell, are run into the boiler, and when the whole is melted, the mixture is heated to ebullition, stirring carefully all the time to prevent the resin adhering to the bottom and sides of the caldron. Should the mass begin to swell out, the heat must be decreased. The first boiling should be continued not more than two or three hours, on account of the facility with which the combination of the fat and alkali is effected. After six hours' repose the exhausted lie is withdrawn, and fresh substituted, and the whole is again boiled for three hours or more. After another repose of six hours, again draw off the spent lie, and renew it with fresh. The ebullitions are thus continued, day after day, until the soap has acquired a proper consistence, which may be ascertained by taking a small portion, and when cool, squeezing it between the thumb and finger. If hard thin scales are formed, it is finished, and after having boiled briskly the fire is removed; but if greasy, clammy, and soft, it is not perfect, and it is necessary to add more lie and reboil. The soap is now to be cooled by adding three bucketfuls of lie, and after two hours the liquor is withdrawn. Six or eight bucketfuls of water are now added, and the whole is again briskly boiled, stirring constantly until the soap is melted. A little of the boiling paste is now removed on a wooden spatula, and if it run clear from the lie,

more water is added, and the boiling is continued. If it should not run, too much water has already been added, and a half pailful of strong solution of salt must be thrown in.

The most delicate part of the operation is that of boiling, and it therefore requires particular attention. That it may be complete, the soap should, when a portion is taken on a spatula, and the latter is held in an oblique position, shake and disperse tremulously, as would a body of gelatinous consistence. Then the fire may be withdrawn, and the soap considered as finished. In France yellow soap is produced by a similar process as the other kinds of common soap, adding at the commencement of the operation fifteen to twenty per cent. of resin. Some manufacturers make a soap with but five to ten per cent. of resin, and this being lower-priced than soap made entirely of grease, has a more extensive sale, and is preferred especially for domestic purposes. By its property of dissolving more readily in sea-water than other soaps, it is also well adapted for use on shipboard. The common brown soap is made as the preceding, but by using a greater proportion of resin, and substituting for the tallow, either in whole or in part, the common kinds of grease, such as soap fat, bone fat, *et cetera*.

MOTTLED SOAP—MARBLED SOAP.—In the manufacture of this variety of soap, the same kinds of materials are used as for white soap, and its different appearance arises from the different mode of treatment of the soap, after the completion of saponification. By a reference to the general process of soap-making given above, it will be observed that even after the complete formation of soaps, that is, when the whole of the oil or fat used is decomposed, and the oily acids have entered into combination with alkali, the soap still requires further treatment before it is brought into a marketable condition. It exists now in the form of immovable globules, and it is necessary to cause these to coalesce into a homogeneous mass. This is effected by a process termed *fitting*, which consists in the fusion of the contents of the boiling caldron in a weak lie, or in water, and afterwards boiling the whole for a longer or shorter period, according to the kind of material operated upon, the mass being prevented from boiling out of the copper by dashing shovels into it, so as to break the froth and favor evaporation. During this process in making white or curd soap, the more or less colored impurities of the materials termed *nigre* or *nigger* fall to the bottom; but in making mottled soap, the mixture is left in a thick or viscid state, so that the impurities cannot subside, and is transferred to the frames in this condition. To produce a good marbled soap, it is necessary that this latter operation be very carefully conducted; as, if too great a quantity of liquid be added, or if the mixture of soap and water or weak lie cools too slowly, all the coloring matter falls to the bottom, leaving the upper stratum of soap perfectly white, while, on the other hand, if it becomes too quickly cold, the soap remains in the granular condition. THÉNARD compares the separation of the coloring material to a kind of crystallization, and MORFIT ascribes the result to the formation of an *alumino-ferruginous soap*, and the lesser solubility of this at a lower temperature. The

lower veins in mottled soap appear to be due to the presence of an exceedingly minute trace of sulphide of iron, derived from the last service of lie, in which it exists in solution as a double sulphide of sodium and iron. As a perfectly colorless lie, apparently free from every trace of iron, will produce mottling if allowed to separate slowly from soap, it has been questioned whether iron is really the coloring agent; but, as noticed by PARNELL, this seems to be proved from the fact that the ash which remains after the calcination of the brown parts of such soap, affords to reagents a sensibly larger quantity of iron than the white parts of the same sample of soap. Granting that the lie used may be free from iron, which, however, is very rarely the case if an alkaline sulphide be present, this has a solvent action on metallic iron, and will therefore take iron from the pans or boilers used; and even supposing the lie to be free from alkaline sulphide, it becomes a matter of doubt whether, in the process of boiling, a portion of sulphate may not be reduced to the state of sulphide by prolonged contact with the organic matter. In some cases—and in such, iron must be present in some form or other—the mottling is produced, or at least the proportion is increased by sprinkling on the surface of the soap, after being boiled with the last service of lie, a small quantity of very strong sulphuretted lie, which produces the mottling by filtering slowly through the mass of soap. At Marseilles and other places where olive oil is used in making soap, a quantity of sulphate of iron is added; in which case the mottling is produced, both by the black sulphide of iron, and by the oxide of iron—the red portion—which latter combines with fatty acids, producing a true ferruginous soap. The quantity of copperas requisite is about eighteen ounces to four hundred and fifty pounds of oil or fat. It is added first mixed with weak lie, and should be poured in during the coction of the soap, and before it has acquired too much consistence. When the soap is ladled out of the boiler, it is of a uniform slate tint; but as it becomes cool, the metallic portion separates into nodules, and by the trickling of the excess of lie through the mass, they assume those forms to which the term *mottled* is applied. By varying the proportion of sulphate of iron a tint is produced of a lighter or darker hue. Soaps containing this have exteriorly a rusty color, owing to the sesquioxidation of the iron at the expense of atmospheric oxygen, and this shade may be deepened by the addition of venetian red, or colcothar, into the particular tint to which the French apply technically a term signifying *hidden red*, and which upon the deep blue produces the appearance of marble, as seen in the variety known as *castile soap*. This peculiar tint may be communicated as well before as after the true marbling; for which purpose it is necessary to thin out the colcothar with water, and in adding it to incorporate it well with the soap. Generally, in the preparation of mottled soap, less care is exerted in the choice of materials than for white soaps, and the heterogeneous mixture of fatty substances, known as *kitchen stuff*, usually forms one of the materials.

COCOA-NUT OIL SOAP.—Cocoa-nut oil is very easy to saponify, and is used to a considerable extent in

the manufacture of white soap, as well *per se*, as in admixture with other oils and fatty matters. The disagreeable odor of this oil is removed most effectually and conveniently by boiling in a wooden vessel by means of steam, with a mixture of six pounds of sulphuric and twelve of hydrochloric acid to each tun of oil. The oil so purified is heated in the boiling caldron, with the addition of a portion of olive or some other readily saponifiable oil or fat, and the soda lies are gradually introduced in the usual manner. Towards the conclusion of the process of saponification, a quantity of caustic potassa lie is thrown in, and the boiling is continued as long as may be necessary. The soap thus formed requires, for its separation from the lies, a much larger proportion of salt or other saline matter, than the soaps formed of tallow, palm oil, or olive oil. Otherwise the process of separation is the same as for other soaps. Pure cocoa-nut oil soap, by the usual method of saponification, can only be obtained by the use of a very large quantity of common salt, and then contains so very little water, or is so extremely hard, that it cannot be cut with a knife. On this account the usual mode of proceeding is not followed, in the production of this soap. The principal distinction between cocoa-nut oil and other oils and fats is, that while the latter are most readily saponified by weak lies, cocoa-nut oil is quite unacted upon until the lies have obtained a considerably higher degree of concentration; saponification then suddenly commences, and proceeds with extraordinary rapidity. Only the strongest soda lies are employed in the production of this soap, and by taking pure and perfectly caustic lie, the use of salt in purifying the soap is dispensed with. Pure cocoa-nut oil hardens much too quickly to exhibit any distinct formation of curd, and is consequently incapable of marbling of itself; it is very white, translucent, exceedingly light, and forms a good lather, but has always a more or less offensive smell.

An important property of cocoa-nut oil is its power of combining with more water than can even be incorporated with tallow soap, and this property frequently leads to dishonest practices. Cocoa-nut oil actually produces no greater quantity of soap than an equal weight of tallow; but the soap from the former can easily be made to absorb one-third more water or lie, and, at the same time, exhibit no want of consistence or softness, as would be the case with other soaps. The more rancid cocoa-nut oil be, the more readily is it saponified.

As previously remarked, cocoa-nut oil is not usually saponified alone, but is added to other oils for the purpose of producing quickly solidifying soaps containing a large proportion of water. When equal parts of cocoa-nut oil and tallow are used, the soap has the smell of common tallow soap. The boiling is continued until a specimen exhibits the proper consistence under the thumb. Tallow itself could not be saponified under the same conditions; but the saponification begins with the cocoa-nut oil, and the tallow is then saponified by means of the presence of the cocoa-nut oil soap. The different varieties of this soap are marbled artificially. The blue or red coloring matter is rubbed up with a little of the soap, or better, with a separate portion

of good cocoa-nut oil soap, until the whole acquires a red or blue color. This is then placed in alternate layers with the colorless soap; and by stirring the mass together streaks and veins are produced in all directions.

MARSEILLES SOAP.—This variety of soap is produced by the saponification of olive oil alone. The process does not materially differ from that described for white soap. The duration of the operation is longer or shorter according to the quality of the oil. Some manufacturers use, in the fabrication of this soap, a certain proportion of poppy oil with the olive oil; and the addition is rather beneficial than otherwise, as the soap produced is less hard, and consequently more easily applicable to detergent purposes. It is at present manufactured on a considerable scale in this country.

An improvement on the old method of soap-making was invented by DUNN, and has been already alluded to. It consists in the application of streams of air to the materials, whilst in the course of saponification. The air is forced below their surface by means of a pump; and the saponification is said to be greatly accelerated, and the process otherwise much improved. The following is the method as stated by MORFIT:—Into each of the ordinary boiling caldrons a circular ring of pipe of about one and a half inch bore, and perforated with small holes, is fixed in the well of the kettle, just below the flange or joint, keeping it sufficiently off the bottom to allow a stirrer to be used to scrape the bottom when necessary. The pipe is supplied with atmospheric air from a cylinder blast, or other suitable forcing apparatus, and is connected with the latter by means of a pipe attached thereto, and rising up to the top of the kettle, where it is furnished with a stopcock and union-joint, for the purpose of connecting or disconnecting the parts of the pipe within and without the copper. For a clean yellow soap ninety gallons of lie of specific gravity $1.14 = 28^\circ$ Twaddell, are run into the caldron. The fire being kindled, the caldron is charged with two thousand and fifty pounds of grease; and as soon as the lie is at or near the boiling point, the blast is commenced, keeping up a brisk fire so as to continue the materials in the kettle as near ebullition as possible. When the lies are exhausted, an additional quantity is gradually added until the grease, oil, or fatty matter is taken up. Five hundred and fifty pounds of resin are then added—a bucketful at a time, with more lie occasionally, until three hundred gallons of the strength above-mentioned have been used, keeping the blast in action the whole time, and the contents of the kettle as nearly boiling as possible. When the whole of the resin is melted, and thoroughly incorporated with the saponaceous mass, and the strength of the lies taken up, the blast should be stopped, and the contents of the boiler briskly boiled, and then allowed to rest, that the spent lies may separate and deposit. These being now drawn off, the soap is then brought to strength by fresh lies as in the ordinary process of soap-boiling. During the operation of the blast, the soap must be kept in an *open* or *grained* state; and for this purpose salt or brine is to be added when necessary. Experience has shown that it is better not to make a change of lie during the operation of the blast, when lie of the

strength above-mentioned is used; but if weaker lie is employed, one or more changes may be made. It is found desirable, also, that the soap should be kept in a *weak* state during the passage of the streams of air through the materials; otherwise it is apt to swell up, from the air hanging in the grain; and this is found troublesome to remove, requiring long boiling. If dark-colored materials are used, it is well to keep the blast in operation three or four hours after the resin is melted; provided the soapy mass is kept *weak* and *open* or *grained*.

Another improvement in the manufacture of soaps was invented by Mr. ANDERSON, by means of which the soaps are more completely purified. This is described by MORFIT as follows:—In the manufacture of yellow or resin soap, the ordinary process is that of boiling the materials upon successive portions of alkaline lie until they become *strength*; that is, until the oily matter is perfectly saponified, after which the curd so produced is subjected to a purifying operation termed *fitting*, performed as follows:—The lie used in boiling to strength is carefully pumped off from the soapy paste; and the latter is diluted with weak lie or water, and boiled to the proper consistence. After two days' repose the lies settle out of the perfect soap, and there is found below the latter an inferior or second quality of soap termed *nigre* or *nigger*. The perfect soap is cleansed or lifted off carefully from this, and transferred to the cooling frames; the mass of imperfect soap either being added to the next charge, or concocted into an inferior soap. The process followed in making curd soap, is to boil the materials upon successive lies until they become saponified; after which, and when the curd is of proper consistence, it is removed carefully to the cooling frames without further treatment. The invention of Mr. ANDERSON, it will be observed, does not interfere with the usual mode of producing the soap, but refers only to its purification, and begins at that point where the materials having been properly saponified, the soap *ribbons out* well on the finger. At this stage, instead of boiling out the head, and finishing as heretofore practised, the new process is commenced by pumping out or drawing off the strong lie on which the materials have been boiled, and then adding weak lie or water in successive portions, and boiling the whole until the mass assumes a proper appearance for fitting. The whole is now allowed to stand at rest for from twenty-four to forty-eight hours, or until the *nigger* or imperfect portion of the soap is deposited. This latter may then be separated, either by pumping it off from under the purified compound into an adjacent kettle, or by removing carefully the upper stratum of purified soap by means of ladles or buckets.

Whichever method be pursued, the cleansed material must now be treated with the proper finishing lie for curd soap; which being added, the whole is boiled until the soap becomes of sufficient consistence to be transferred to the cooling frames. When the materials employed in the production of this soap are very impure, the fitting or purifying process as above described is repeated one or more times; in which case after the first separation of the imperfect soap,

the remaining partially-purified material is treated with a lie only of moderate strength, instead of the ordinary finishing lie, and the whole is boiled with weak lie or water until sufficiently diluted to allow the proper performance of the fitting process; after which, time is allowed for deposition, the imperfect soap is again removed, and after the addition of the finishing lie, the remainder is boiled to a curd as before. The further treatment of the separated *nigger* or imperfect soap and its conversion into mottled soap, is effected by adding to it in an ordinary caldron the usual finishing lie for a mottled soap, and boiling until it is of proper consistence to be removed to the frames. The quantity obtained from one charge of soap by the fitting or purifying process, is not enough to be conveniently boiled by itself; it is therefore set aside, and six or more batches operated upon at one time.

SOFT SOAP.—This variety of soap differs in many essential particulars from those already described. The alkali used in its production is potassa exclusively, and the oil, either in whole or in part, a drying oil, as that of hemp seed, poppies, *et cetera*, or fish oil, as whale or seal oil. The theory of the reaction of potassa upon fats and oils is precisely the same as in the case of soda. Soaps with potassa base are, however, manufactured on an entirely different system to those of soda or hard soaps. In the latter, the soap is withdrawn from the lie when only a portion of the oil has been saponified, and fresh lies are added until saponification is complete.

In the production of potassa or soft soaps, no lies are separated during the whole course of operation; the only object being the combination of the potassa with the fat or oil. Potassa soap, therefore, of course contains the whole of the base of the oils or glycerin, which is expelled from combination by the stronger base, as well as the impurities always existing in the lie, as carbonate of and caustic potassa, chloride of potassium, sulphate of potassa, and in small quantities, many other salts, which in the manufacture of hard soaps are removed in the exhausted lies. Potassa soap, also, always contains a much greater proportion of water than hard soaps, the quantity being in the majority of instances from fifty to sixty per cent. If desired, the glycerin of the fat and saline impurities of the lie might easily be removed by the application of strong lies towards the completion of the process, but on the large scale such a system is never pursued. A much larger proportion of alkali is consumed by a given weight of oil or fat, when saponified by potassa, than when soda is used, one part of pure potassa being taken up by from four and a half to five parts of oil; and hence the quantity of real soap produced from a given weight of oil or fat when saponified by potassa is considerably greater than when the alkali used is soda; and this quantity is still further augmented by the large proportion of water, together with the glycerin and saline impurities always contained in the lies, and which, as above stated, are not removed from the soap. From the great analogy which exists between soda and potassa compounds, it would be expected that potassa soap would be separated from its solutions by chloride of potassium, as soda soap is by chloride of sodium. This, however, is not the case, as when to a solution of potassa soap, procured

by treating oils or fats with caustic potassa lies, a considerable quantity of chloride of potassium is added, no separation of soap takes place; the salt dissolves in the soapy mixture, and the solution remains clear. Potassa soap can only be separated from the lies and eliminated glycerin by adding strong potassa lies after the soap is complete, and the excess of alkali and the glycerin may then be allowed to subside, and subsequently be more completely removed by placing the soap to drain. On the large scale, however, as before observed, soft soap is never separated as above; the soap solution is boiled down until homogeneous and of a proper pasty consistence.

The process of manufacture of soft soap is as follows; the proportions of oil and lie being regulated according to the strength of the latter, and the qualities operated upon at once varying with the greater or less capacity of the boiling caldron. According to MORFITT, whose extensive experience in the soap manufacture renders his remarks of great value, the larger the caldron the better and more economical. To be properly proportional, the diameter should always be greater than their depth, and should be only half filled with material, as the soap when boiling swells up and rises considerably. In some soaperies the whole of the oil and tallow is introduced at once, together with a portion of the lie, and the remainder of the lie is added after some hours' ebullition; in others, both the oil and lie are introduced gradually. The lie should, indeed, always be gradually added, and in small quantities at a time, spreading it superficially over the whole mass. As soon as the two clear liquids, separately introduced, unite together, the whole becomes much thicker, and in some cases boils quietly, but in others swells up into froth. In the latter case it must be thrashed with a stirring pole, and dosed with a sufficient quantity of lie to lessen the commotion and prevent loss of the material by running over. The caldron requires to be constantly watched while over the fire. If too much lie is added at the commencement, no union is effected between the oil and the alkali; and if the lies are too strong they seize on the oil too rapidly, and instead of becoming thick and viscid, the mass becomes clotted. This latter inconvenience may be remedied by adding lies of a lower degree of strength. If the lies are not sufficiently strong, combination ensues so tardily that part of the superabundant water must first be expelled by evaporation before a perfect union between the oil and alkali can be effected. When combination is perfect and the great foamings have subsided, the pasty mass should become clear and transparent, and free from clots or granules, and no acrid taste should be perceptible. To ascertain if this be the case, a small sample is taken out and cooled. If it should not be of proper consistence and free from opacity, the boiling is continued, and after some time another sample is taken, and so on until the soap is properly finished. If the test sample thickens on cooling, has a brown color, is perfectly homogeneous, and is not ropy when worked between the fingers, the soap is finished, and the fire should at once be withdrawn. A fair criterion of the quality of the soap is said to be furnished by a peculiar phenomenon observable during its cooling; a little opaque zone forming around the test-portion taken

from the caldron for an assay, indicates perfect saponification, and is called *strength*, the absence of which denotes a deficiency in strength; and when the zone vanishes soon after having made its appearance, the soap is said to have *false strength*. When it comes in the best form the soap is perfect, and may be secured in that state by removing the fire, and then proceeding as subsequently directed.

To allay the foaming and render the finished soap fit to be transferred to the barrels or casks without endangering its detergent quality or diminishing its causticity, the soap should be cooled as rapidly as possible. For this purpose a quantity of ready-made soap—a ton or more, according to the size of the caldron—is added to the hot mass. This, in melting, rapidly abstracts a portion of the heat of the recently made soap, until the degree of that and its own is uniform. The foaming having subsided, the soap is raked off into the barrels, in which it is sent away. In the manufacture of soft soap MORET observes, that it is better that the boiling should be too much than too little protracted. Soap which is not sufficiently cooked, changes and spoils, while the only disadvantage produced by excessive boiling is a diminution in the quantity of the product. The usual time requisite for a charge is six or seven hours, but varies with the strength of the lie, the temperature of the atmosphere, and other incidental circumstances.

In Great Britain a small proportion of tallow is usually introduced as one of the materials for the production of soft soap. This addition is for the purpose of producing the solid white granulations of stearate of potassa termed *figging*, because the soap then resembles the granular texture of a fig. Hence British soft soap presents the appearance of a brownish transparent body, through which white grains are disseminated. These figged granulations do not usually make their appearance until two or three weeks after the soap has been made, and during the hot summer months they do not appear at all. They are improperly considered to be a proof of the good quality of the soap, and hence the figged appearance has been imitated by the admixture of starch. Messrs. LUND and UNSWORTH of Liverpool are said to be the largest makers of soft soap in England. They generally turn out fifty or sixty tons weekly of a most excellent article.

The Scotch process for manufacturing soft soap is as follows:—Two hundred and seventy three gallons of whale or cod oil, and four hundred pounds of tallow are introduced into the soap pan, together with two hundred and fifty gallons of potassa lie, of such strength that one gallon contains six thousand six hundred grains of real potassa. Heat is now applied to the pan, and as the mixture approaches the boiling temperature, much froth appears, and to prevent boiling over, it is beaten down on the surface. Should it subside quickly into a doughy looking paste, it is an indication that a too strong lie has been used. Its proper appearance is that of a thin glue. There should now be added about forty-two gallons of a stronger lie, equivalent to eight thousand seven hundred grains of potassa per gallon, and after a short interval, an additional forty-two gallons; and thus successively

until nearly a total of six hundred gallons has been introduced. After properly boiling, to complete the saponification of the fats, soap will be obtained amounting in quantity to six thousand four hundred pounds, from the above proportions of materials.

American soft soap, MORET states, differs very little from the preceding in its mode of manufacture; two hundred pounds of oil saponified by seventy-two pounds of potassa in lies of specific gravity 1.110 = 22° Twaddell, yielding four hundred and fifty pounds of finished soap. Fish-oil soft soap has usually a dark-brown color, and that made from refuse fat and oil, a dirty-white shade. Soap made with colza oil is slightly bluish. When hempseed oil is used, the soap has a greenish color. The latter is by some consumers preferred to other kinds of soft soap; and hence ordinary soft soap made from fish oil is frequently tinged green by adding a small proportion of powdered indigo, or a solution of indigo in alkali, the yellow of the soap forming a green with the blue of the indigo. Soft soap is always of a pasty consistence, and even if excessively boiled, does not harden, but becomes scorched and dry. In this country it is chiefly used for fulling, and for the scouring and cleansing of woollen stuffs. Being possessed of greater solubility, and having a much more powerfully detergent action, it is also especially applicable for scouring floors and wooden utensils. In Germany, Belgium, and Holland, it is also used for washing linen, which thereby acquires a most disagreeable odor of oil. When chloride of sodium is added to soft or potassa soap, decomposition ensues, the chlorine of the salt seizes the potassium of the soap producing chloride of potassium; and at the same time, the sodium takes the place of the potassium in the soap, and a hard or soda soap results. The proportions recommended by PELLETIER and others for the conversion of soft into hard soaps, by means of the above-mentioned decomposition, are six pounds of salt to every three pounds of oil, and the solution of the salt in water is to be added in small portions and gradually to the soap, the latter being in a state of ebullition. The soda soap produced separates quickly from the lie, and the operation is terminated in the usual way. This process for producing hard soap is of great importance in those countries where soda is not to be procured, as potassa and its salts may be substituted for the latter in the process of saponification.

SILICATED SOAPS.—Many varieties of soap are met with in commerce termed silicated soaps. They are produced either by the addition of silica itself or an alkaline silicate to the soap paste, just before cooling and solidification. Under this title are included also those soaps admixed with pipe-clay, and matters of a similar nature, which, though not strictly silica soaps, are usually classed with them. Sand soaps differ from silica soaps inasmuch as in the latter the admixture has been prepared artificially, while in the former common white sand is the silicious ingredient, and the only preparation it has undergone is finely sifting. In the preparation of sand soap, the finely-sifted sand is added to ordinary white soap and thoroughly incorporated with it while in the pasty condition, in the proportion of seven or eight per cent; and as soon as the mass has

cooled, it is taken from the frame and cut into tablets or moulded into balls. Of the three silicated soaps, the first that claims mention is that prepared by Mr. GOSSAGE's patent process. It consists in the introduction into soaps prepared from fatty or resinous materials of a highly concentrated solution of silicate of alkali. The process for the preparation of this silicate, termed also *soluble glass*, is described in the specification as follows:—When soda is used as the alkaline solution to be combined with silica, nine parts of soda ash are mixed with eleven parts of clear sand, and the mixture is to be fused in a reverberatory furnace, provided with a tap-hole through which to allow the finished product to run off. Sufficient heat is to be applied to the mixture, stirring from time to time until combination has been effected; the product is then drawn, and received either in metallic moulds, or in moulds formed of damp or moistened sand. The charge for a furnace having a bed or sole measuring sixty square feet, is about a ton of the mixed sand and alkali, and each charge requires four or five hours to be properly fused and combined. For the preparation of silicate of potassa the proportions are equal weights of crude carbonate of potassa and sand, and these are melted exactly as in the production of silicate of soda. It is always desirable to use such proportions of alkali and sand for the production of the silicate, that the latter may be almost wholly soluble in water; when the alkali is deficient, however, this is not the case, and to obtain perfect solution, it is necessary to use as the solvent a solution of caustic soda or potassa.

The solution of the perfect silicate may be effected simply by grinding the latter to powder, and agitating this in a pan containing boiling water; but a much preferable method of solving is, by the employment of an apparatus consisting of a vessel formed of iron plates, or other suitable materials, which vessel is fitted with a perforated diaphragm or false bottom placed about mid-way between top and bottom. The silicate, first broken into small lumps, is placed upon the false bottom, and hot water is introduced into the vessel to a sufficient height to cover the pieces of glass to be dissolved. Steam is then introduced into the water so as to maintain the latter at a high temperature.

As the glass dissolves, it communicates additional gravity to the water, and the heavier solution descends in the vessel whilst the lighter fluid rises, and coming in contact with the glass also dissolves it, and acquiring density again descends. In this manner a continued circulation of the fluid takes place, and the glass becomes nearly all dissolved, yielding a strong solution.

After allowing undissolved matters to deposit, the solution is transferred to a cast-iron evaporating pan, and by the application of heat concentrated until of specific gravity 1.450, when it becomes viscous on cooling, and is then in a condition to be added to the soap. When the solution of the silica is to be added to a soda soap, the latter, prepared in the usual manner, is to be transferred from the caldron into a tub or pan, termed the mixing vessel, capable of containing about fourteen hundredweight of soap, and the viscous solution of silicate of soda is to be added in such proportions as to yield the particular quality of soap

desired to be produced; and the mixture is then well agitated by means of crutches or paddles. The soap and the viscous solution should be each at such a degree of heat that the mixture, when formed, may be at a temperature of 160°, and the agitation is to be continued until the temperature is reduced ten degrees, that is, to about 150°. The mixture is then transferred to the cooling frames, and agitated therein by means of crutches, until it becomes of such consistence as to render its continuance no longer practicable.

Although the mixture of the solution of silica with the soap may be effected by means of crutches worked by hand, as above described, it may be stated that when a more rapid agitation is applied than can be effected by this means, the soap produced is a more perfect mixture, and of more uniform quality.

For admixture with soft soap, the soluble glass is formed by the fusion of a mixture of sand and potassa, as previously mentioned, for the preparation of a silicate of potassa. This is dissolved, and after concentrating the solution to the viscous condition, it is mixed with the soft soap, exactly as described in the case of soda or hard soaps. As the proportional amount of alkali contained in a mixture of soap with soluble glass is greater than that contained in the unmixed soap—if it is desired to reduce this amount, as the excess of alkali may be injurious for some purposes to which the soap may be applied, it is effected by the addition to the solution of the silicate of sulphuric or hydrochloric acid, previously to its reduction to the viscous condition. The mixed silicated soaps may be obtained of any requisite degree of hardness by the greater or less concentration of the solution of soluble glass. The compound soaps produced by the above process, the patentee states, are possessed of valuable detergent properties, independently of the real soap contained in them.

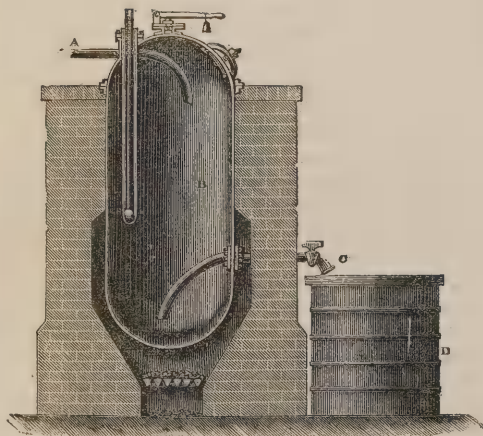
In the process invented by Mr. SHERIDAN for the preparation of silicated soap, either calcined flint, or quartz, or sand is used for the production of soluble glass. If sand is the silicious ingredient, he directs that it be mixed with carbonate of soda in the proportion of one part of sand to three of soda, and the mixture is then to be calcined to fusion in a reverberatory furnace. The product of calcination is drawn out into water and dissolved by the aid of heat. Thus far the process resembles that of Mr. GOSSAGE. Mr. SHERIDAN, however, now directs that a current of carbonic acid be passed through the solution of silicate of soda, whereby the silica is displaced from combination and precipitated in a gelatinous form. From this the liquid containing the soda, reconverted to the state of carbonate, is withdrawn, and evaporated to dryness for use again; the precipitated silica is mixed with caustic soda or potassa of specific gravity 1.1515 = 30° Twaddell, and boiled for eight hours, with constant stirring, until it becomes a homogeneous mass. This latter part of the process seems a very useless operation. It is simply the destruction of a compound already in the liquid condition, and its reproduction in exactly the same state, but by another and more objectionable mode of treatment—objectionable because combination between silica and an alkali is effected

much more easily and perfectly by fusion than by ebullition of the materials together with water. When the silicious ingredient is flint or quartz, the calcined material is to be reduced to nearly an impalpable powder by wet grinding with horizontal stones. The powder obtained is thinned out with about twenty per cent. of water, and then boiled with caustic soda lies of the strength above mentioned, for eight hours, or until it becomes a homogeneous mass. In this condition, in which it is technically termed *detergent mixture*, it is ready to be mixed with the soap paste.

A method for the preparation of silicated soap was also invented by Mr. DUNN, in which either silica itself, or an alkaline silicate, is made to unite with soap under steam pressure. According to the author of this process, the method is also applicable to the manufacture of soap even when silica is not an ingredient, with the advantage over the usual mode of boiling, of effecting a more perfect union of the ingredients in a shorter time, with greater economy, and at a diminution of expense.

The apparatus employed is represented in section, Fig. 506. The boiler, B, should be furnished with a

Fig. 506.



man-hole, safety valve, a thermometer plunged into a mercury chamber, and all the ordinary appendages of such an apparatus. A is the feed-pipe, and C the pipe through which to discharge the finished product. The crushed flint or quartz to be combined with the soap is mixed with caustic soda or potassa lie, in the proportion of one hundredweight of silica to one hundred gallons of lie of specific gravity $1.16 = 32^\circ$ Twaddell, and introduced into the steam-tight boiler. The fire is then kindled, the valve being so regulated as to allow the temperature of the materials to rise gradually to about 310° , or at a pressure of fifty to seventy pounds to the square inch. When it has remained at this temperature for about three or four hours, the contents are discharged and cooled down. The solution of silicate of potassa or soda thus obtained, according to the kind of alkali used, is added in the proper proportion to the soap paste, either in the caldron or frame after the saponification is complete, and before the soap is become cold.

SULPHATED SOAP.—The variety known to manufacturers and in commerce as sulphated soap, is produced by a process patented by Dr. NORMANDY. The object of the patent appears to be, to enable manufacturers to produce a soap from inferior oils and fats possessed of detergent properties, and also of a hardness equal to that from oleaginous bodies of much higher value. The great objection to soaps made from the inferior kind of fats, and also to soaps containing more than a due proportion of resin, is their very ready solubility in water, in consequence of which great waste is always experienced when these soaps are used for washing or cleansing purposes. By Dr. NORMANDY'S process, a soap is obtained from the cheaper oil possessed of equal detergent properties, and also of an equal degree of hardness, to that obtained by the employment of the more valuable fats and oils; thus rendering a large class of oleaginous bodies available in soap-making, to which purpose they were not previously applicable. The following, extracted from the specification of the patent, will render the process sufficiently intelligible.

When the soap is made in the usual manner, and is ready to be cleansed, there is to be introduced and crutched into it a certain quantity of neutral anhydrous sulphate of soda, or of neutral sulphite of soda, or of the two salts conjointly. These salts have the property of imparting to soap made with more than the usual proportion of resin, or with those kinds of fat or grease known as *weak goods*, a greater degree of hardness than they would otherwise possess; and of rendering such soaps generally of a paler color, and enabling them to retain their weight better than would be the case without such addition. The soap containing sulphite of soda has, in addition, the property of removing from textile fabrics and fibrous substances the chlorine which they are apt to retain after bleaching. The mode of procedure with the sulphate of soda, or *salt cake*, is as follows:—

The salt is to be treated with a quantity of hot water, less than is necessary to dissolve the whole of it, and to the saturated solution thus obtained as much solution of caustic or carbonate of alkali is added as is necessary to impart to the liquid a faint alkaline reaction. This addition is made not only to saturate any free acids that may be present, but also to remove the sesquioxide of iron always contained in crude salt cake, and which, by this treatment, will be precipitated. When this precipitate has completely subsided, and the supernatant liquor is perfectly clear, as much of the latter is added to the soap paste as is necessary to confer upon it the requisite degree of hardness when cold; the particular quantity varying according to the nature of the fat or oil saponified, or to the proportion of resin present. The mixture of salt-cake solution and of soap are to be thoroughly incorporated by stirring or crutching, continuing the agitation until the mass has become so hard that the stirring can be no longer practised. When the sulphite of soda is used, the patentee recommends that it be dissolved in as little hot water as is necessary for the purpose; and the solution is added to the soap exactly as above described for the sulphate of the same base, or salt

cake. If the salt be a bisulphite of soda, or if it is not in a state of purity—in other words, if it contain an excess of sulphurous acid, or be contaminated by oxide of iron—the excess of acid should be neutralized, by adding to the solution of the salt as much carbonate of or caustic soda as will impart a slight alkaline reaction; and after allowing the separated matters to deposit, the clear supernatant liquor is to be introduced and crutched into the soap, precisely as directed above in reference to the salt cake. The usefulness of this invention has been tested and carefully examined by several eminent chemists, among others by HOFMANN, MILLER, and URE, all of whom speak in high terms of its merits; and the Editor is gratified to have this opportunity to add his testimony as to the value of an invention the object of which is to supply a cheap soap as economical to the consumer as that produced by the more expensive fats and oils.

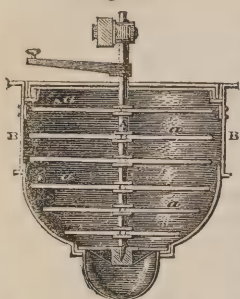
SNELL'S DEXTRIN SOAP.—This soap contains, in a state of admixture, a greater or less amount of vegetal matter, obtained from either potatoes or other sources. It is termed by the inventor dextrin soap; as prepared, however, according to his directions, no dextrin enters into its constitution, but, instead of this, woody fibre and unaltered starch. The method of preparation is said to be preferable to the old plan of combining farina with alum and soda in the manufacture of soap, inasmuch as it insures the perfect incorporation of the admixture with the saponified fats and oils, whereas, when they are previously acted upon by alum and soda, their tendency to union is partially impaired. The vegetal matter used by the inventor is obtained from potatoes as follows:—The washed potatoes are reduced to as fine a pulp as possible, by a revolving cylinder furnished with parallel plates of steel or iron. These plates have fine teeth like saws, the teeth rising just above the surface of the cylinder under a hopper, which receives the potatoes. The pulp falls on sieves or screws below, and passes over the upper sieve. This is a plane of five feet in breadth and eight in length, with one or two bars crosswise, covered with a wire-cloth of thirty holes to the inch. At the top, and about midway down the sieve, are pipes containing water, so arranged that the water shall run from the pipes through small holes the whole breadth of the sieve, the finer parts of the potatoes running through the meshes of the sieve into a vat. The finer parts, termed dextrin by the inventor, which fall on a wooden plane placed under the second sieve, but in a contrary direction thereto, are received in vats, where they are repeatedly washed over sieves of finer wire-cloth until cleansed from all impurities. The grosser parts—fibre—are washed over coarse sieves. The finer parts, having precipitated, are taken up in buckets, and are fit for use; the coarse portion remains in a vat covered with water until required for use, or the dextrin may be dried by any convenient means, and preserved in the dry state. The usual proportion of dextrin to soap is from three hundred to three hundred and fifty pounds of the first, mixed with a hundred and fifty pounds of water, to every ton of tallow or oil saponified. The mixture of water and dextrin having been allowed to stand for an hour,

should be further treated with six hundred pounds of water, as subsequently described. The white soap should be made of tallow, and by steam heat; and when as much alkali has been added as can be taken up in the usual way, and when the soap is in a fit state to transfer to the frames, there is to be added from four hundred and fifty to five hundred pounds of dextrin in its wet state; and after being further mixed with six hundred pounds of boiling water, or as much as is sufficient to convert it into a thick paste, this paste is to be poured in by pailfuls into the soap, the latter being well agitated during and after each addition. When the mixture is homogeneous, and has been heated, it may be put into a frame for cooling, and afterwards cut up in the usual way. Before adding the mixture of dextrin and water, the spent lie must be pumped or otherwise withdrawn from the caldron. When, as in the ordinary method of manufacture, yellow soap is made from resin, and is *fitted* or purified from portions of imperfect soap, coloring matters, *et cetera*, it should be heated with steam, and dosed with the proper proportion of dextrin, as above directed. If no resin is used, a larger quantity of dextrin may be applied, and the operation of fitting is not then absolutely necessary. In the manufacture of either the brown or yellow variety of common soap, the addition of a quantity of the fibre, first mixed with a sufficient quantity of water to make it of thick creamy consistence, will render the product, especially when an excess of alkali is present, of much better quality and color, and it will then also dissolve much less rapidly in hot water. If a naked fire is used for the soap thus mixed, the dextrin is liable to become carbonized, and the separated charcoal would then communicate to the soap a black, or at least a darker color, than when steam is applied. The latter should therefore be always used in the above process of admixture.

A person named HAWES some years ago invented a process for the production of soap, in which intimate combination and admixture of the soap ingredients without boiling induces combination and perfect saponification of the fat with the alkali. By this method, the high degree of heat requisite in making soap by the usual process is entirely dispensed with. His mode of procedure is, as follows, described as for tallow; but, according to the inventor, it is equally applicable to the oils and fatty matters ordinarily employed as soap ingredients:—Two tons and a half of tallow, or any given quantity, are taken and melted at as low a degree of heat as possible, and then mixed with the quantity of alkaline lie required to completely saturate the tallow and convert it into soap. The mixing is performed by mechanical means. Ordinary soap boilers' lie is used, preference being given to that made from the strongest and purest alkali. The saponification of the tallow or other fatty matter, may be ascertained by its absorption or combination with the lie, care having been taken, in the first instance, to use a sufficient quantity of the latter; the proper proportion, it must be observed, varying according to the nature of the fat or oil. To each hundred pounds of tallow are required about

twenty gallons of lie, made from strong alkali, and of specific gravity $1.125 = 25^{\circ}$ Twaddell. An ordinary boiling caldron may be used as the combining vessel, with the addition of a machine to produce an intimate admixture, and the minute redivision of the tallow. Figs. 507 and 508 will convey an idea of this apparatus.

Fig. 507.



An upright shaft, A, Fig. 507, which may be of wood or iron, and from which arms, a, a, a, a, radiate to the sides of the caldron, is fixed permanently or temporarily in the copper. The mode of fixing and the material used, will depend on the nature of the caldron and the convenience of the manufacturer. An oscillating or rotatory motion is given to the shaft and connected arms by any of the ordinary methods of communicating motive power. If more convenient, a cylinder—Fig. 508—may be employed, with a shaft, C, passing through it horizontally,

Fig. 508.



and from which arms, c, c, c, c, c, radiate, when a rotatory motion will thoroughly incorporate the fatty matter and the lie. For two and a half tons of tallow the cylinder should be about six feet in diameter and twelve feet in length. At D it must be provided with convenient doors for filling and discharging the materials. The caldron or cylinder having been charged with tallow, motion is communicated to the machine, and the lie is then gradually added. In a short time every particle of the fatty matter will be brought into contact with alkaline lie, and by such means saponification will be effected. The agitation must be continued for about three hours, or until the tallow appears to be completely saponified, which is known by the mass becoming thick, after which it is allowed to stand from one to four days, according to the quantity of the paste. When a cylinder is used in the above operation, the lie is run in, and motion communicated to the shaft immediately after the introduction of the tallow, the latter being only sufficiently heated to retain it in the fluid state, and the agitation is continued from three to four hours, or less if the tallow is perfectly saponified before its expiration. As the benefit of this process arises mainly from the saponification of the ordinary materials in a comparatively cold state, it is desirable that as soon as the mass thickens and the lie is absorbed, the cylinder should be emptied and the contents turned into an ordinary caldron, preparatory to being finished and converted into yellow soap by the addition of resin, or into mottled or white soap by the operation of finishing lies, according to the usual method. By this transfer from the cylinder to the caldron, time is allowed for the combination of the tallow and alkali to become perfect.

Another method for the manufacture of soap, according to the patentee more particularly applicable to palm-oil soap, was devised by Mr. WALTERSON of Manchester. The inventor claims for his process that a purer and more perfect soap is produced in a much shorter period of time than by the ordinary method, the soap being sufficiently hard for sale or use in the course of a few hours. His method consists in a mode of mixing or combining the oils or fatty matters employed with caustic soda, and in subsequently adding water for the purpose of converting such mixture or produce into soap. The ingredients used are animal or vegetal oil, either separately or mixed, caustic soda lie of 22° Twaddell, and water if possible free from any earthy or metallic impurity. The following description of the process applies more particularly to the production of palm-oil soap, and requires to be variably modified when other oils or fats are to be saponified. The quantity of bleached palm oil taken for one operation is seven hundred and eighty-four pounds; and after having melted this in a caldron, there is to be added gradually four hundred and seven pounds of caustic soda lie, testing 22° Twaddell, and the whole is carefully and thoroughly intermixed by agitation. The heat is then gradually increased, and the mixture constantly stirred, so as not to allow it to concrete on the bottom of the pan. After the operation has been continued three or four hours, the mixture assumes a whitish appearance, and by continuing the heat the aqueous portion is entirely evaporated, and the mass reduced to a perfectly dry state. The heat is now increased, and in a short time the mass again assumes the liquid form, and becomes of a brown color, which, according to the inventor, shows that combination with the alkali has been effected. The fire is then speedily withdrawn, and the agitation of the mass is continued as long as any fear of scorching is apprehended, after which the pan is left to become cool. The solid product of this operation is then to be broken up into powder, to which is afterwards added forty-five gallons of water, and the mixture is well agitated for about half an hour. Heat is then applied, and the contents of the pan raised to boiling, and kept so for about three hours, the stirring and agitation being continued during the whole period. As soon as the evaporation has been carried to the desired extent, and the soap appears of proper consistence, it is allowed slowly to cool. The contents of the pan, still in a liquid form, are then transferred to the ordinary frames, and left to cool and solidify, and in twenty-four hours the soap will be sufficiently hard to cut into bars. Soap prepared according to the above method, is never of so fine a color as that prepared by the old process from the same ingredients; besides which it is also less pure, as it contains of course all the saline impurities of the lie. The only advantage appears to be that the soap is finished in a much shorter period, but this, in the Editor's opinion, does not counterbalance the great disadvantages above mentioned.

Since the remission of the duty on soap, a process for its manufacture has been introduced by H. C. JENNINGS, but has not been adopted on a very considerable scale; for though it undoubtedly gives a purer

and more perfect soap, the expense of production is much greater. In this method the oleaginous ingredient used is stearic or margaric acid as nearly pure as possible, and the alkali is derived from bicarbonates of potassa or soda; the fatty acids, possessing a decomposing power over these salts, render their previous caustization unnecessary. The fatty acids and solution of alkaline bicarbonate of specific gravity 1.500 are mixed in proper proportions, and heated at 212° until an intimate combination is obtained. The mass is then allowed to cool down to about 60°, and there is now added to each hundred pounds one pound of solution of ammonia of specific gravity .880, and the same quantity of the strongest caustic potassa lie. These are to be added gradually, and well stirred with the soap until thoroughly mixed. The quantity of caustic alkali required to be added is greater or less in proportion to the state of purity of the fatty acids saponified. Lastly, the separation of the soap is effected in the usual manner by means of common salt or sulphate of soda. In the manufacture of yellow soap by the preceding method, there is added previously to the addition of caustic soda or potassa lie, fifteen to eighteen pounds per cent. of resin, first dissolved by boiling with a solution of pearl ash and common soda ash in equal proportions, so as to give a solution of specific gravity 1.800, while boiling hot. This is added to the solution of soap, and afterwards there is poured in a sufficient quantity of caustic lie to produce perfect saponification, and the soap is then separated as before. The Editor would especially recommend the above process of saponification for the production of the potassa soap ordered by the London Pharmacopœia. It is indeed the only method by which a perfectly pure potassa soap can be procured. This soap not being separable from its solutions, like soda soap, by salts of soda or potassa, as ordinarily prepared, is always contaminated by glycerin and other impurities.

In the manufacture of the variety known as GWYN and WILSON'S soap, the oils and fatty matters employed are heated with concentrated sulphuric acid, by which decomposition of the fats is effected, and glycerin eliminated, while the oily acids probably enter into combination with sulphuric acid. The fat so treated becomes much harder and less readily fusible, and is likewise rendered much more easily saponifiable, although it is true that not only a greater proportion of alkali is required, but the amount of product obtained is less than when the fat is saponified in the usual way. The following is the method of procedure as described by the inventors:—Ten tons of palm oil, whale oil, or other oily matter, are put into a wrought-iron vessel provided with a perforated steam worm, through which steam is admitted until the contents are heated to 350°. The fatty matter is then run into a tank formed of brick, lined with lead, and sunk into the ground. The tank is furnished with a pipe for the introduction of steam, but which does not terminate in a worm, as it would be liable to become choked by the sediment from the fat. The cover of the tank is made of wood, lined with sheet lead, and has two man-holes closed by an oil joint about eight inches deep;

through the cover a pipe passes connected with a high shaft, to allow the escape of offensive vapors. Two thousand pounds of concentrated sulphuric acid, specific gravity 1.80, are poured into the tank, the temperature of the mass being at the same time carefully watched by means of a thermometer immersed in it, and not allowed to exceed 350°. The heat is regulated partly by slackening the speed at which the acid is poured in, and partly by diminishing the quantity of steam admitted into the tank. The introduction of steam is continued throughout the operation; but as soon as the whole of the acid has been added, the fire employed for heating the steam is extinguished, and after that the steam continued for about four hours. The steam is heated after it leaves the boiler, by passing through pipes placed over a fire. At the expiration of four hours the steam is shut off, and a large pump introduced through a pipe in the cover of the tank; then as soon as vapors cease to be evolved, and the pump can be worked, the product is pumped into a wooden vessel, lined with lead, and provided with a steam worm. In this vessel the fatty matter is washed by means of free steam, with about half its bulk of water, for two hours, and then allowed twelve hours to separate.

TOILET SOAPS — SCENTED SOAPS.—The great variety of soaps thus designated, are usually prepared by remelting and clarifying white or curd soap, and adding various perfumes, colors, *et cetera*. These operations belong more properly to perfumery than to the soap manufacture; and their preparation has therefore been included in the article devoted to the consideration of this art, Vol. II., pages 676 to 679. Sometimes, however, since the remission of the soap duty in this country, the perfumer prepares soap directly by the cold process above described, and this is a more convenient method. The marbling of these soaps is produced by rubbing up the coloring material, such as vermilion, smalts, or ultramarine, with a little olive oil or soap, a small portion of which being taken on a palette knife, is pushed through the melted mass; thus the pink color of rose soap is produced by vermilion; blue by means of ultramarine; and brown by the addition of the various kinds of ochres and umbers. The cakes or tablets are formed by placing a soft mass of soap in a mould fixed in a lever press; the mould consists of a top and bottom die, fitting into a loose ring; by a sudden pressure the shapeless mass assumes the form of the ring, and is embossed on the top and bottom. Soap is ornamented with colored cameos by first forming the cake at a press, which makes a depression for the reception of the differently-colored soap, which latter is put in by hand, and the colored portion is embossed at a second press.

A very superior and beautiful marbled soap is manufactured by the Messrs. CROSFIELD of Warrington, Lancashire.

NAPLES SOAP.—This, so highly esteemed as a shaving soap, is said to be produced by saponifying mutton suet with lime, and then separating the fatty acids from the soap so formed by means of a mineral acid. These fatty acids are afterwards combined with caustic potassa by ebullition in the usual way. FAISZT, who

examined Naples soap, gives the following as its composition centesimally :—

Fatty acids,	57.14
Potassa combined with fatty acids,	10.39
Sulphate of potassa, chloride of potassium, with a trace of carbonate of potassa,	4.22
Silica, <i>et cetera</i> ,	0.46
Water,	27.68
Loss,	0.11
	100.00

ADULTERATION.—In the manufacture of soap certain substances are frequently added besides the fat, alkali, and water essential to its production. These additions cannot always be considered as sophistications, inasmuch as in some cases the quality of the soap is thereby greatly improved. Thus, in Dr. NORMANDY'S patented process, the addition of a small proportion of fused sulphate of soda to an otherwise very soft soap, confers upon it a hardness which prevents its melting or dissolving too rapidly in the process of washing. Though it may be said that the manufacturer is, by such addition, enabled to use an inferior oil or fat, still no deception is practised, as the soap so produced is little inferior in detergent properties to the soaps of the better kinds of fat, while it may be purchased at a much lower price. Other additions are also frequently made. In those cases, however, in which the substance added rather improves than deteriorates the quality of the soap, it cannot be considered as a fraud. It is true that soap is extensively and fraudulently adulterated in the true sense of the term. The Editor would remark, however, that in his opinion the public craving for cheap goods has urged upon the makers the necessity of preparing soap at a low price; and as the simplest mode of doing so was to incorporate saline water with the curd, when in the act of solidifying in the frames, to the extent commensurate with the reduced price, this mode has been adopted. So far as this addition is concerned, it does not involve the character of the manufacturer or dealer; but when the addition of water is covertly made by the maker, and the article sold as a better quality, as is frequently done, at once the public is defrauded. In like manner, dealers are in the habit of purchasing soaps at cheap rates—soaps which are highly adulterated—with the view of disposing of them at prices which better qualities command. Here, again, the consumer bears the weight of the villany, whilst its guilt presses upon the dealer, and the maker even does not escape with impunity. Certainly the maker, and the maker only, can protect the public from fraud in the matter of soap. By making certain qualities of soaps with definite and invariable amounts of ingredients, the public would in a short time become so well acquainted with the quality of the article, that inferior kinds which the cupidity of some makers might induce them to utter, would rapidly meet with its condemnation. If, however, the consumers will always purchase in the cheapest market, and whatever be the price asked, will, if possible, obtain the article at a still lower rate, they must expect to be imposed upon.

ANALYSIS.—Under this head the most important point to be considered is the proper amount of water in soaps. The proportion of water in mottled or mar-

bled soap, should never exceed thirty to thirty-five per cent. It is indeed impossible to introduce an excess of water into the paste of mottled soap, since the mottling being due to the presence of sulphide of iron and other ferruginous compounds, held partly in solution and partly in a state of suspension, if the soap has not a certain retentiveness the insoluble iron compounds would precipitate, leaving the soap perfectly white. The admixture of water with mottled soap is, however, practised in another way, namely, by plunging the soap as taken from the frames into a solution of salt, when it may be made to absorb from eighty to eighty-five per cent. of water, and become so soft as to be kneaded easily between the fingers. Properly prepared white soap should contain from forty to forty-five per cent. of water. Frequently, however, the proportion amounts to fifty-five or sixty per cent., and cases have been known in which soaps, combined with from eighty-three to one hundred and fifty-four per cent. of water, have been sold. This is either added directly to the soap when run into the frames, or the soap is kept for some time in a solution of salt. The proportion of water is also sometimes increased by submitting the bars of soap to the action of high-pressure steam in tight chests or bins; also by boiling the soap in high-pressure coppers before *cleansing*.

The proportion of water contained in a sample of soap, may be most readily ascertained by treating a portion in a water or oil bath, until it ceases to lose in weight. Two ounces or more of the sample to be examined should be taken and reduced to small thin shavings. Of these, after carefully mixing together, one hundred grains are taken, placed in a small porcelain or platinum crucible, and dried by exposure in a water bath for a sufficient length of time. When the water is completely disengaged, that is, when after repeated trials the weight remains constant, the operation is at an end. The difference between the first and last weighing indicates the per centage of water present. As previously mentioned, marbled soap should not contain more than thirty to thirty-five; and white or yellow forty to forty-five per cent. of water. The amount of water contained in soap may also be estimated indirectly as follows:—From five hundred to a thousand grains of the sample are taken and dissolved in water. To the solution hydrochloric acid is added in excess. Decomposition of the soap ensues, the greasy matters rise to the surface, and must be collected on a weighed filter, and when well washed and dried, carefully weighed, deducting the counterpoise of the filter. The filtrate, together with the washings, is now evaporated to dryness, and, after carefully drying, the weight of the residue is taken. This latter contains the alkali in the form of chloride, every one hundred parts of which indicate fifty-three parts of soda, or sixty-three of potassa soap, according as the soap under examination is a hard or a soda soap, or a soft or potassa soap. The amount of greasy matter or alkali thus ascertained is subtracted from that of the soap taken, and the remainder expresses the proportion of water present. Mottled soap treated as above should yield of fatty acids sixty-four parts, of soda six parts, and thirty parts of water. White soap should give of

fatty acids fifty parts, of soda four and a half parts, and of water forty-five and a half parts.

It is evident that if other substances are present than those indicated, the results obtained by the foregoing method will be to that extent inaccurate. In such cases the other method must be pursued, and if it is desired to estimate also the proportion of fatty acids and of alkali, special examinations must be made as will be explained presently. Whenever the object is solely the determination of the amount of water, the method by direct evaporation is the simplest and best. To ascertain the proportion of oil or fat in a given sample of soap, the following process is recommended by DUMAS:—

One hundred grains of the soap are taken and dissolved in four or five ounces of boiling water, and the solution is filtered. A sufficient quantity of dilute acid is added to effect neutralization, and afterwards a weighed portion of pure and dry white wax. The whole is then heated until the wax is liquefied, and has combined with or taken up the oil or fat liberated from the soap by the stronger acids. After allowing it to cool the cake of wax obtained is removed and weighed; the increase above the original weight of the wax indicates the proportion of fat, oil, or grease contained in the soap. If the fatty matter of the soap when liberated by the acid itself concretes on cooling, the addition of wax is unnecessary, as the fat may be weighed *per se*. The liquid decanted from the fat, or solidified wax, may afterwards be submitted to examination, to ascertain the nature and state of purity of the base. If this is intended, hydrochloric acid should be used for the liberation of the fat, and then the presence of potassa is immediately recognized by the production of the very characteristic yellow precipitate, on the addition of bichloride of platinum. To ascertain the nature of the fatty material, DUMAS directs the aqueous solution of the soap to be saturated with tartaric acid, the fatty acids to be collected, and their point of fusion carefully observed. It is a matter of great difficulty to determine the particular kind of fat or oil used in the production of the soap under examination; yet by the above method, it is possible at least to prove the identity of the fatty component; as, for instance, whether the soap is made from tallow or from oil, or whether it is of the same kind as the sample from which it may have been purchased. The odor evolved by the fatty acids at the moment of decomposition of the soap by a stronger acid, or that developed when the fatty matter so liberated is treated in a small porcelain dish, will often indicate the nature of the fatty substance employed in its production, or that at least which is present in the greatest proportion. According to NORMANDY, another test as to the quality of the soap is, that the fatty or oily acid should be readily and completely dissolved by hot alcohol. The estimation of the proportion of alkali contained in a sample of soap, is frequently a point of great difficulty. When only one alkali is present, the determination is most easily effected by means of a test acid, and the operation is performed exactly as directed in the estimation of the value of potassa, Vol. II., page 729. For hard or soda soaps in the absence of potassa, an acid is used of

which each alkalimetric division is equivalent to one grain of soda; and, therefore, when the amount of soap taken for the assay is one hundred grains, the number of measures of acid required to effect neutralization at once indicates the percentage amount of soda contained in the sample. Such an acid is prepared by adding to each measure of concentrated sulphuric acid of specific gravity 1.8 to 1.84 about nine measures of water, and mixing thoroughly by agitation. When the mixture has become cool, its exact strength is ascertained, as follows:—One hundred and seventy-one grains of pure and dry carbonate of soda are taken and dissolved in water, and the solution is heated. The alkalimeter shown in Fig. 422 is then filled up to the point marked 0° with the mixture of acid and water, and sufficient of the latter is then poured into the solution of carbonate of soda to effect neutralization. The exact point is determined by testing, from time to time, with slips of blue litmus paper; and when the latter is tinged of a slight red color, the addition of the acid is discontinued, and the number of measures employed is noted. If the whole of the hundred measures are required, the acid is of proper strength; but if any less number have been added, it is then necessary to add more water, so that a hundred divisions shall exactly neutralize the hundred and seventy-one grains of carbonate of soda, this quantity being equal to, and indeed containing, one hundred grains of pure soda. This dilution, it will be observed, may now be effected with the greatest ease; for if ninety measures are required, then to each ninety measures remaining must be added ten additional measures of water, and the quantity of the latter required to be added is, of course, greater or less in proportion to the quantity of dilute acid employed, so that one hundred divisions shall contain only as much real acid as was before contained in the number of measures used. The acid being prepared, one hundred grains of the soap to be examined are dissolved in hot water, and the solution is filtered. The alkalimeter having been filled with acid, the latter is then poured into the soap solution until exactly saturated. The number of measures required at once indicates the centesimal amount of soda present. For the estimation of the alkali in soft or potassa soaps, an acid is generally used of different strength to that indicated above. This acid is of such strength that one hundred measures represent one hundred grains of pure potassa. Full directions for its preparation will be found under POTASSA, Vol. II., page 730. The process of estimation is performed exactly in the same way as for hard soaps. The test acid for hard soap may also be used to determine the alkali in soft soaps, simply by allowing for the difference in the atomic weight of the two bases. In this case it is only necessary to calculate for every ten grains of alkali found, 15.16 grains of potassa.

In Germany, America, and some other countries, soda and potassa are frequently both used in the production of hard soap. The determination of the amount of alkali in such instances is much less easily performed. The most convenient process is as follows:—A hundred grains of the soap are taken and dissolved in water, as before, and the solution is exactly neutralized by means of the soda test acid. By a simple calcula-

tion one may then ascertain the quantity of dry sulphuric acid which it has been necessary to add, for in every hundred alkalimetric divisions of acid are contained one hundred and twenty-nine grains of anhydrous sulphuric acid. The proportion of dry acid added being known, the solution is filtered to remove the liberated fatty acids, and the filtrate evaporated to dryness. The residue, consisting of the mixed sulphates of the alkalies, is then heated to redness, and after cooling, weighed. The weight of acid added, and that of the mixed sulphates being known, the relative proportion of each alkali contained in the soap may then be easily calculated; for as one hundred parts of sulphuric acid give 177·5 of sulphate of soda, and the same quantity of the acid gives 217·5 of sulphate of potassa, if the weight of the dry sulphate obtained exceeds the ratio 100:177·5, the excess is due to the salt of potassa, from which the proportion of pure potassa may now be ascertained, since eighty-seven parts of sulphate of potassa represent forty-seven of potassa.

The amount of foreign matters—that is, substances other than fatty matters, alkali, and water present in soap—is determined by taking a weighed portion, and after having reduced it to thin shavings, treating them with boiling alcohol. A white soap should dissolve completely, and a mottled soap should not leave more than one per cent. The exact amount of the residue is determined by weighing it; its nature is ascertained by treating it with cold water, by which the soluble salts are extracted, and the proportion of these is estimated by evaporating the liquor to dryness. The residue unaffected by the cold water, is then treated with boiling water. The presence of starch or fecula is now recognized by the appearance of a more or less thick gelatinous mash. The filtered solution, upon the addition of a little iodide of potassium and nitric acid, or a bubble of chlorine, if starch be present, becomes violet blue. The insolubility of the residue in either hot or cold

water, denotes the presence of lime, clay, *et cetera*. If lime, it is readily soluble in hydrochloric acid, and upon the addition of ammonia and oxalate of ammonia to the solution, a white precipitate appears. What remains unaffected by alcohol, acid, and water, is clay, silica, pumice-stone, *et cetera*. The presence of an alkaline silicate in soap is detected by dissolving a portion in water, neutralizing by means of dilute hydrochloric acid; if the silicate is present in moderate quantity, silicic acid at once falls, and may be easily recognized. When it exists in lesser proportions the fatty acids should be removed by filtration, and the filtrate then evaporated to dryness, and the residue treated with water; if silica be present, it will remain as a white gritty powder, and may be collected, dried, ignited, and weighed.

It not unfrequently happens that a soap contains more or less uncombined or non-saponified fatty matters, and in this case, when the soap is dissolved in water, a film of oily matter is seen to float on the surface. MORFIT gives a method for determining the amount of this as follows:—The aqueous solution is decomposed by means of hydrochloric acid, when the fatty acids as well as the unaltered fatty matter collect together on the surface of the liquid. These are separated by filtration, thoroughly washed, and then treated with caustic baryta. The precipitate produced is thrown on a filter, washed with boiling water, and then acted upon by hot alcohol. By this means, the non-saponified grease dissolved is from the soap of baryta, and after separation of the alcohol by evaporation, its weight may be ascertained. When tested by litmus paper, it should not show an acid reaction. In the appended table, the great discrepancies in the value of different kinds, of soap are clearly pointed out; yet it must be noticed that the portion of alkali in combination with the fatty acids was not separated in the analysis from that portion contained in a free state—for instance, as lie:—

Variety of Soap.	Fatty Acids.	Dry Potassa.	Dry Soda.	Water.	Common Salt.	Analyst.
Castile soap; specific gravity 1·0705,	76·5	"	9·0	14·5	"	URE.
Castile soap; specific gravity 0·9669,	75·2	"	10·5	14·3	"	"
Fine white toilet soap,	75·0	"	9·0	16·0	"	"
Ordinary white soap from Glasgow,	60·0	"	6·4	33·6	"	"
Mottled tallow soap of good quality, prepared from potassa after having been kept for several years,...	81·25	1·77	8·55	8·43	"	HEEREN.
Brown resin soap from Glasgow,	70·0	"	6·5	23·5	"	URE.
London cocoa nut oil soap—marine soap,	22·0	"	4·5	73·5	"	"
Hard poppy oil soap,	76·0	"	7·0	17·0	"	"
French white soap,	50·2	"	4·6	45·2	"	THENARD.
Marseilles marbled soap,	64·0	"	6·0	30·0	"	D'ARCET.
Marseilles marbled soap,	60·0	"	6·0	34·0	"	"
White Marseilles soap,	68·4	"	10·24	21·36	"	BRACONNOT.
White Leipzig tallow soap,	76·3		8·8	14·7	"	ABENDROTH.
White Leipzig tallow soap,	50·0		9·4	29·8	"	"
Leipzig marbled soap,	45·0		9·8	38·0	"	"
Soap from hazel nut oil,	64·0	7·0		28·0	1·0	"
Soft soap,	44·0	9·5	"	46·5	"	THENARD.
London soft soap,	45·0	8·5	"	46·5	"	URE.
Belgian soft or green soap,	36·0	7·0	"	57·0	"	"
Scotch soft soap,	47·0	8·0	"	45·0	"	"
Good green soap,	34·0	9·0	"	57·0	"	"
Scotch soft rape oil,	51·6	10·0	"	38·33	"	"
Scotch soft olive oil soap,	48·0	10·0	"	42·0	"	"
Semi-hard soap for fulling,	62·0	11·5	"	26·5	"	VERVIERS.
Ordinary soft soap, 1st sample,	44·0	9·5	"	46·5	"	CHEVREUL.
Ordinary soft soap, 2nd sample,	42·8	9·1	"	48·0	"	"
Ordinary soft soap, 3rd sample,	39·2	8·8	"	52·0	"	"

There are several other important considerations relating to the determination of the value of soaps, besides what is revealed by analysis. As KNAPP observes, the consumer should not be satisfied with a soap in which the amount of the dry fatty alkaline compound accords with the price, unless the soap fulfils another condition of equal importance. The problem to be solved by the soap boiler, is the production of an article from which no more is dissolved or washed away, when it is employed as a detergent, than is absolutely necessary for cleansing purposes. When this is not the case, much soap is uselessly wasted. This property of soap is carefully watched by the laundress; and for purposes of domestic economy, the quantity of soap employed is much more materially affected by it, than by the state of the articles to be cleansed. If the soap contain too much water, or its consistence be rendered too loose by reason of an excess of lie or salt disseminated through it, as is the case with many of the varieties of soap described, the waste from this cause will be proportionately great. On the contrary, if the soap is over dry, much laborious exertion will be required to detach a sufficient quantity for the purposes required. Curd soap is the only kind which maintains the proper mean between these two opposing characters, and this is due to the quantity of water which it contains, and its state of solidity. Soap that has become too dry, is improved by being kept in a moist place, and an opposite treatment improves soap that contains too much water. But, of course, as regards the foreign salts they contain, no alteration or improvement can take place. Curd soap is therefore the proper form in which soap should be sold; no deception need however be practised, when soap containing a large amount of water, as that from coconut oil is manufactured, provided a corresponding reduction be made in the price. The same applies to soap prepared from bones, fuller's earth, silica, *et cetera*, which, if they cannot positively be called adulterations, are very much calculated, like the former, to promote dishonest traffic. The production of these articles will find very little encouragement when the soap boilers understand their own interests and responsibilities. These remarks, of course, do not apply to soft soaps which are used for entirely different purposes, and in a different manner.

USES OF SOAP.—Soap is applied for washing, for fulling woollen cloths, *et cetera*, and in medicine. Its application for washing is founded on two conditions, namely, on its power to remove fatty matters from textile and other materials, and to form therewith an emulsive mass soluble in soapy water; and on the readiness with which the neutral salts of fatty acids are decomposed by warm water into acid compounds and free alkali. The latter acts upon the impurities of substances, and forms with them compounds partly soluble, and partly such as will no longer adhere to textile fabrics and other bodies, whilst the separated acid salts of the fatty acids keep the surface of the material in a smooth condition.

STATISTICS.—The manufacture of soap is carried on more extensively in the United Kingdom than in any other country of the world. The number of manufac-

turers has gradually decreased since the year 1801, when there were six hundred and twenty-four. In 1811 the number was five hundred and twenty-two; in 1845, three hundred and fifty-six; and in 1850, three hundred and twenty-nine, besides sixty-eight remelters or perfumers. But, notwithstanding this decrease in the number of makers, it is almost needless to say that the quantity of soap produced was greater each year, and since the remission of the duty, has increased in still greater proportion. The quantity made in Great Britain in 1850, amounted to ninety-one thousand two hundred and fifty-five tons. Of this quantity five thousand six hundred and five tons were exported to foreign parts, and there were therefore detained for home consumption eighty-five thousand six hundred and fifty tons. Of this ten thousand two hundred and four tons were consumed by manufacturers of woollens, silks, and cotton. After deducting the quantity exported, and that used by manufacturers, it appears that seventy-five thousand four hundred and forty-six tons were employed for domestic purposes in Great Britain, a quantity equivalent to eight pounds and one ounce to each person. In 1851 the quantity manufactured in Great Britain amounted to ninety-one thousand nine hundred and fifty-three tons. Of this quantity England produced eighty-one thousand five hundred and sixty-nine tons, and Scotland nine thousand nine hundred and eighty-four tons. In 1852 the quantity manufactured was ninety thousand six hundred and sixty tons. In England the quantity is made up, of *hard soap* seventy-five thousand three hundred and seventy-eight tons; of silicated soap, five hundred and ninety tons; and of *soft soap*, five thousand six hundred and one tons. The nine thousand nine hundred and eighty-four tons produced in Scotland, consisted, of *hard soap* six thousand seven hundred and eighty-eight tons; silicated soaps, three tons, and of *soft soap*, three thousand one hundred and ninety-three tons. The quantity imported into Great Britain in the above year, was—from foreign countries, one thousand five hundred and thirty-three hundredweight three quarters of Naples soap; from Ireland fifty-two tons seven hundredweight of hard soap, and twenty-seven hundredweight ten pounds of soft soap. The quantity of soap produced in the latter country cannot be ascertained, as there having been no duty levied upon it, no returns were required. The annual revenue derived from the soap manufacture in Great Britain in the last years the duty was levied, exceeded one million pounds sterling. It was entirely remitted in 1853.

The following, the Editor understands, are among the largest and best soap factories in the three kingdoms:—The West of England Soap Company, Plymouth; Mr. JOHN WHEEN, London; Messrs. TYSON and RICHMOND and Mr. WILLIAM MOORE, Liverpool; Messrs. WILKIE and SOAMES, East Greenwich, London; Messrs. J. BARRINGTON and SONS, Dublin; Messrs. HOWE and Company, Old Brentford; Messrs. CHARLES TENNANT and Sons, Glasgow, *et cetera*.

SODIUM.—*Sodium*, English and French; *Natrium*, German and Latin.—This is one of the metals discovered by SIR HUMPHREY DAVY, through the agency of voltaic electricity. Moistened hydrate of soda was employed, and the oxygen both of the water and of soda was liberated at the positive pole, and the sodium of the oxide at the negative pole.

About the same time, 1807, were discovered also potassium, barium, strontium, and calcium, and, besides, traces of metallization were also obtained from the earths. The compounds of sodium with other substances are of great importance in the arts and manufactures; for example, it enters into the composition of common salt, of sulphate of soda, and of the carbonates of soda—substances so important as articles of commerce, owing to their daily employment in domestic economy, in the manufacture of glass, of soaps, in bleaching, and in numerous processes of manufacture little less important. Sodium itself, too, has lately become of great interest, and its preparation, it may safely be predicted, is destined shortly to occupy a position amongst the useful arts scarcely less important than the extraction of iron from its ores. As a metal, owing to the great facility with which it becomes oxidised, it is never likely to be much employed; but it is this very property of rapid oxidation which has caused it to be applied in the liberation of other metals from their combinations; and, from the extreme cheapness of carbonate of soda, and the facility with which sodium may be obtained from this salt, it would be doubtless possible to procure it on the large scale at a price little, if at all, higher than that of zinc.

PREPARATION.—The processes already described for the production of potassium are applicable also, with slight modifications, for the preparation of sodium. The apparatus required is also of exactly the same description as in the case of potassium. The substances employed are either hydrated soda and iron, or carbonate of soda and charcoal. These are placed in a malleable iron bottle—those in which mercury is imported answer admirably—and heated to whiteness in a powerful wind furnace. The gas, which after some time makes its appearance, is conducted into a receiver of iron or copper containing mineral naphtha or rock oil, and which receiver is kept cold by surrounding it with cold water, which is frequently changed. It should, of course, be provided with a vent for the escape of the incondensable gases evolved during the decomposition. The operation is much more productive than in the case of potassium, owing to the fortunate circumstance that sodium does not combine with carbonic oxide.

It appears, nevertheless, that the decomposition either of hydrate of soda by metallic iron, or of carbonate of soda by charcoal, is effected with greater difficulty than is the case with the corresponding potassa salts. It appears also, that by mixing the soda or carbonate of soda with a little potassa or carbonate of potassa, the operation is effected with greater facility, but the metal obtained is then a brittle alloy of sodium and potassium. From this, however, the whole of the potassium may readily be separated by means of slow oxidation, without any considerable loss of sodium. To

effect this, the alloy obtained is founded into plates, and placed in a large bottle; these are covered with naphtha, and the air in the bottle is occasionally removed. After a few days the whole of the potassium will have disappeared, and pure and very ductile sodium remains. The process usually employed in the preparation of sodium is that recommended by SCHOEDLER. The carbonate of soda used is obtained by the ignition of acetate of soda, free access of air being avoided. The object of this is to obtain the carbonate in a very pure state, since, if sulphate of soda be present, it becomes reduced in the process to sulphide of sodium, which acts strongly on the iron bottle. The mixture of carbonate of soda and charcoal obtained is to be mixed with a fourth of its weight of charcoal in fine powder, and with double this quantity of charcoal in a coarse state, to prevent fusion of the mass, which, should it occur, the fused contents spirt into the tube, and choke it up. This mixture, heated in the iron bottle, yields pure sodium, with very little black residue.

The proportion of sodium obtained by the author of this process was, from three pounds of the commercial acetate, about four and a half ounces of sodium; but in the laboratory at Giessen, even when it was obvious that the result was capable of considerable improvement, three pounds of acetate yielded nearly five ounces of sodium, the whole of the sodium present being about seven ounces. To remove the impurities from the globules of sodium, SCHOEDLER directs them to be pressed through strong and not very fine linen, the metal being first heated in naphtha to the boiling point.

PROPERTIES.—Sodium is of a silver white color; its lustre is more brilliant than that of lead, but scarcely equals that of silver. At the ordinary temperature it is solid, but soft and ductile like wax. At 4° it is rather hard, at 32° very ductile, at 120° it is semifluid, and at 194° perfectly so. Though less fusible than potassium, it is more readily volatile, and hence a less intense heat is required in its preparation. When exposed to the air it quickly becomes tarnished, owing to the formation of a crust of soda; and if heated nearly to redness, it inflames, and emits brilliant scintillations. The specific gravity of sodium is 0.972 at 60°, and it is consequently lighter than water, and if thrown into this liquid exposed to the air it swims about, presenting the appearance of a silvery-fused globule, constantly decreasing in size and producing a hissing noise, owing to the escape of hydrogen gas. These phenomena continue until the whole is dissolved as soda.

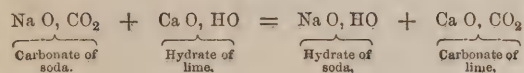
Potassium under the same circumstances takes fire, and continues to burn until dissolved; but sodium, in decomposing water, either produces less heat or requires a higher temperature to inflame it. If, however, the water be thickened with gum, so as to retard the movement of the sodium over the surface, or if there be only a few drops of water, the metal then ignites.

Sodium, like potassium, decomposes most oxides, metallic and non-metallic; also by far the greater number of salts, deoxidising not only the acid but the base also, if it happen to be oxide of a heavy metal. When thrown upon the surface of mercury, sodium

forms an amalgam, with the production of heat and light; this does not take place with potassium. Sodium is employed in the arts, principally in the preparation of aluminium, by the decomposition of the chloride of that base.

OXIDE OF SODIUM.—SODA.—When sodium is burned in dry air or in oxygen a white powder is formed, which attracts moisture and carbonic acid from the atmosphere. This is the *protoxide* of sodium— Na O . It is very similar to the protoxide of potassium, but may be known from it by the following properties:—When exposed to the air at the ordinary temperature, it first attracts moisture, becomes liquid, and, after further exposure, again solidifies; the protoxide of potassium, however, always remains moist. The other oxides of sodium are the *suboxide*— $\text{Na}_2 \text{O}$ —which is a greyish-white dull brittle mass, more combustible than the metal itself; and the *peroxide*, which is a dirty greenish-yellow substance, supposed to have the composition Na O_3 , but, never having been obtained in the pure state, this of course has not been proved. Neither of the oxides of sodium *per se* have any application in the useful arts, but the combination of the protoxide with water, namely hydrate of soda, sometimes termed simply soda, and also known as caustic soda, is an article of very great importance. It was known probably at a very early period, though, up to the time of the discovery of the alkaline metals, this and the hydrate of potassa were regarded as anhydrous alkalies.

PREPARATION.—The hydrate of soda is usually obtained by decomposition of the carbonate, by means of quick or hydrate of lime. To a boiling solution of five and a half parts of crystallized carbonate of soda, in twenty parts of water, a quantity of milk of lime, prepared by treating one and a half parts of burnt lime with four parts of warm water, is added in small portions at a time, and the mixture is boiled, with the addition of more milk of lime, until the filtered solution ceases to effervesce on the addition of an acid. The decomposition is expounded in the annexed equation—



By evaporating the solution to dryness, a hydrate of soda is obtained, which, however, usually contains traces of silicic acid, aluminacic, and phosphoric acid. These impurities may be removed, except a minute trace of alumina, by treating the solid hydrate with alcohol, in which the soda salts of those acids are insoluble. In evaporating the alcoholic solution, it is necessary to add a little water from time to time to prevent blacking of the mass. Probably the purest hydrate of soda is procured by decomposing the pure sulphate by means of hydrate of baryta. The soda salt being dissolved in water, the hydrate of baryta, also in solution, is added as long as precipitation ensues. The clear solution decanted from the precipitate and carefully evaporated to dryness, yields a mass of hydrate of soda perfectly free even from alumina.

PROPERTIES.—Hydrate of soda is a white opaque brittle substance, of a fibrous texture; it fuses below

redness. In properties, it greatly resembles the corresponding salt of potassa, but is less volatile at a red heat than this salt. When exposed to the air it rapidly attracts moisture, becomes liquid, but soon dries up again; the mass becoming converted into carbonate, which, unlike the carbonate of potassa, is not deliquescent. A solution of hydrate of soda, which is very caustic and powerfully alkaline, dissolves wood, hair, the skin, and most animal matters; tallow and other unctuous substances, with formation of soaps; sulphur, and some metallic sulphides; silica, alumina, and several metallic oxides quite insoluble in water.

The following table, constructed by ZIMMERMAN, shows the quantity of soda— Na O —in alkaline menstrua at different densities:—

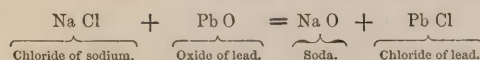
QUANTITIES OF SODA IN A SOLUTION OF SODA AT 15° CENTIGRADE—59° FAHR.—BY ZIMMERMAN.

Specific gravity.	Per cent soda.	Specific gravity.	Per cent. soda.
1.4285	30.220	1.2392	15.110
1.4193	29.616	1.2280	14.506
1.4101	29.011	1.2176	13.901
1.4011	28.407	1.2058	13.297
1.3923	27.802	1.1948	12.692
1.3836	27.200	1.1841	12.088
1.3751	26.594	1.1734	11.484
1.3668	25.989	1.1630	10.879
1.3586	25.385	1.1528	10.275
1.3505	24.780	1.1428	9.670
1.3426	24.176	1.1330	9.066
1.3349	23.572	1.1233	8.462
1.3273	22.967	1.1137	7.857
1.3198	22.363	1.1042	7.253
1.3123	21.759	1.0948	6.648
1.3125	21.758	1.0855	6.044
1.3053	21.154	1.0764	5.440
1.2982	20.550	1.0675	4.835
1.2912	19.945	1.0587	4.231
1.2843	19.341	1.0500	3.626
1.2775	18.730	1.0414	3.022
1.2708	18.132	1.0330	2.418
1.2642	17.528	1.0246	1.813
1.2578	16.923	1.0163	1.209
1.2515	16.319	1.0081	0.604
1.2453	15.714	1.0040	0.302

Solution of caustic soda constitutes the soda lie of the soap manufacturer, and is usually prepared on the spot by decomposing carbonate of soda or *soda ash* by means of lime. The mixture is placed in large cast-iron vats and covered with water, and after some hours the lie is withdrawn through a plug at the bottom of the vat, and either fresh water or a weak lie introduced at top. Full directions for the proper performance of the process are given under the article SOAP.

The solution of soda so prepared is contaminated with the common salt, sulphate of soda, and other constituents of soda ash; these may, however, be separated in great part by concentrating the solution considerably, these salts being insoluble in a strong solution of soda. A very useful article has lately been introduced by some alkali manufacturers, intended to supersede the use of the soda ash in the soap manufacture, and in other processes of fabrication in which caustic alkali is employed; and considering the advantages likely to ensue on its introduction, and the great simplicity of the process of production, it is a matter of surprise that its preparation on the large scale has been so long delayed. The article in question is a very pure solid caustic soda, containing hydrate of soda to the amount of nearly eighty per cent.

Probably the oldest method of producing caustic soda on the large scale, though it was applied as a preliminary to the preparation of the carbonate of soda, is that originally discovered by SCHEELÉ. It consists in the decomposition of chloride of sodium by means of protoxide of lead or litharge. This method was employed in England by Mr. TURNER, and in France by CHAPTAL and BERARD, for producing, besides caustic soda, the fine yellow pigment designated *patent yellow*; the operation was performed by intimately mixing and rubbing together one part of salt and from four to six parts of litharge, and a little water. Double decomposition takes place between the salt and a portion of the oxide of lead, with formation of caustic soda and chloride of lead, as shown in the annexed equation:—

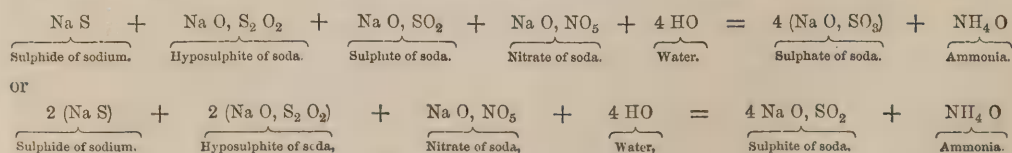


The latter salt afterwards unites with a portion of undecomposed oxide of lead, and remains as an insoluble oxychloride of lead. About twenty-four hours are required to complete the decomposition, during which time the mixture is to be constantly agitated. It is then allowed to stand a few hours to settle, and the solution of caustic soda is then decanted, the residue well washed with successive portions of water, the washings being used in the preparation of a fresh quantity. The decanted solution on evaporation yields a very pure hydrate of soda, and the lead compound, after being dried and fused, becomes of a beautiful yellow hue. The decomposition of the common salt is in this process very complete; but owing to the high price of litharge, and the limited sale of the pigment, the method has been generally abandoned as a manufacturing process.

The attention of manufacturers was first directed in 1853, by Mr. GOSSAGE, to a source of caustic soda, from which it may be obtained with great economy and by a very simple method. This source is the liquor obtained by lixiviation of black ash or ball soda, a compound which will hereafter be minutely described. The chief object of the manufacture, of which black ash is an intermediate product, is the preparation of carbonate of soda—that salt which is contained in the largest proportion in black ash liquors—and one of the principal advantages of this method of procuring caustic soda, is that by its separation from black-ash liquors, the carbonate is obtained in a considerably pure condition. The liquor resulting from the lixiviation of black ash contains carbonate of soda, sulphate of soda, and caustic or hydrate of soda, chloride

of sodium—a deep-reddish compound of sulphide of sodium—and a few other substances, in very minute quantities. When the menstruum is concentrated by boiling, crystals of monohydrated carbonate of soda separate; and if the evaporation be continued the whole of the carbonate falls in this state and can be readily separated, leaving a reddish or sometimes a blackish lie, the principal constituent of which is caustic soda. On further concentrating this mother-lie to a certain point, and adding an oxidising agent, the double sulphide of sodium and iron is decomposed, and the solution loses its deep color; any sulphates or other compounds which separate during the concentration are removed; and there remains a liquor, which in boiling to the necessary degree, affords an almost perfectly white solid hydrate of soda, contaminated with only a very small proportion of other matters. In GOSSAGE'S specification, which will be alluded to more in detail in connection with the improvements in the manufacture of *soda ash*, he directs the black-ash liquor first to be exposed to the air, so as to absorb oxygen therefrom, the effect of which is to destroy a great proportion of the double sulphide contained in such lie, and, consequently, the removal of much of the coloring matter. To the menstruum so purified he gradually adds a solution of chloroxide of calcium or bleaching powder, in order to convert any hyposulphite of soda which may be present into a sulphite or sulphate of soda; he then concentrates the liquor by evaporation, and removes the whole, or nearly the whole, of the carbonate of soda and other salts, and afterwards continues the evaporation till, on cooling, a solid mass of hydrate of soda is obtained.

Prepared according to the directions given above, the caustic soda is still very highly colored, and would certainly be objected to by most consumers of this article. By a modification of the process, however, the hydrate may be obtained white, or with only the slightest possible tint; and this improved process is now generally employed by alkali manufacturers. The liquor, after the separation of the greater portion of the carbonate of soda, is conveyed to an iron boat-shaped pan, and further concentrated to remove the remainder of the salts present. Whilst the liquor is in a state of ebullition in this pan, and at a density of 1.50, nitrate of soda is added in sufficient quantity to effect the decoloration of the fluid; this salt yields oxygen to the sulphide, and converts it into sulphite, in which the sulphide of iron is insoluble; whilst its nitrogen is liberated in the form of ammonia, and the base is set free in the fluid. Thus—

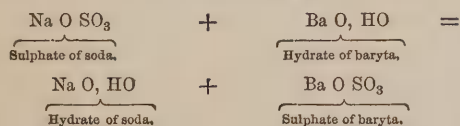


The liquor is drawn off from the forementioned pan after the salts have deposited, which happens in a period of four hours' repose, and transferred to another pan or pot, and the evaporation continued till the liquid readily solidifies on cooling. From half to one hundredweight

of the nitrate of soda is sufficient to purify such a quantity of liquor as will yield one ton of caustic soda.

A process in which caustic soda is produced was patented some years ago by Mr. WILLIAM HUNT, the principles of which were briefly as follows:—When the

product of the decomposition of sulphate of soda by coal or coke is lixiviated with water, and the solution which contains sulphide and bisulphide of sodium with caustic and carbonate of soda, is boiled with oxide of zinc or black oxide of copper, double decomposition ensues between the sulphide of sodium and the oxide of copper or zinc, and sulphide of either of the metals results, with caustic soda in the solution. The metallic sulphide thus produced is made available in the preparation of another quantity of sulphate of soda from common salt, by a process which will be described in treating of the preparation of sulphate of soda. It has been proposed also to procure caustic soda directly from the sulphate, by decomposing this salt by means of a solution of hydrate of baryta. When a solution of sulphate of soda is mixed with one of caustic baryta, changes ensue as in the annexed equation:—



Sulphate of baryta is insoluble; and, therefore, if the mixture be made in proper proportion, nothing remains in the solution but caustic soda. The difficulty of procuring with facility the requisite quantity of caustic baryta, will probably always prevent this process from becoming general. The process for the production of caustic soda on the large scale from black-ash liquors is so convenient and economical, that it will probably be never entirely superseded. If there be a demand for greater quantities than can be obtained from this source, the carbonate of soda in black-ash liquors must be converted into caustic soda by the addition of lime, and the caustic soda then separated as previously described.

Caustic soda is indeed now produced on a very large scale; and from a consideration of the advantages likely to ensue, as its use becomes more general amongst manufacturers requiring alkali, a very great increase on the present demand may certainly be expected. It is to the soap manufacturer that the introduction of this salt will prove to be the greatest stimulus the trade has received since the introduction of artificial soda; indeed, the soap manufacture will be so greatly simplified by the use of this salt, that the present mode of production may be expected in a short time to be entirely abandoned.

CHLORIDE OF SODIUM—*Common Salt, Sea Salt, Muriate of Soda; Chlorure de Sodium*, French; *Kochsalz*, German.—This substance possesses a peculiar interest, from its being one of the usual and necessary constituents of food; whilst the enormous consumption in the arts, and the variety of purposes to which it is applied in manufacturing operations, invest the study with an importance second to none. Salt is the longest known compound of sodium. As early as the time of the destruction of Sodom and Gomorrah mention is made of it in connection with the judgment against Lot's wife, *and she became a pillar of salt*. In Leviticus it is alluded to as a preservative and a component of the prescribed sacrifice. In the gospels of the New Testament its preservative qualities are

beautifully inferred from CHRIST's testimony and charge to the Apostles—*Ye are the salt of the earth, but if the salt lose its savor wherewith will it be salted*. Salt, it is said, appears in the sacred volume as the emblem of eternity, of repentance, of reconciliation, and of wisdom. NUMA among the Etruscans, and PYTHAGORAS among the Greeks, repeated the precept of MOSES—*Do not speak of Deity without fire; nor sacrifice without salt*. PYTHAGORAS calls it *a substance dear to the gods*; HOMER designates it *divine*; and PLUTARCH remarks, *it symbolizes the soul*. Salt has always been, and is now, with the Arabs, the emblem of hospitality. It figures largely in Eastern story. A thief, for instance, entering an Arab's tent at night while the master is asleep, seizes some food and becomes aware of the flavor of salt; bound involuntarily by the laws of hospitality, he withdraws, without carrying out his felonious intention. In the story of the Forty Thieves, the chief robber, who enters the house of MORGIANA's master on a false pretence, is enjoined to make such excuses whenever his host offers him salt as will enable him to refuse partaking of it without suspicion.

It would be interesting if one could learn the secret of the strange yearning mankind has for salt, which ages have not diminished nor civilization annihilated. Chloride of sodium occurs in every part of the human frame. It is organized in the solids and dissolved in the fluids; it creeps into every corner of the body, and plays a part in all the complicated processes of life, without which the machinery would be arrested in its operation. In England and America, the quantity of salt consumed gives twenty pounds per annum to each person; in France the average ranges about fifteen pounds; but in some countries the love of salt amounts to a mania. In Abyssinia every man carries a lump of salt; and when he meets a friend, he offers it to him to lick. Its use may be said to be almost as universal as water, and it may safely be regarded as among the most abundant mineral compounds in nature; certainly of all the minerals eaten, none can claim so high a place in science, history, and literature, and in the kitchen it is an indispensable condiment—

Even cooks would deem't a grievous fault,
Were viands eaten without salt.

When pure, chloride of sodium consists, in one hundred parts, of 59·67 chlorine and 40·33 sodium. It crystallizes generally in the form of the cube, the crystals usually being very perfect. It may, however, under particular circumstances be made to assume other shapes, but all closely allied to the cube. When a saturated solution in water is slowly evaporated, and the surface of the fluid kept perfectly still, the crystals as they form sometimes assume a very remarkable appearance. A cubical crystal first forms on the surface; other crystals as they grow attach themselves to the edges of the upper faces; the middle cube then sinks below the surface of the liquid, but is still held up by the lateral crystals, and the process goes on until a hollow square pyramid of considerable size, having its apex downwards, may thus be produced.

Chloride of sodium is only slightly more soluble in boiling water than in cold; according to POGGIALE:—

100 parts water at 32°	dissolve	35.52 of salt.
“ “ 57-2°	“	35.87 “
“ “ 212°	“	36.61 “
“ “ 229-46°	“	40.35 “

The last is the temperature of a boiling saturated solution of common salt, which will therefore deposit very little salt on being allowed to cool; but if there be some chloride of calcium or of magnesium present, the solubility of common salt at a high temperature rapidly increases, and a considerable crop of crystals of chloride of sodium may be obtained on cooling.

Common salt decrepitates when suddenly heated, owing to a small quantity of water becoming inclosed between the plates of the crystal, and its sudden expansion at a high temperature causing a fracture of the crystal. It melts at a low red heat, and may readily be volatilized in a hot furnace. The specific gravity of pure salt is 2.557. It has an agreeable and saline taste, and is slightly deliquescent in moist air.

There are two varieties of common salt in commerce—rock-salt, and the salt produced by the purification and evaporation of salt brines. Of the latter there are in England three qualities, differing not so much in their freedom from impurities as in the size of the crystals adapting them for special purposes in the arts.

ROCK-SALT.—*Native Salt, Mineral Salt, Sal Gem.*

—Rock-salt occurs as a regular mineral deposit associated with gypsum; its position is properly within the new red sandstone, but it has been met with in other situations. It occurs in layers varying in thickness from a few inches to several hundred feet. The rock is usually of a reddish-brown tint, and is rarely found colorless. The cleavage is cubical. Salt beds usually appear to have been formed by the evaporation of inland seas, the salt as it accumulated gradually filling up the bed of the sea or lake. The limited extent of these deposits, as compared with the stratified rocks over and under them, would seem to imply this. Indeed there are several instances of this kind of deposit in process of formation in various parts of the world. Thus the bed of the Dead Sea is gradually being filled up with such a deposit, and a leaden plummet dropped in deep water will bring up with it crystals of remarkable size and beauty, and at the same time almost chemically pure; but there are several lakes distributed over the globe in which the water is either quite or very nearly saturated with salt. In Asia and Africa there exist basins of sand, from which salt water has evidently been removed by evaporation, leaving the bed of the basin covered to some depth with salt; indeed, in the neighborhood of the Red Sea, and Salt Lake in Western America, every considerable depression of the soil is more or less incrustated with salt. The mines of rock-salt, most probably originating in the manner described, are not found at any determinate elevation. Thus, the great deposit extending from Upper Austria through Salzburg, is found at an elevation exceeding three thousand feet above the level of the sea; the saline rock of Arbonne in Savoy is seven thousand two hundred feet above sea level; and the immense accumulation in the Saletres of Peru, where the

salt is associated with nitrate of soda, three thousand feet; while that in Wieliczka in Poland is eight hundred and sixty feet below sea level. All these beds, like other mineral deposits, are intersected by faults, and broken up by the upheaving and subsiding of the earth; but from their limited extent, the continuity of the bed is less frequently observed to be affected.

The great deposit of rock-salt that furnishes most of the salt used in England exists in Cheshire. The broad valley extending from near Malpas to Congleton, sweeping in the form of a crescent between the red-sandstone hills of Shropshire and the Staffordshire coal field on the one side, and the high ground of the Peckforton hills and Delamere range on the other, appears to be occupied by the saliferous and gypsiferous beds, lying as it were in a trough, to which the adjoining portions of both the above ranges dip. There are several faults and dislocations in this field; thus, at Lawton, rock-salt is found two hundred and ninety feet above sea level, while at Winsford it occurs ninety feet below, and at Frodsham Bridge no salt was found at four hundred and fifty feet below sea level. The continuity of the bed is frequently broken in the course given; and perhaps the number and depth of borings might to some appear insufficient to establish the extent of the bed; but the existence of the rock where it has not actually been reached, is ascertained with equal certainty by the peculiar sinking of the overlying ground, due to the withdrawal of the brine. The gypsiferous and saliferous beds at Northwich and Middlewich, where alone one has satisfactory information respecting them, may be estimated to be on an average seven hundred feet thick. The rock-salt lies in two beds principally. The depth to the first bed at Northwich varies with the undulations of the land, and also slightly with the irregularity of the bed itself, from ninety-six to one hundred and fifty-nine feet. At Winsford the depth is one hundred and eighty-nine feet. The thickness of the upper bed varies at Northwich from eighty-four to ninety feet in the pits sunk to the north-west, decreasing near the east border to eighty-one feet. It thins off towards the south-west, losing fifteen feet in thickness in the course of a mile. Below this lies a bed of indurated clay, thirty feet in thickness, and containing several thin veins of salt, and this overlies the second or great bed. At a pit at Marston, to the North of Northwich, this has been ascertained to be ninety-six feet thick. At Winsford, however, it is two hundred and twenty-five feet thick. At Northwich, the first sixty to seventy-five feet of rock are impure, the salt being contaminated with much clay and bituminous matter; in the next twelve or fifteen feet the salt is much clearer, and this portion only is worked. The clear portion corresponding to this is worked at Winsford at a depth of two hundred and ten feet in the rock.

The mining operations concerned in the getting of rock-salt hardly require any description. A shaft like that of a coal pit is sunk to such a depth as the position of the rock necessitates, and galleries are worked out from this. The rock is broken down by blasting, beginning at the top of the working and proceeding downwards. But little skill is required in supporting the roof from sinking in upon the miners, the rock being

so hard and firm that the galleries are worked from sixty to eighty feet broad without danger. As the rock gives off no gases injurious to animal life in any quantity, the usual great difficulty of ventilating the mines becomes easy; and sometimes the motion communicated to the air by the descent and ascent of the bucket in which the salt is wound up from the pit, is all the ventilation supplied for some months in the year.

Salt is, however, seldom found in mining operations of sufficient purity to be used in the arts, without being previously submitted to some process of purification. A pure and colorless salt is met with sometimes at Cardona in Catalonia, and in the mines of Wieliczka; and this is, therefore, simply cut into a convenient shape for the market. But most of the rock-salt mined is of a reddish hue, and contains a very small proportion of marl, a little bitumen, and a red coloring matter, analogous in character to the red fungous growth that appears on crystals of salt produced by the slow evaporation of sea-water. In addition to these impurities, rock-salt contains small quantities of various other salts, which impart to it a bitter taste, and make it deliquescent; among these are sulphate of soda and sulphate of magnesia, chloride of magnesium and chloride of calcium. But although rock-salt contains these impurities, it is a curious fact that the more deliquescent of these *are not contained in the rock as solid bodies*, but as saturated solutions in water inclosed in very minute cavities of the crystal.

Rock-salt from various mines is frequently observed to contain, pent up within its substance, a quantity of gas in a state of great compression. This phenomenon has been noticed in the rock from Wieliczka to a remarkable extent. In dissolving this salt in water a crepitation is heard, and this is occasioned by the sudden fracture of the walls of the crystal, when the gradual process of solution has reduced them so far that they are no longer capable of resisting the pressure of the inclosed gas. The gas evolved has been examined by M. DUMAS, and found to be nearly pure hydrogen. This gas may sometimes be heard blowing out in a mine like the light carbide of hydrogen of the coal mines; the quantity, however, is small, and it does not appear that an explosion has ever ensued from the incautious use of a candle.

It was customary to purify rock-salt in England formerly; but at present, salt brines of great purity and strength, and in unlimited quantity, may be obtained at so little cost, that recourse is now seldom had to the solution and subsequent evaporation of the rock. There is, therefore, little use for it, and most of the rock mined is exported. The quantity carried on the river Weaver, according to R. HUNT's report, from the 5th April, 1857, to 5th April, 1858, amounted to sixty-five thousand seven hundred and seventy-three tons.

There exists a large field of salt in Worcestershire, of which the principal bed lies three hundred feet below the surface of the ground; but the rock itself is not worked, and owing to a deficiency of borings, the geological characters of the deposit have not been so thoroughly studied as is the case with the Cheshire field. The whole of the salt prepared in the county is made by the evaporation of strong brines.

There is no country so favored in respect to the abundance and ease with which common salt may be procured as is England; and as this substance is a necessary of life, it sometimes happens that it becomes requisite in countries not so favored, to carry on the manufacture by the evaporation of very weak brines, and even of sea-water.

The following analysis may be considered to be the mean composition of the water of the ocean:—

ANALYSIS OF SEA-WATER.	
Water,	96.470
Chloride of sodium,	2.700
Chloride of potassium,	0.070
Chloride of magnesium,	0.360
Sulphate of magnesia,	0.230
Sulphate of lime,	0.140
Carbonate of lime,	0.003
Bromide of magnesium,	0.002
Iodides, <i>et cetera</i> ,	0.025
100.000	

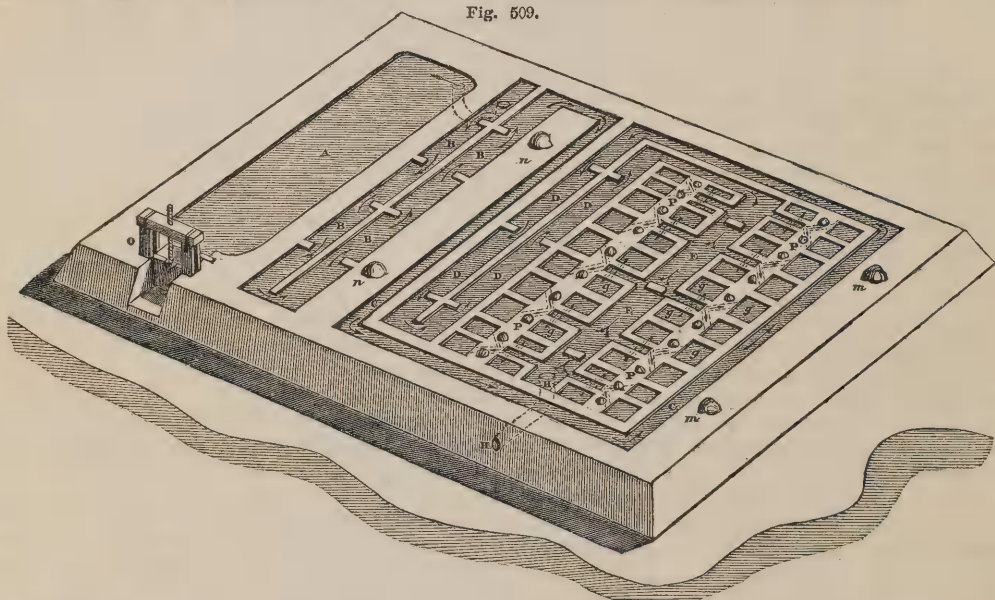
OBTAINING SALT FROM SEA-WATER.—In consequence of the small proportion of salt existing in sea-water, direct evaporation by means of fuel is never had recourse to in the preparation of common salt from this source. Slight variations are observed in the results obtained by various chemists as to the actual amount of salt in sea-water; but these discrepancies are most probably due to the influence of local causes and climate. The actual amount in the water of the Mediterranean is 2.7 per cent., as near as possible. Sea-water is always brought to a certain degree of concentration by placing it under such circumstances that it shall be most favorably affected by the drying influence of the atmosphere; and, as will be readily understood, the actual method of proceeding will vary greatly in accordance with the character, the climate, and the actual position of the works. Thus, in the South, where evaporation is rapid and the condition of the soil favorable, the sea, at the rising of the tide, is allowed to run through sluice-gates into a pond covering about an acre or more of ground, and about six feet deep. When full the gates are closed, and the water gradually deposits all the mud and matters in suspension. From this reservoir the clear water is conducted by pipes into a series of shallow basins, the whole covering some acres of ground, where, by exposing a very large surface of water to the drying influence of the sun and air, it rapidly evaporates. These basins are so arranged that the water shall flow slowly from the first reservoir downwards through the whole series, and the flow so regulated, that by the time the water arrives towards the last basins, it shall be in such a state of concentration as to deposit crystals of salt. A certain redness appearing on the surface, due to a fungous growth, is a good indication of the degree of concentration of the liquors, and its appearance is accompanied by the crystallization of the salt. The crystals as they fall are raked out at certain intervals and collected in small heaps on the ledges separating the basins one from the other. As soon as the mother-liquors begin to deposit salts of magnesia and sulphate of soda, they are run away into the sea, or they are allowed to flow into another series of evaporating ponds, to be there treated in such a way as to separate the sulphate of soda and other

salts contained in sea-water from the common salt still remaining in them.

The manufacturing process will be best seen by a reference to the woodcut—Fig. 509. A is the large reservoir into which the sea is allowed to flow at high tide through the gate, o. From this it flows through a pipe into the long canal, B B C. The flow of water is very slow, and is regulated by means of the supply pipes. The sea-water then enters the reservoirs, D D, in which the water assumes a green tint, due to the growth of conferva; these die, however, when the brine attains a specific gravity above 1·040. From the reservoirs, D D, the brine flows through the channel, E E, into the divisions, where it deposits a considerable quantity of sulphate of lime; this takes place when the brine is of a specific gravity between 1·116 and 1·145, and when it attains a specific gravity of 1·210 it no longer contains a trace of sulphate of lime—this salt being insoluble in a solution containing much sulphate of magnesia. The brine is now let into the

compartments, g g, where it begins to deposit common salt. The depth of liquid on these beds is not much above two or three inches, and is renewed every two or three days, according to the state of the weather. The brine is allowed to concentrate until it attains a density of 1·263, when, although the whole of the common salt has not been removed from it, the liquors are allowed to run out on the crystallizing tables as they are called. The salt as it deposits forms a hard incrustation on these tables, which, during the five or six months the operation is conducted, attains a thickness of about three inches. The mother-liquors are now run off the tables, and the salt scraped up and collected into small heaps, p p, to drain. These are collected together into larger heaps, m, n, and covered with straw in the form of a haystack to protect them from the rain. They are then allowed to remain for some time, that the moisture of the atmosphere may gradually remove the more deliquescent salts, consisting of the chlorides of magnesium and calcium.

Fig. 509.



The product obtained in the manner described is contaminated with clay from the bottom of the ponds, and it therefore requires to be purified by dissolving it in water, separating the clay by subsidence, and evaporating the solution to dryness. The manufacture of common salt on the plan described is carried on only during the summer months, that is, from March to September. The value of the process, of course, altogether depends upon the state of the atmosphere, and it frequently happens that a continued moist condition of this altogether arrests the evaporation.

The manufacture of salt, as described, is extensively carried on in France and Spain, and all parts bordering on the Mediterranean, and was formerly practised in England, particularly at Lymington in Hants.

In Russia, salt is manufactured by allowing sea-water to freeze, and removing the ice as it forms. The success of this process depends upon the fact, that when

sea-water partially freezes, the ice formed contains proportionately less salt than the remaining water; the mother-liquor, therefore, by repeating this process of congelation, becomes more and more impregnated with salt, until, indeed, a saturated solution of brine may in this way be formed.

Dr. WALKER, from experiments made in the Polar Seas, found that at 28·5° sea-water begins to freeze, and as the process of congelation went on he observed a saline *efflorescence* to form on the surface of the ice; but when the ice had attained a considerable thickness this efflorescence was not observed to increase, and Dr. WALKER concludes that the excess of the salt was then precipitated. It may be remarked that, according to Dr. KANE, if the cold be sufficiently intense, the water produced by melting the ice will be so far free from salt as to be fit to drink. In Dr. WALKER's experiments, however, the purest specimen of water obtained

by melting the ice formed at 42° was of specific gravity 1.005, and afforded abundant evidence of the presence of common salt, and in quantity sufficient to make the water unfit for most domestic purposes. The

salt obtained by the evaporation of the mother-liquors, as described, is however very impure, containing many of the foreign salts present in sea-water, as will be seen from the analysis as under:—

ANALYSIS OF SPECIMENS OF RUSSIAN SALT PRODUCED BY THE FREEZING PROCESS.

	Salt from			
	The Sea of Okhotsk.	Salt works at Ouskout.	Salt works at Irkoutsk.	Salt works at Seleginsk.
Chloride of sodium,	77.60	74.84	91.49	74.71
Chloride of aluminium,	6.20	1.17	2.60	6.50
Chloride of calcium,	0.94	5.21	1.10	1.44
Chloride of magnesium,	1.66	3.57	2.05	3.55
Sulphate of soda,	13.60	15.20	2.76	13.80
	100.00	100.00	100.00	100.00

The salt obtained would have been of much better quality if such a quantity of milk of lime had been added to the concentrated mother-liquors as would have been sufficient to carry down the sulphuric acid, and to decompose the chlorides of calcium and of aluminium.

SALT SPRINGS AND WELLS—Brines.—When a fresh-water spring in its underground course passes

over a bed of rock-salt, it becomes more or less impregnated with that substance, and there results a salt spring or well. The amount of saline matter in salt springs, varies so much in character and quantity, as will be seen in the analyses given below, as to require a very decided difference in the method of treating them:—

ANALYSES OF SALT BRINES

The numbers refer to one hundred parts by weight of water.

	Moutiers.	Schonebeck.	Friedrichshall.	Clemenshall.	Hall.	Sulz.	Durrenburg.	Rodenberg.	Artern.	Nauheim.	Kreuznach.	Salzhau-sen.
Chloride of sodium,....	1.058	9.623	25.5625	25.9021	25.7180	23.4733	6.599	5.173	2.829	2.3600	1.415	0.943
“ potassium, ..	..	0.007	..	..	..	..	0.008	..	0.004	0.0524	0.006	0.009
“ magnesium, ..	0.030	0.083	0.0059	..	..	..	0.092	0.166	0.038	0.0339	0.023	0.080
“ calcium,....	..	..	..	..	..	..	..	..	..	0.1935	0.261	..
Sulphate of potassa,...	..	0.014	..	..	..	..	0.004	..	0.004	..	..	..
“ lime,.....	0.251	0.339	0.4374	0.4445	0.1705	0.5080	0.250	0.515	0.158	0.0052	..	0.080
“ soda,.....	0.100	0.249	..	0.0197	0.0289	..	0.208	..	0.092	..	..	..
“ magnesia,...	0.055	0.012	0.0221	..	..	..	0.004	0.005	0.004	..	..	..
Carbonate of lime,...	0.076	0.026	0.0100	0.0195	0.0037	0.0162	0.026	0.010	0.042	0.2133	0.003	0.057
“ magnesia,...	..	..	..	..	..	..	..	..	..	..	0.001	..
“ protox. iron,...	0.012	0.001	..	..	..	..	0.004	..	0.012	..	0.005	0.001
Silicic acid, .....	..	..	..	..	..	..	..	..	..	0.0021	0.013	0.001
Organic matter,	0.001	..	..	..	..	..	0.012	..	0.017	..	..	..
Total,.....	1.593	10.354	26.0379	26.3859	25.9211	23.9975	7.207	5.869	3.190	2.8604	1.727	1.171

Salt wells are made artificially by pumping water into an excavated salt mine. The saturation of the water with salt is effected; and yet the process of pumping in pure water and drawing out strong brine made continuous by letting down a pipe into the well, opening nearly but not quite at the bottom. The water in the pipe was always much below the level of the great bulk of water in the well, because the sole opening in the pipe being near the bottom, it only allows that to ascend in it which has become dense from the quantity of salt it has taken up; and thus, while pure water or weak brine is pumped into the well, only strong brine is pumped out of it through the pipe.

When the brines are very weak, they are always made to undergo a preliminary evaporation in the air; and when the presence of sulphates and the chlorides of calcium and magnesium are calculated by their quantity to impair the commercial character of the product, certain purifying processes are had recourse to by which these are removed. When carbonate of iron is present in the weak brine, it is generally got rid of by exposing the brine for some time to the air. The carbonic acid by which the iron is held in solution gradually escapes

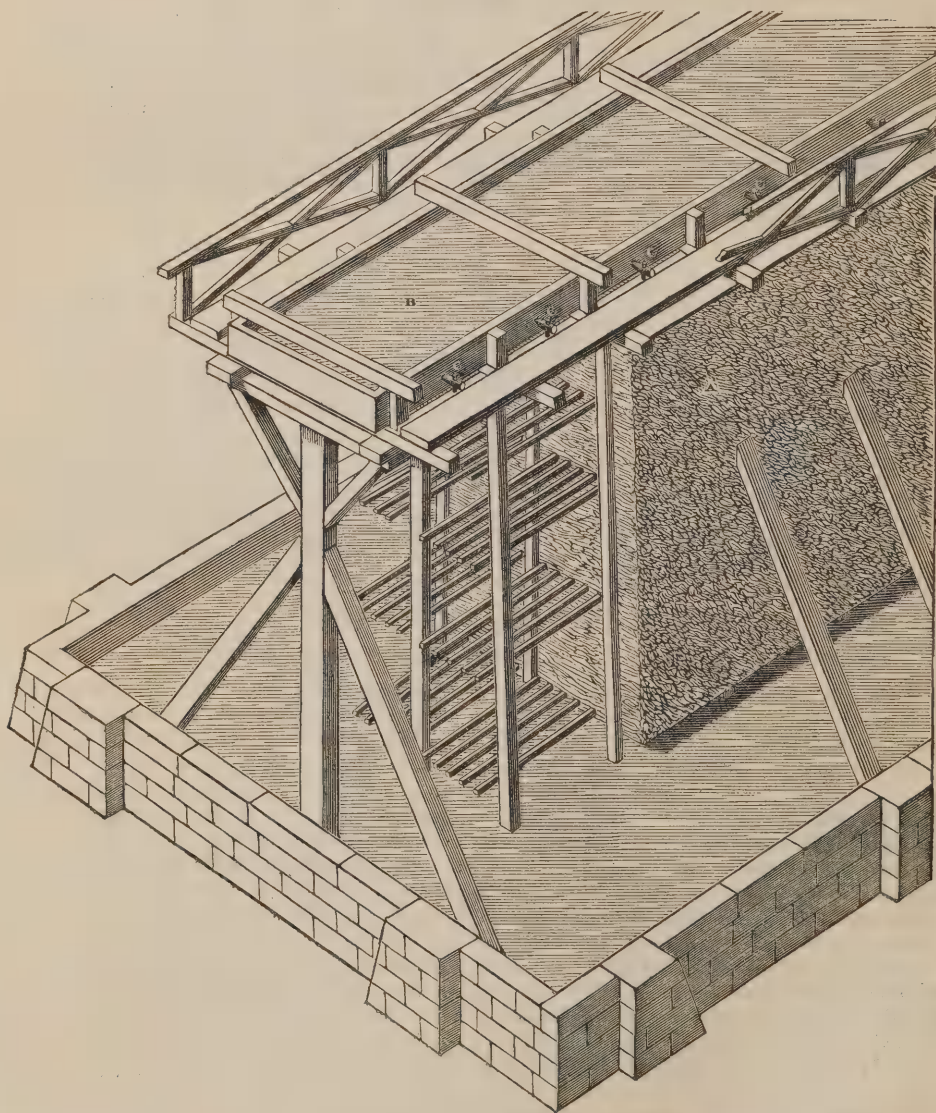
into the atmosphere, and the carbonate of iron becomes converted into sesquioxide of iron, and falls. The muddy sediment, consisting of this and a little carbonate of lime, which also falls as the carbonic acid escapes, induces the growth of certain species of confervæ, and these impart an odor of decomposing organic matter to the water, which is, however, gradually removed in the subsequent operations. The process of evaporation with weak brines is carried on in France and Germany in what are termed graduating houses. These are large wooden structures from eight hundred to upwards of five thousand feet long by about forty feet broad, covered over at the top, and open at the sides to allow a free circulation of air through the interior. The roof covers and protects from the rain several very large but shallow wooden cisterns intended to receive the brine, or there may be only one cistern, divided by wooden partitions into several separate compartments, but the extent of these divisions, their collection under one roof, or their separation, are determined by circumstances purely local, such as the character of the water, or indeed the motive power available in distributing it. The several compartments are used to contain the brine

in different stages of concentration. The first is intended to receive the brine itself; the second to receive the same after it has been concentrated by exposure to the air in minute streams, *et cetera*. The position of these graduating houses is such, that they shall be exposed in the direction of their greatest length to the prevailing winds.

Various arrangements have been devised to increase the evaporating surface of the brine; but that which now supersedes all others consists in pumping the liquor up to the summit of a high reservoir, and allow-

ing it to trickle through the interstices of bundles of thorn built up in the form of a wall and supported by woodwork. This plan was first practised in Lombardy, thence introduced into Saxony, and in 1559 thorn stacks were used at Bavières; and the great advantages of the plan, over the thin inclined planes and long cords then employed on the continent, began to be fully appreciated and generally adopted. The particular apparatus used will be best described from the woodcut. In Fig. 510, A is the wall of thorns, usually from thirty to fifty feet high, and from one thousand two hundred to one

Fig. 510.



thousand five hundred feet long. It is supported by wood beams firmly secured at the base with masonry. The thickness of the wall is nine feet at the base, diminishing to six feet at the summit; B, is a large

cistern intended to receive the weak brine, and furnished with a number of small taps, C C, on either side, by which the brine may be distributed over either surface of the wall.

Weak brine is pumped up into the cistern, C, and the taps are opened on that side on which the wind prevails. The brine now slowly trickles through the thorn sticks, and from the large surface it thus exposes to the drying influence of the atmosphere the brine becomes rapidly concentrated. The brine, however, is never sufficiently strong by passing through only one stack; it is therefore pumped up again and allowed to trickle through another, and so on until the liquor has attained a particular degree of saturation, which is generally something between 22° and 32° Twaddell, depending upon the price or abundance of fuel in the locality. It is then ready to be evaporated by artificial heat.

On the thorn sticks there gradually deposits a scale, consisting of oxide of iron, carbonate of lime and magnesia, and sulphate of lime, and forming what is called *thornstone*. This incrustation at length attains such a thickness as to fill up the interstices between the sticks. The stack has then to be taken down, and the thorns renewed. This happens about every five or eight years, according to the character of the brine.

The rapidity with which water is evaporated by the use of thorn stacks is remarkable. Thus at Schönebeck the thorn surface is three hundred and ninety thousand square feet, and under very favorable circumstances evaporates 3·7 cubic feet during the twenty-four hours from each square foot. And from very careful experiments by BERTHIER, at his works at Moutiers, it appears that thirteen gallons of water are evaporated under ordinary circumstances every twenty-four hours from each square foot of thorn wall. It is a remarkable fact that the water evaporated from the thorn surface is practically proportional to the surface exposed, whatever be the density of the brine. Thus, from a series of researches made at Moutiers by the above eminent chemist, brine of specific gravity 1·010 was evaporated to 1·140, and tested at three different periods to ascertain the loss; and this, as the process of concentration advanced, is expressed by the numbers 10, 12, 11. Now, the excessive evaporation indicated during the last stage was undoubtedly due to the fact of the salt itself becoming volatilized; for the experiments of BERTHIER were conducted on a large scale, and independently of the quantity carried away bodily by the wind, one recognizes, by the sense of taste, a small quantity in the air, even when the process of evaporation is very gentle and regular. The same fact is shown in a manner more decisive in the thin incrustation of salt which may be seen on glass exposed in the vicinity of salt works; and the loss of salt from this source may be estimated at about ten per cent. The results, however, of BERTHIER's experiments show that practically the rate of evaporation between a strong and a weak brine is inappreciable; although, when the experiment is conducted with great care, so as to protect the surface of the liquid from rapid currents of air, Dr. B. G. BABINGTON has shown that the degree of concentration exerts a very decided influence in respect to the amount evaporated.

When the brine in the tanks under the thorn stacks has been brought to a specific gravity of between 1·14 and 1·16, it is run out into large settling reservoirs

with just sufficient lime to decompose the chloride of magnesium. These reservoirs are of immense capacity, for the evaporation in the air taking place only during the summer months, the reservoirs are made large enough to hold a great quantity of the concentrated liquor to be evaporated during the winter months. The eight reservoirs at Salza have a capacity of nearly three million cubic feet. In these reservoirs the brine deposits all suspended matters, and the clear liquor is then run into wrought-iron tanks to be evaporated to dryness. The process of evaporating the brine to the point of saturation is termed the *schlottage* of the salt. The further evaporation to obtain dry salt is termed the *soccage*.

SCHLOTTAGE.—The pans used in this operation are from about sixty to eighty feet long, by from twenty to forty feet broad, and two feet deep, and are made of thin sheets of wrought-iron rivetted together. Each pan is heated by two or even four fires, and the flues are so built that the heat shall be distributed over the whole bottom of the pan in a manner as effective as the brick supports for the pan will allow.

The pans being three parts filled with brine, and a little blood or grease added, are brought as rapidly as possible to the boiling point. A scum now forms on the surface, which is skimmed off. This scum consists of the organic matter in the brine, and a little bitumen, which is found in all brines from natural springs. In the meanwhile the brine, which is saturated with sulphate of lime, gradually deposits this on the bottom of the pan. When about one-fourth of the original brine has been evaporated, new brine of specific gravity 1·16 is again pumped in, and the process of boiling and removing the scum is continued until the brine in the pan has been brought almost to the point of saturation; it is then run into other pans of a similar shape, and about equal capacity, to be evaporated to dryness.

The deposit on the bottom of the schlotting-pan gradually attains a thickness calculated to interfere very materially with the conducting power of the iron, and so occasions much loss of heat; the pan has then to be scaled. Of course the necessity for performing this operation will vary considerably with the degree of purity of the salt. It is usual, however, to scale the pan after it has been filled up from eight to about fifteen times.

The deposit consists of sulphate of lime and sulphate of soda, inclosing mechanically a quantity of common salt.

SOCCAGE.—This operation is performed in wrought-iron pans, similar to those described before for the schlotting process. They inclose an area of about four hundred square feet. The bottom of the pan inclines a little towards the centre. Over the pan is a dome-shaped structure of wood, terminating in a kind of chimney, for the purpose of carrying away the vapor. The woodwork supporting the dome is open at the side, immediately over the pan, that there may be a free circulation of air over the surface of the brine. During the beginning of the boiling down the pans are briskly heated; towards the end, when much salt becomes deposited on the bottom, the fires are slackened, that the bottom of the pan may not be burned.

The process is continuous, the salt being taken out as it falls by means of scoops, perforated at the bottom, to allow the mother-liquor to percolate.

In the case of lime having been added in the settling pan, or at the beginning of the schlotting process, the mother-liquors do not become too impure to be evaporated down to dryness, even after the pan has been filled up with new brine several times. There is also an additional advantage experienced at this stage of the manufacture, from lime having been added to throw down magnesia, inasmuch as, during the process of evaporation, chloride of magnesium forms a crust on the surface of the liquid, which re-forms almost as soon as broken, thereby preventing very materially the escape of vapor. The formation of the crust, however, may be avoided equally well by the addition of a little sulphate of soda. An interchange of elements is thus occasioned; the sulphuric acid of the soda going to the magnesia to form sulphate of magnesia, and the chlorine of the magnesium passing to the soda to form chloride of sodium. The soccage pan requires chipping out about once a month or rather oftener.

Salt having been removed from the crystallizing pans by the strainers, is collected into larger heaps on a perforated floor to drain further; it is then transferred to the drying chamber. This is simply a long chamber, heated by the flues from the fires used to evaporate the brine. These flues converge into one or two main flues, which are made to pass along the bottom of this chamber. The salt is either packed up in shallow wicker baskets, or it is put into moulds, and these are piled up above the flue in the drying chamber, and there allowed to remain until the salt no longer loses much moisture, when it is fit for the market.

In England, all the salt prepared is obtained from the evaporation of strong brines by artificial heat. The brines used are saturated, or nearly saturated solutions of salt in water, containing from 23 to 26.5 per cent. of pure chloride of sodium, besides other constituents; while a saturated solution of salt in water only contains 27 per cent. of salt. Indeed, several experiments tend to show that some brine springs would seem to hold in solution more chloride than would be taken up by the same amount of water, however long it were left in contact with dry salt.

The brine springs of Cheshire do not rise to the surface of the ground. They emerge from the surface of the rock; and when the spring is tapped, will rise in the bore hole from eighty to ninety feet. In the neighborhood of Winsford and Northwich, a shaft is sunk in the ground six feet square, and about one hundred and eighty feet deep. The sides of the shaft are carefully boarded with planks, and an inner planking of six inch boards, four feet square, is then built in, and the space between the boards well puddled with clay, to keep out the fresh-water surface springs. The inner boarding is firmly built in, and made more secure by cross-stays of stout wood. An iron pipe about nine inches internal diameter is then let down into the boring. The brine will rise in this pipe about ninety feet; it has consequently to be lifted by a pump to about the same extent. A continuation of the pipe from the pump conducts the brine into a larger

reservoir lined with masonry. This reservoir, which may be about two hundred feet long by about sixty or eighty broad, and perhaps six feet deep, is not built for the purpose of allowing sedimentary matter to deposit, for the brine as it is pumped up is perfectly clear and free from particles in suspension. It is of a clear sea-green color, and the reservoirs are built to serve merely as a store of brine on a high level, and from which it may be drawn down to supply the evaporating pans as needed.

The evaporating pans are contained in a shed which may be four hundred feet long by about eighty feet broad, and about thirty feet high, open at the sides to permit a free current of air to pass over their surface. The pans are set in a firm foundation of brickwork, which does not, however, extend up the sides. There are generally four furnaces to each pan, and the flues, so built as to support the pan, radiate over the whole of the bottom. There are usually three pans in a series, under two of which furthest removed from each other are the fire-places. The flues passing under these are continued under the third, and meet in the centre, at which point they unite into one, and the flue is connected with the chimney; but so as to economize as much as possible the heat of the flue, a chamber is built over it in its course to the chimney, and this is made use of as a drying stove for the squares of salt.

The Cheshire brines, which are of specific gravity 1.200, and contain about 24 per cent. of common salt, are of so pure a quality that they require no preliminary februation. The brine is, therefore, at once run into the evaporating pans, which are of sizes varying with the source of heat, and evaporated by the direct action of the fire, or by the waste heat of the steam engine used to pump up the brine.

Those pans in which the salt is evaporated by a boiling heat, are about twenty feet square and eighteen inches deep. Those where a lower temperature is used, are about forty feet long by twenty broad, and two feet deep. The pans are made of quarter-inch iron boiler-plates rivetted together. They incline somewhat towards the end furthest removed from the fires, that more salt may be deposited on that part. The inclination is from six to eight inches in the whole length.

Three kinds of salt are manufactured in Cheshire; the difference, however, consists in the size of the crystal, depending upon the rapidity with which the evaporation is conducted. Thus the finest-grained salt is made by rapid boiling; the coarsest at a temperature of about 150°; and the medium quality between these two points.

The evaporating processes are conducted as follows:—Brine is run into a pan until it is three parts full; a little glue, and sometimes a little waste grease is then thrown in to assist in the formation of a scum, and partly to prevent the crystals of salt as they fall from adhering to the bottom of the pan. The brine is then brought to the boil as rapidly as possible, and a scum which forms on the top is removed by lightly skimming the surface with a piece of board. The crystals of salt begin to separate almost as soon as the brine is brought to the seething point, and when about half the

water has been evaporated fresh brine is run in. The salt that has boiled out is removed twice in the twenty-four hours. This operation is effected by a perforated scoop, and the salt is put into wooden moulds, or tubs, about eighteen inches high and nine inches broad at the top, and diminishing to about seven inches at the bottom. These tubs are put into the salt pan to be filled, and stand on a ledge on the side about six inches from the bottom of the pan. When the tubs are filled the salt is slightly pressed down, and the tubs are removed from the ledge on to a perforated floor, so that the mother-liquor may drain away from the salt. To allow of this there are two slits in the bottom of the tub. When the salt in the tubs has drained twelve hours, the tubs are reversed, and then withdrawn from the squares of salt, which are removed to the drying chamber, where they are allowed to remain until they become dry. From a salt-pan twenty feet square two hundred tubs of salt, each containing thirty pounds of dry salt, are removed in a day. The pans are not allowed to cool, except for purposes of cleansing, the brine being repeatedly pumped in, and the process of evaporation being continuous. About once a week the salt is more thoroughly removed than usual, and the brine in the

pan allowed to run low; the pan is then seated over the fireplace. This operation, called *dodging* or *scabbing*, is performed with a pickaxe furnished with a long handle, and having the iron flukes flattened at the ends. A man stands on the floor that runs round the pan, and by striking with the axe he loosens the incrustation, and then removes it with a rake and spade. The scab consists of a little clay and sulphate of lime, but principally of common salt which has been burnt on to the bottom of the pan. When a pan has been worked for a month, a scale will have gradually formed over the entire bottom. The whole of the salt is then removed, the fires put out, and the mother-liquors, being of little value where there is such abundance of brine, are run away. The whole underpart of the pan is then scaled with a hammer and chisel.

The brines of Worcestershire are of higher specific gravity than those of Cheshire, and contain twenty-six per cent. of salt; but the method of working does not differ in any essential particular from the description given, and, therefore, they do not require a separate notice.

The following tables, by Dr. CAMPBELL MORFIT of New York, show the constitution in one gramme of various samples of salt:—

RANK.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
Commercial Brand, and Source of the Specimen.	Key, West Solar, Florida.	St. Martin's	Liverpool Rock.	Kiskiminitas from Tarentum, Pa.	Omn.	Liverpool fine.	Liverpool ground alum.	Cudwell's boiled, from Syracuse, New York.	New York.
Chloride of sodium,	0.993514	0.985266	0.982713	0.977931	0.975485	0.969917	0.969423	0.968882	0.968488
Water,	0.008900	0.007000	0.005000	0.019000	0.020000	0.005000	0.014000	0.012000	0.012000
Insoluble residue,	0.000050	0.002000	0.006000	0.000200	0.000300	0.000400	0.000700	0.000400	0.001100
Chloride of potassium, ....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Chloride of calcium,	0.000119	.....	.....	0.003017	.....	.....	.....	.....	0.002671
Chloride of magnesium,	0.000934	0.002123	0.002547	0.000849	0.002123	0.006708	0.005774	0.000849	0.002547
Sulphate of lime,	0.000554	0.000510	0.001700	.....	0.001900	0.010005	0.003011	0.014300	0.015624
Sulphate of potassa, .....	.....	.....	S. trace.	.....	.....	trace.	S. trace.	.....	trace.
Sulphate of soda, .....	.....	0.002520	0.000659	.....	0.001364	0.004330	0.007628	0.003085	.....
Nitrate of soda,	trace.	.....	S. trace.	trace.	.....	.....	.....	.....	trace.
Silicate of soda,	trace.	0.000336	0.000505	0.000252	0.000505	.....	trace.	trace.	.....
Organic matter—soluble, ..	.....	.....	.....	.....	trace.	.....	.....	.....	.....
Iron (Fe ₂ O ₃),	0.000800	0.000400	0.001100	0.000200	trace.	0.000500	0.000700	0.000400	0.000800
Alumina (Al ₂ O ₃), .....	.....	0.000200	.....	0.000500	0.002000	0.000600	0.000900	0.001200	0.000500
Total,	1.003971	1.000355	1.000224	1.001949	1.003677	0.997460	0.999136	1.001116	1.003730

RANK.	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.
Commercial Brand, and Source of the Specimen.	Kanawha, Virginia.	Haskin's salina, coarse, from Syracuse, New York.	Goose Creek, Kentucky.	Bonaier,	Spencer's boiled, from Syracuse, New York.	Hope Factory, New York.	Nassau.	Anguila.	Syracuse Company, New York.
Chloride of sodium,	0.967460	0.965540	0.964276	0.963288	0.962938	0.962851	0.960321	0.957348	0.956663
Water,	0.022000	0.014000	0.022000	0.017000	0.022000	0.014000	0.011000	0.022000	0.016000
Insoluble residue,	0.000600	0.000000	0.000300	0.001000	0.000300	0.000600	0.001000	0.005800	0.001800
Chloride of potassium,	S. trace.	.....	S. trace.	.....	trace.	.....	.....	.....	.....
Chloride of calcium,	0.003257	.....	0.007747	.....	0.000009	.....	.....	.....	.....
Chloride of magnesium,	0.002887	0.000509	0.001613	0.007132	0.002717	0.002123	0.008665	0.002293	0.000509
Sulphate of lime, .....	.....	0.014500	.....	0.004000	0.013992	0.016500	0.004800	0.008600	0.020000
Sulphate of potassa, .....	.....	S. trace.	.....	S. trace.	.....	trace.	.....	.....	.....
Sulphate of soda, .....	.....	0.000809	.....	0.006777	trace.	0.000667	0.009562	0.004410	0.002978
Nitrate of soda,	trace.	.....	.....	.....	.....	.....	trace.	.....	.....
Silicate of soda,	0.000421	0.000252	trace.	0.000168	0.000168	0.000168	0.000673	0.000168	0.000168
Organic matter—soluble, ..	.....	trace.	.....	.....	trace.	.....	.....	.....	.....
Iron (Fe ₂ O ₃),	0.000400	0.000500	.....	0.000500	0.000800	0.000600	0.000500	0.000200	0.000700
Alumina (Al ₂ O ₃),	0.000400	0.001300	.....	0.001700	0.001700	0.002000	0.000500	0.001200	0.001300
Total,	0.997325	0.998010	0.995936	1.001565	1.004624	0.999509	0.997021	1.002019	1.000118

TABLE—(Continued.)

RANK.	XIX.	XX.	XXI.	XXII.	XXIII.	XXIV.	XXV.	XXVI.	XXVII.
Commercial Brand, and Source of the Specimen.	Tarentum, Pa.	Liverpool Ashton.	Turk's Island.	Pomeroy, Ohio.	Curaçoa.	Alleghany saline, Penna.	Cadiz.	St. Ubes.	Inagua.
Chloride of sodium,	0.943494	0.941656	0.940776	0.938382	0.929816	0.915437	0.913722	0.890402	0.878509
Water,	0.040000	0.044000	0.032000	0.046000	0.053000	0.064000	0.063000	0.061000	0.096000
Insoluble residue,	0.000300	0.000500	0.003600	trace.	0.001500	0.000800	0.001700	0.001900	0.005000
Chloride of potassium, ....	.....	.....	.....	S. trace.	.....	.....	.....	.....	.....
Chloride of calcium,	0.007541	.....	.....	0.008971	.....	0.013495	.....	.....	0.004844
Chloride of magnesium,	0.008491	0.002462	0.007047	0.005095	0.011036	0.005394	0.010699	0.023870	0.000594
Sulphate of lime,	0.002740	0.012200	0.009400	.....	0.002300	.....	0.003300	0.009800	0.013059
Sulphate of potassa, .....	.....	trace.	trace.	.....	trace.	.....	trace.	trace.	.....
Sulphate of soda, .....	.....	0.001262	9.007330	.....	0.007208	.....	0.009942	0.014475	.....
Nitrate of soda,	trace.	.....	.....	.....	.....	.....	trace.	.....	trace.
Silicate of soda,	0.000336	0.000421	.....	trace.	trace.	0.000505	0.000252	0.000337	0.000336
Organic matter—soluble, ..	.....	.....	.....	.....	.....	.....	.....	.....	.....
Iron (Fe ₂ O ₃),	0.000200	0.000200	0.001000	trace.	trace.	0.000200	0.000300	0.000400	0.000100
Alumina (Al ₂ O ₃),	0.000600	0.000200	0.000600	trace.	trace.	0.000200	0.000700	0.000500	0.000200
Total,	1.003702	1.002901	1.001953	0.998448	1.004860	1.000031	1.003615	0.002682	0.998642

This article would be incomplete without adverting to the saline springs of Syracuse, in the state of New York. Numbers VIII., XI., XIV., and XVIII., in the analyses by MORFIT are samples from this district. The springs of Syracuse, to which in a great measure the growth and prosperity of New York are attributable, are among the most interesting natural productions with which America is blessed. They occupy a circuit of about nine miles around the Southern extremity of the Onondaga lake. The salt is obtained from the water by the heat of the sun. The process of obtaining salt by solar evaporation is very simple. A series of wooden vats are built, twelve feet wide, six inches deep, and several rods in length. The brine is let into the first tier direct from the reservoir, and is left in repose until the dirt and other impurities have subsided. The clear supernatant liquor is then drawn off by siphons into the second tier of vats, which are lower than the first, where the sulphate of lime is deposited in beautiful crystals. The brine, thus purified, is redrawn off into the third and lowest tier of vats, where by exposure it evaporates, and the crystallization of chloride of sodium commences. At first the crystals are seen on the surface of the brine, and resemble drops of melted tallow let fall upon a surface of cold water. These particles accumulate, and precipitate themselves to the bottom of the vat in large quadrangular and hexangular crystals of the purest salt, hard, dry, and of a beautiful white color. This Onondaga solar or coarse salt is unsurpassed, it is said, in the world, and its antiseptic properties are widely known and appreciated. The rapidity of the process, and the consequent proportional crop, depends upon the heat of the weather; the process of evaporation being greatly retarded by a humid atmosphere. Sunshine is of course desirable at the salt works, and the superintendent keeps a close watch upon the weather. At the first symptoms of a shower all hands are immediately summoned to *push on the covers*, and the temporary roof, which is passed on rollers over the crystallizing brine, is ready to be removed the very instant the sun shines again.

The state of New York, through its superintendent, bores the wells, procures the supply of brine, and conducts it through logs to the salt works, which are the property of individuals. The localities are leased at a nominal rent, and for an indefinite number of years, but are only to be employed for the manufacture of salt. For the *raw material* a tax of one cent per bushel is levied on every bushel of salt produced. This amounted in 1856 to fifty-nine thousand nine hundred and forty-six dollars and forty-four cents; the expenses were fifty thousand two hundred and fifty-five dollars and sixty-five cents.

PHYSIOLOGICAL EFFECTS.—In minute quantity chloride of sodium is injurious to very few, if any plants, and to some it appears to be beneficial. Used moderately, it is on certain lands a most excellent fertilizer.

Salt serves many important and essential uses in the animal economy. It is employed, on account of its agreeable taste, by the people of all nations. It is an invariable constituent of the healthy blood. There is a deficiency of this saline constituent in cholera.

As a chemical antidote, chloride of sodium may be administered in poisoning by nitrate of silver. As an alterative and tonic, it is useful in scrofula and glandular diseases. As an astringent in hemorrhage, dysentery, and diarrhœa, it has been given in conjunction with lime or lemon juice. It is frequently employed as a dentifrice.

As an external application, salt has been employed for various purposes. A saturated solution, applied with friction, is used as a counterirritant and discutient in glandular enlargements and chronic diseases of the joints; as a stimulant, it is rubbed on the chest in fainting and asphyxia.

The inmates of every sea-side infirmary can tell a yet happy tale of the beneficence of salt breezes. They speak of lingering diseases fortunately ended; of long convalescence speedily consummated by cure. Many a life which seemed gradually ebbing away in the atmosphere of a crowded city hospital, have these briny vapors called back and fortified, and cheered

with long years of health. Salt plays here the part of a good fairy: it makes of this infirmary a kind of healing heaven for the bodily sick.

The duty on salt was repealed in 1823; but in 1815 the makers of bleaching powder were allowed to use rock salt duty free, under the inspection of the excise, who required that the salt should be crushed at the mines and mixed with a certain proportion of ground manganese, so as to render it unfit for curing purposes. The Editor's father decomposed salt which was six pounds a ton in Dublin in the year 1819. Mr. MUSPRATT mixed it with oil of vitriol, condensing the evolved hydrochloric acid in a series of stone jars. It was in Liverpool, in 1823, that he first decomposed salt in an open furnace, *disregarding entirely the hydrochloric acid*, which escaped and was diffused throughout the atmosphere. The salt he employed at first was termed *herring salt*, and cost forty shillings a ton. The price now is only eight shillings.

RETURN OF SALT COMPILED AND ISSUED BY THE NORTHWICH AND WINSFORD CHAMBER OF COMMERCE.

	Tons
White salt carried on the river Weaver from 5th April, 1857, to 5th April, 1858,	647,437
Rock salt,	65,773
Carried by rail from Winsford and Northwich, estimated at.....	525,000

WORCESTERSHIRE.

Stoke and Droitwich,	196,500
----------------------------	---------

IRELAND.

Duncone, near Carrickfergus, belonging to the Belfast Mining Company, shipped	16,660
Used for manufacturing purposes,	5,798
White salt manufactured,	4,877

Total produce of the United Kingdom,..... 1,462,045

TOTAL QUANTITY OF WHITE SALT EXPORTED FROM JANUARY 1 TO DECEMBER 31.

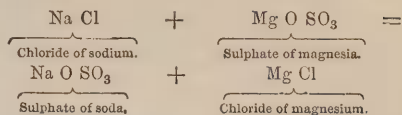
	Tons.
1855,	583,770
1856,	720,689
1857,	648,516

ROCK SALT EXPORTED.

1857,	87,119
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SULPHATE OF SODA.—GLAUBER'S SALT.—SALT CAKE.—*Sulfate de Soude*, French; *Schwefelsaures Natron*, German.—This salt was discovered by GLAUBER in 1658, and since that time has been commonly known by his name. It exists in nature in both the mineral, vegetal, and animal kingdoms. It is a very common ingredient of mineral springs of the purgative class, and is also one of the salts met with in small quantity in most terrestrial waters. Amongst the English medicinal waters, it exists in considerable quantity in those of Cheltenham, of Leamington, and of Spital.

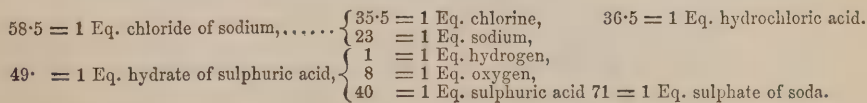
In some springs, as in that of Paipa among the Andes, it is so abundant that crystals of it are formed upon the surface over which the water is thrown; it is likewise found in crystals in the brine springs at Salinas d'Espartinas, near Madrid. In the latter locality the sulphate exists as *Thenardite*; while in the former it is in the hydrated state, or *Mirabilite*. GMELIN accounts for its presence in mineral waters, on the supposition that it is formed by double decomposition from common salt and sulphate of magnesia contained in the liquid, thus—



Sulphate of soda in the form of mirabilite is also found in several localities in Austria, in Bohemia, in the Tyrol, and in several places in Spain and Hungary, as well as in Switzerland; on lavas, and as an efflorescence on the Siberian and Caspian steppes. A mixture of the crystallized salt with gypsum—*Glauberite*—was discovered by GIMBERNAT in the canton of Argovie in Switzerland; the same compound has been found in crystals and reniform masses, embedded in rock salt, at Villarubia in Spain, at Vic in Lorraine, Berchtolsgrad in Bavaria, and at Atacama in Chili. In the vegetal kingdom, sulphate of soda is found in the ashes of some plants which grow by the sea-shore, as the *Tamarix gallica*; and lastly, it is found in some of the animal fluids, as the blood and urine. Artificially this salt is extensively made, and its production being the first stage of the process for the conversion of common salt into carbonate of soda, it is a most important article in commerce.

It is obtained by heating common salt with sulphuric acid, and is also a by-product in the preparation of nitric acid, of sal ammoniac, of carbonate of magnesia, in the amalgamation of silver ores; and it may also be obtained from many glass slags, if native or artificial soda has been used in the preparation of the glass.

Preparation.—Sulphate of soda may be most conveniently prepared in the pure state, by causing liquid sulphuric acid to react on chloride of sodium. When the two substances are mixed, violent effervescence ensues, hydrochloric acid being evolved; the effervescence having partially subsided, heat is applied to the vessel, and continued until the whole of the hydrochloric acid is expelled, and the mass becomes dry. The following diagram shows the change that takes place:—



The dry mass obtained as above, usually contains a little sulphuric acid more than is required to produce neutral sulphate of soda. This is removed, after solution in water, by the addition of a sufficient quantity of carbonate of lime, or the excess of acid may be neutralized by the addition of carbonate of soda. The

solution is now to be filtered, evaporated, and set aside to crystallize. The crystals obtained by resolution and recrystallization yield the salt chemically pure. Or the menstruum may be obtained directly by dissolving carbonate of soda in dilute sulphuric acid.

Crystallized sulphate of soda, procured as above,

contains to each equivalent of sulphate ten equivalents of water, and consequently, is represented by the formula $\text{Na O, SO}_3, 10 \text{ HO}$. The anhydrous salt is obtained by heating the crystals to redness, or, according to FARADAY, in anhydrous crystals, by evaporating an aqueous solution at a temperature considerably below 212° . MISTCHERLICH gives the degree at 104° , and others state it to be as low as 91° .

Properties.—The primitive form of the ordinary crystallized sulphate is the oblique rhombic prism. The anhydrous salt forms in crystals belonging to the right prismatic system. This latter, which is transparent, when exposed to the air becomes opaque on the surface, owing to absorption of water. The taste of the crystallized salt is cooling and bitterish saline. By exposure to the air it effloresces, with the loss of all its water. The perfectly effloresced salt intumesces in very moist air to three times its bulk, and then becomes a crystalline mass of ordinary Glauber's salt, with a slight excess of water. When the crystallized salt is heated, it undergoes the aqueous fusion, gives off its water, and thereby becomes a white solid; but at a red heat this again becomes liquid. One part of the crystals dissolves in three parts of water at 60° ; at 212° water dissolves its own weight of the salt. It is insoluble in alcohol. A crystallized sulphate of soda is also known, containing eight equivalents of water, and having the formula $\text{Na O SO}_3, 8 \text{ HO}$.

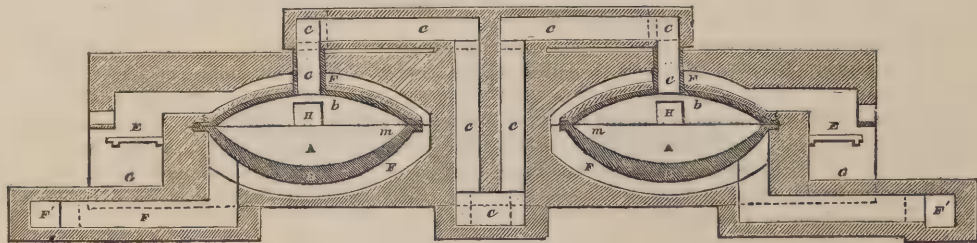
Physiological Effects.—Sulphate of soda is a mild but efficient cooling laxative or purgative salt, promoting secretion and exhalation from the mucous membrane of the stomach and bowels without causing inflammation or fever. It was formerly the most favorite saline cathartic in this and other European countries, but since the beginning of the present century has gradually been displaced by the sulphate of magnesia.

Manufacture of Sulphate of Soda.—Sulphate of soda possesses more than a chemical interest. Its preparation, as previously mentioned, is the first stage of the

process now so extensively carried on for the conversion of common salt into carbonate of soda. In the production of the dry salt, technically known as *salt cake*, sulphuric acid is caused to act upon common salt in a proper apparatus, the products of the reaction being salt cake and hydrochloric acid. Until of late years the decomposition was effected in an ordinary reverberatory furnace, named the decomposing furnace. Some furnaces of this kind were constructed with two compartments, in one of which the materials were mixed, the greater part of the gas liberated, and the liquid evaporated to a pasty condition; in the other the calcination of the residuary sulphate was effected. In many decomposing furnaces the whole operation was carried on in the same division. An important improvement on this plan of decomposition was effected by introducing into the decomposing bed of the double furnace a lining of sheet lead, upon which the materials are mixed and brought to a pasty consistence, and they are then removed to the roasting bed to be more completely freed from acid. Furnaces of this kind are still in use in many alkali works. But for the most complete apparatus for the production of salt cake, manufacturers are indebted to Mr. JOHN LEE, who proposed the substitution of a concave iron pan for the leaden one previously employed. The advantages obtained by the use of these pans are, first, a great diminution of the expense of production, since the leaden pans rapidly become corroded during the process; and, secondly, that with the iron pan a much stronger sulphuric acid may be employed to effect the decomposition, with the further advantage of preventing the formation of so much bisulphate of soda as by the old method.

A description of the annexed woodcuts—Figs. 511 to 514—will show the most approved form of apparatus in use at the present day. Fig. 511 is a transverse section of two decomposing pans, A, A, formed of cast-iron, weighing about five tons each, and suitably set in brickwork, so as to allow the bottom and sides to be

Fig. 511.



exposed to the fire. The pans are covered with a sheet of iron, *b*, the joints made good with luting. *E* is the fireplace; and the flues, *F*, *F*, pass over and under the pans, but not through them. The roof of the pan is not always constructed of iron; a brick roof is frequently in use, the arch being higher in proportion to allow of its being self-supporting.

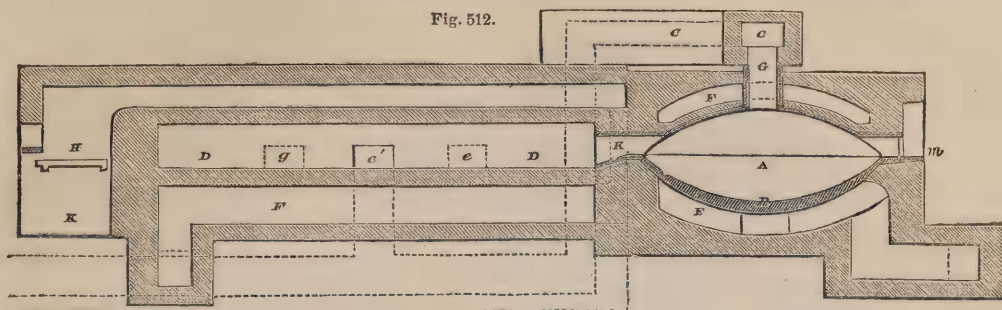
There are three openings into each of the pans, one through which the charge is introduced, and shown at *h*; the other immediately opposite, through which the charge is pushed out, seen at *k*, in Fig. 512; the

third is for the escape of the acid vapors through the pipe, *c c*. This pipe is composed of short lengths of closed earthenware fitting into one another, and well luted to prevent escape of gas.

Two of these pans are usually worked together, and the hydrochloric acid gas brought into one main flue, as shown in the figure. The salt cake furnace is attached to the decomposing pan, as shown in Fig. 512. The sole of this furnace, which is flat, is constructed of good fire-brick or Welsh tiles, and the roof, which is only slightly arched, is of fire-brick. *h* is the fireplace,

and *F F* are the flues passing over and under the furnace, but not through it. *G* and *E* are openings for the purpose of turning over and withdrawing the charge. *C* is the tube through which the acid gas escapes.

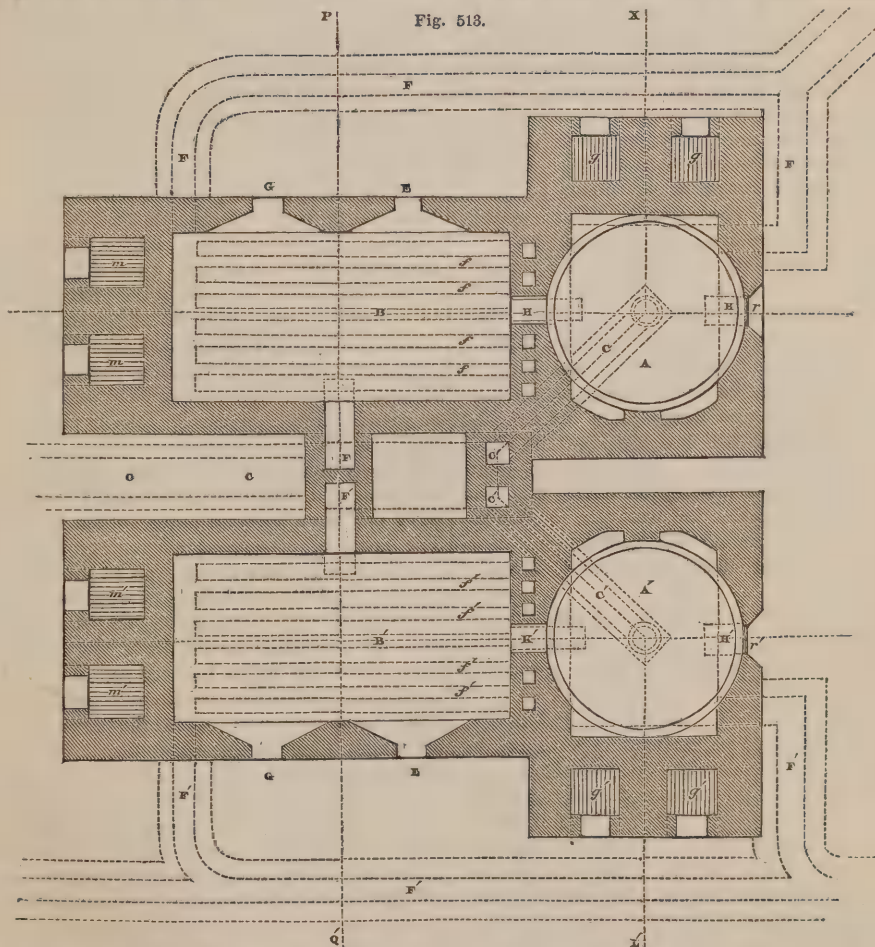
Fig. 512.



The charge is pushed into the furnace from the decomposing pan through *K*.

Fig. 513 shows a plan of the decomposing pans and furnaces. *A A'* are the decomposing pans; *C C'*, the acid flues; *F F'*, and the dotted lines, *fff*, show the arrangement of smoke flues.

Fig. 513.



charge of salt, amounting to about sixteen hundred-weight, is introduced through the doorway, *H*. The tile which closes this is now fitted into its place, and the sul-

Fig. 514 is a transverse section of the same through *P, F, Q*, in which the arrangement of flues is plainly seen.

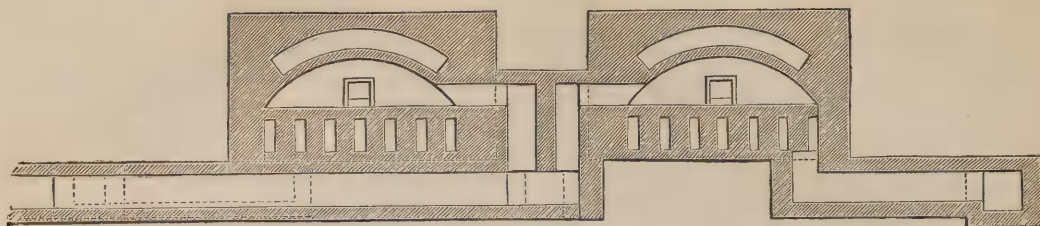
The following is the method of producing salt cake with the use of the apparatus described. The pan, *A*, is first heated to a suitable temperature, and the

phuric acid is run in. It is preferred to use acid of about specific gravity, 1.450, and heated to a temperature of about 120°, so as not to cool the pan more than is neces-

sary. The proportion of acid required is about one thousand eight hundred pounds, or one hundred and

twenty-three and a half gallons, that being the quantity which, making allowance for water and slight impurities

Fig. 514.



in the salt, is just sufficient to convert all the chloride of sodium into sulphate of soda; and the charge is usually measured out by filling a small leaden vessel, of known capacity, placed near or over the decomposing pan, so as to allow of the acid being run in upon the salt by a siphon. The acid and salt having both been introduced, the tile closing the opening, *H*, is now removed, and the materials thoroughly mixed with an iron rake. This mixing serves at the same time to prevent frothing, by facilitating the escape of gas. The doorway is then effectually closed with the tile and proper luting, and the fire urged under the pan. In the course of an hour nearly all the acid vapor will have been disengaged, and the greater portion of the common salt be converted into sulphate of soda. Much of the sulphuric acid, however, is now found combined with soda as bisulphate of soda; and to decompose this, so as to render the excess of acid serviceable in forming sulphate of soda with the undecomposed common salt, a high temperature is required, to obtain which the charge is now pushed forward through the opening, *K*, into the salt cake furnace, *D D'*—Fig. 512—by means of rakes inserted through *H*. The charge is spread evenly over the floor of the furnace, the tools being worked through the doorways, *E* and *G*. The salts are here exposed to a low red heat for about one hour, and frequently turned over during this interval. Meanwhile the decomposing pan having remained empty for a time, to enable the workman to raise the temperature to the proper extent, a new charge of common salt and acid is introduced, and worked off in the manner described.

The sulphate of soda is heated in the salt cake furnace until it assumes a reddish-yellow tint, when it is raked out through the doorway, *G*, and is considered finished.

From two furnaces, such as shown in the drawings, and of the dimensions given, ten charges each may be drawn in a day, or sixteen tons of common salt may be decomposed, with the production of nearly nineteen tons of salt cake. The working of sulphate of soda is effected, however, under different arrangements, in a manner even more rapid than this. Thus, when an open reverberatory furnace is used in place of the closed furnace described, sixteen charges a day may be drawn; the open furnace being capable of more rapid heating than the *blind* or *closed* furnace described, and the acid gases being more readily carried away by the current of air passing over the heated salt.

Condensation of the Hydrochloric Acid.—It now remains to consider the various plans adopted to effect the condensation of the hydrochloric acid gas evolved from the mixture of acid and salt. The whole or nearly the whole of this was, in the early days of the manufacture, allowed to escape into the air, the inconvenience attending its condensation having been considered of greater consequence than the value of the liquid acid. But owing to the great demand for bleaching powder, the manufacturer found it would be to his interest to condense *the whole* of the acid, so as to use it in the preparation of bleaching agents.

The plan of apparatus at present employed for effecting the condensation of gaseous hydrochloric acid to the liquid form, was first suggested and patented in 1836 by Mr. GOSSAGE; the condensers have, however, been greatly improved since that period. The gas, as evolved from the mixture of sulphuric acid and salt, is conducted by means of pipes inserted in the brickwork of the dome of the pot, and in the arch of the furnace, to a massive tower or series of towers—Fig. 515—constructed of large rectangular slabs of silicious stone, cemented together and bound exteriorly by stout iron clamps. These towers may be filled with small pebbles or rounded flints, but usually coke is preferred, and a stream of water is allowed to flow from a cistern on the top slowly through the mass; this, meeting with the ascending gas, completely condenses it, and ultimately flows out by an aperture in the bottom to a recipient. The mode of condensing adopted previously to the introduction of these towers was, as previously stated, by a series of WOLFFE'S bottles; a system far too cumbersome to be adopted successfully on the very extensive scale on which the manufacture is now carried on.

A connection exists between the first and second towers near the summit, and from the base of the second tower an underground flue, for the purpose of creating a draught through the apparatus, is carried to the chimney-stalk. The gases eliminated from the mixture of salt and sulphuric acid enter the first tower at its base, and pass upwards through the moistened coke; whatever is uncondensed is carried into the second tower, and in its passage through this downwards the whole of the acid is removed; and the uncondensable gases pass by the flue to the chimney.

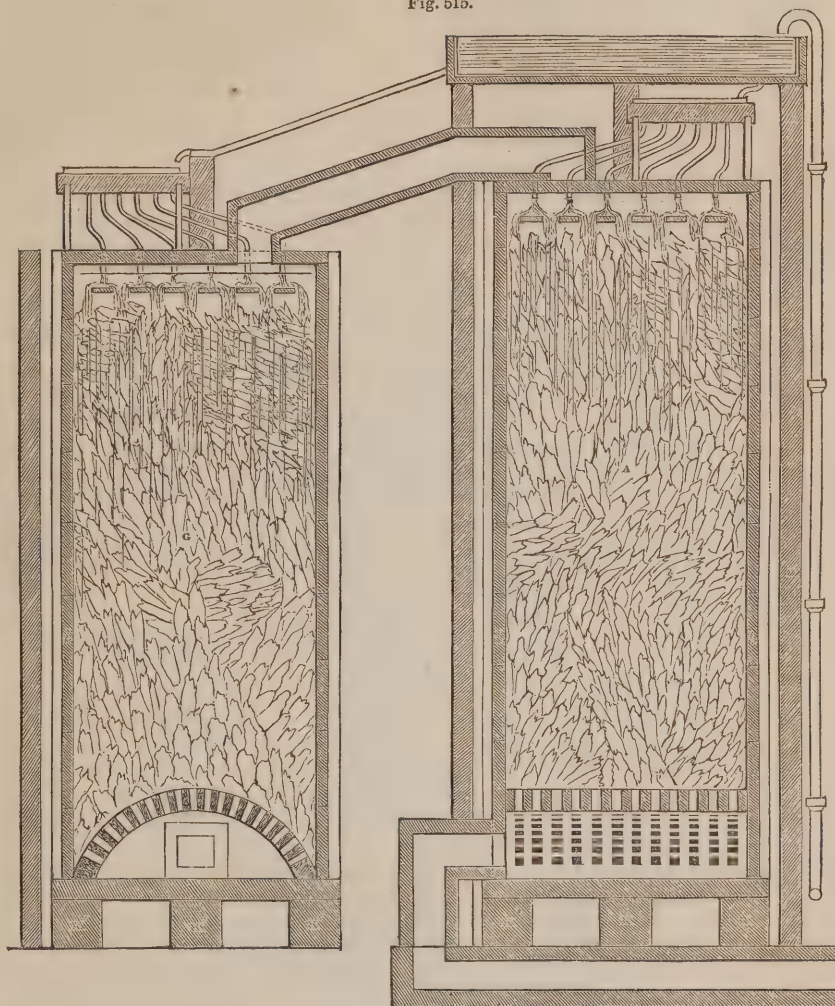
If the towers are of sufficient height, two only will be requisite to effect complete condensation of the acid; but if this should not be the case, three or more may be connected together; the first two at the summit,

the second and third at the base; the third with the fourth at the top, and so on through the series. By this arrangement acid may be obtained of specific

gravity 1·150 to 1·160, quite strong enough for the decomposition of binoxide of manganese.

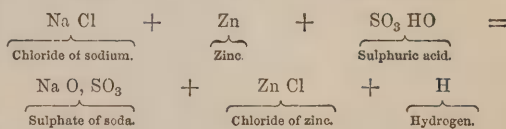
If the hydrochloric acid be required for other pur-

Fig. 515.



poses than the decomposition of binoxide of manganese, as for the evolution of carbonic acid from chalk or limestone, condensers of a still more simple nature may be employed; because then, a weaker acid answering the purpose equally well with a strong one, a far greater proportion of water may be used. In this case, a single tower divided into two compartments by a partition wall, and the whole well filled with small pieces of coke and supplied with water in sufficient quantity, will effect the condensation of the whole of the acid evolved. But unless the acid can be at once consumed on the spot, it is of course always desirable to obtain it in as concentrated a condition as possible. In some manufactories, as well to prevent the escape of hydrochloric acid as for economy, the towers, constructed as above described, are filled with limestone instead of coke or pebbles; and the carbonic acid evolved is applied in the preparation of bicarbonate

of soda, as will be hereafter mentioned. It has also been proposed to avoid the evolution of hydrochloric acid altogether, by adding sulphuric acid and zinc to a solution of chloride of sodium. In this case, hydrogen is eliminated, and there is produced chloride of zinc and sulphate of soda as in the annexed equation:—



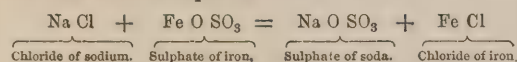
The products can be separated by crystallization; and from the mother-liquor, lime will precipitate hydrate of zinc, which can afterwards be substituted for metallic zinc, for the production of sulphate of soda from common salt.

Various other processes for the preparation of salt-

cake have been adopted on a more or less extensive scale. In some of these, hydrochloric acid is also obtained; in others chlorine, or a mixture of this and hydrochloric acid; and in others, the chlorine is removed in combination with bases. One of the oldest of these methods consists in heating together in a reverberatory furnace a mixture of common salt and pyrites—bisulphide of iron. In this process, the sulphur of the bisulphide becomes oxidised to sulphuric acid, under the influence of heat, atmospheric air, and of sodium; and the sodium being at the same time converted into soda, combines with the acid produced. The chlorine of the common salt partly combines with the iron, and the other portion unites with the hydrogen of the water or steam evolved from the combustible materials employed to form hydrochloric acid. The heat being continued, the chloride of iron at first formed becomes decomposed; nearly pure chlorine is evolved, and sesquioxide of iron remains in admixture with the sulphate of soda. By lixiviating the mass with water, the sulphate of soda is dissolved; and by evaporating the solution, the pure salt may be obtained in crystals, or as an anhydrous mass. Mr. LONGMAID, some years ago, proposed this method for the preparation of sulphate of soda for the alkali manufacturer, and at the same time of pure chlorine for the production of bleaching powder. He suggested that the chlorine might be freed from hydrochloric acid by bringing it in contact with a surface of wood, kept moist from the outside; and the gas from it, if to be used in the production of bleaching powder, must then be dried by any convenient method. The mixture of sulphate of soda and oxide of iron he directs to be employed, instead of the pure sulphate, in the preparation of black ash according to the usual process.

This plan is not likely to supersede the old method of manufacture; for, besides the great defect arising from the slowness with which the decomposition of the common salt proceeds, there is, according to DUMAS, a considerable loss of sulphur during the process, owing to the incomplete oxidation of this element. This portion of sulphur is evolved as sulphurous acid in admixture with hydrochloric acid.

Protosulphate of iron has been used to a considerable extent for the conversion of chloride of sodium into sulphate of soda. This may be effected in two ways; firstly, by dissolving the copperas and salt together in water, when a double decomposition takes place, with formation of sulphate of soda and protochloride of iron as in the annexed equation:—



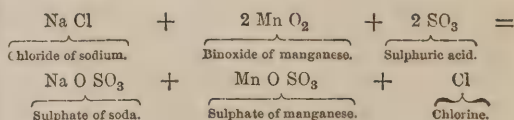
The sulphate of soda may be procured in hydrated crystals— $\text{Na O SO}_3, 10 \text{ HO}$ —by exposing the solution to a low temperature; or, in an anhydrous state as an opaque precipitate, by concentrating the solution at the boiling point. In either case the chloride of iron remains in the mother-liquor.

The other process for the conversion of chloride of sodium into sulphate of soda, by means of sulphate of iron, consists in the calcination at a red heat, in a reverberatory furnace, of an intimate mixture of the

two salts in the proportion of sixty parts of chloride of sodium to one hundred and forty of the iron salt. In this case, there is formed, at first, sulphate of soda and chloride of iron as above. By heat, however, the chloride is transformed, by virtue of the decomposition of water, into hydrochloric acid, which is disengaged, and into oxide of iron, which remains mixed with the sulphate of soda. There is also eliminated a little sulphuric acid and chlorine. DUMAS states that the process may be rendered more productive of sulphate of soda, by mixing the two substances together in powder, and leaving the mixture for some days in a heap moistened with water, and afterwards heating to redness. This mode of manufacture of sulphate of soda is employed in the North of France.

Among the processes for the manufacture of caustic soda, that of Mr. WILLIAM HUNT has been mentioned. It consists in the decomposition of sulphide of sodium by means of oxide of zinc or of copper, when there are produced caustic soda and sulphide of copper or zinc. The metallic sulphide thus obtained, he directs to be applied in the preparation of sulphate of soda, either by roasting so as to produce sulphuric acid in the ordinary manner, and causing this to act upon common salt; or by heating the sulphide to a temperature of about 400° , with exposure to the air, whereby the sulphide is converted into sulphate. The sulphate of copper or zinc thus obtained, after having been freed from the accompanying oxide or unaltered sulphide by lixiviation with water, is mixed with a solution of common salt, when there are produced sulphate of soda and chloride of zinc or of copper. The alkaline sulphate is separated from the metallic chloride by crystallization, and from the chloride remaining in the mother-liquor, oxides of zinc or of copper, in a condition to be used for the decomposition of more alkaline sulphide, is obtained by the addition to the solution of milk of lime.

The preparation of sulphate of soda and of chlorine for bleaching powder was carried on simultaneously at former periods. The process which was first adopted by the Messrs. TENNANT and Company of Glasgow, consists in heating together a mixture of chloride of sodium, binocide of manganese, and sulphuric acid in leaden vessels, when changes ensue, as represented in the subjoined equation:—



The whole of the chlorine of the common salt is therefore evolved in the pure state, while there remains a mixture of sulphate of soda, sulphate of manganese, and the excess of sulphuric acid employed. To this as much common salt is added as is necessary to saturate the free sulphuric acid, and the whole is heated in a reverberatory furnace. In this operation, the manganese and iron-salts are decomposed; and the sulphate of soda may then be withdrawn from the fused mass with water. It will be observed that in this process one half of the sulphuric acid employed is lost; and this

being of greater value than the equivalent proportion of hydrochloric acid lost in the other methods of treatment, the plan has been generally abandoned.

Besides these sources of sulphate of soda, it is obtained also frequently from the mother liquors of common salt. When these solutions are sufficiently concentrated, a substance separates in flakes, which is a double salt composed of sulphate of soda and sulphate of lime. This is collected, washed with cold water to remove adhering chloride of sodium, and then treated with boiling water. The sulphate of soda now dissolves; and the solution, after being allowed to deposit, is decanted and evaporated to the crystallizing point or to dryness. The sulphate of soda in these liquors is probably formed by double decomposition of sulphate of magnesia and chloride of sodium.

Crude salt cake, prepared by the action of sulphuric acid upon common salt, usually contains from ninety-two to ninety-six per cent. of sulphate of soda, and, besides free sulphuric acid, chloride of sodium, minute quantities of other matters, as sesquioxide of iron, *et cetera*. A sample prepared at the works of JAMES MUSPRATT and Sons, Liverpool, was examined in the Editor's laboratory, and gave the following results:—

Sulphate of soda,	96.515
Sulphate of lime,	0.923
Sulphuric acid,	0.616
Chloride of sodium,	1.345
Sesquioxide of iron,	0.191
Water,	0.187
Insoluble matter, coal, <i>et cetera</i> ,	0.130
Loss,	0.093
	100.000

NITRATE OF SODA—CUBIC NITRE—SODA-SALT-PETRE.—*Nitrate de soude*, French; *Salpetersaures Natron*, German.—Nitrate of soda may be prepared artificially by saturating nitric acid with carbonate of soda, and evaporating the solution to dryness; by precipitating nitrate of baryta or of lime with sulphate of soda, allowing the solution to deposit the insoluble earthy sulphate, decanting the clear liquor, evaporating and allowing the nitrate to crystallize; and lastly by mixing solutions of nitrate of potassa and of sulphate of soda, when double decomposition succeeds, producing sulphate of potassa and nitrate of soda. The latter salt, being much the more soluble of the two, remains in the liquid after the former has crystallized, and may be obtained as already directed. The pure salt may likewise be obtained from the common variety, by dissolving the latter in the least quantity of boiling water, filtering the liquid whilst hot, and stirring the filtrate till quite cold. The crystalline deposit which forms during the last operation is transferred to a funnel loosely plugged with cotton, allowed to drain, and then washed by pouring on it cold water in small portions at a time, allowing each washing to drain off thoroughly before the succeeding edulcoration, and continuing the operation till the washings give no milkiness with nitrate of silver. The powder is then dried.

Properties.—Nitrate of soda crystallizes in transparent rhombohedral prisms; it has a cooling and bitter taste. Water dissolves it with great reduction of temperature; three parts at 60°, one part at 125°,

and much less than its own weight at 212°, are required to dissolve one part of the salt. It becomes damp only in moist air; but, according to some chemists, deliquesces perfectly in an atmosphere saturated with watery vapor. When heated, it melts and evolves at first pure oxygen gas; afterwards the oxygen becomes mixed with nitrogen, and fumes of nitrous acid. It detonates with charcoal and other combustible bodies, but less violently than the corresponding salt of potassa. It is composed centesimally of—

	At. weight.	Centesimally.
1 Eq. of soda,	31	36.47
1 Eq. of nitric acid,	54	63.53
	85	100.00

Its chemical symbol is Na O, NO₅.

COMMERCIAL NITRATE OF SODA.—*Sources.*—This compound is not a manufactured product, but is found associated with other saline bodies distributed over various parts of the earth in the form of a mineral deposit, or as an efflorescence on the surface of the ground. Associated with nitrate of potassa, it is met with in Spain and in various parts of India; but the most remarkable deposit of this salt occurs in Peru, where a tract of country one league long and several broad, in all comprising, perhaps, fifty square leagues, is more or less incrustated with that substance. The existence of this salt in Peru has been known for about a century, and in 1820 some of it was sent to England; but the duty imposed was so high that it was not brought into the country. Between 1820 and 1830 several attempts were made to induce manufacturers to use the salt in England, America, and France; but it was not until 1831, that its real value as an article of commerce became generally known.

On the coast of Peru the land rises in a very precipitous manner to the height of about four thousand feet above sea-level; at this height the rocks shelve down a little into the country, and the view opens out on a plain of immense extent, varied only by slight undulations of the surface. These grounds, called the Pampas, are dry, arid plains, on which hardly a trace of vegetation is seen; plants of the cactus family even scarcely being able to maintain a struggling existence. No rain falls on these plains; and the deep blue of the sky or the bright glare of the sun is never obscured by a cloud; even the phenomenon of wind is hardly known; and the character of the locality is that of stillness, so profound indeed as to impress itself upon both man and beast.

From thirty to thirty-five miles from the coast, just before reaching the level ground of the Pampas, are found the deposits of nitrate of soda most esteemed for their purity and most easily procurable from their thickness. The depth of the layers varies from a few inches on the level plains to four, and even seven feet, on the slopes and hollows of the ground. The salt is found on the surface of the ground, or covered only to a very slight extent with a hard crust, consisting of a mixture of common salt and clay. This crust increases in thickness in some parts to four or five feet; and the crude nitrate or *nitrate calèche*, as

it is termed, under the thick layers, is the material most sought after for its purity. The workable nitrate—being that found of sufficient thickness—occurs in patches of about five hundred yards, mean breadth; and the character and value of the deposit varies considerably even within the limit of a few hundred yards. From an examination of several samples, the crude material has been found to contain on an average from twenty-five to thirty per cent. of impurity; this consisting principally of common salt, but associated with small quantities of chloride of iron, sulphate of soda, sulphate of lime, and iodide of sodium, and in some specimens clay.

Purification.—It has already been observed that the purest layers of nitrate lie under a hard crust of earthy matter, mixed with chloride of sodium; this is so hard that it is usual to employ the aid of gunpowder in dislodging the material by blasting. The powder used for this purpose is a coarse material made on the spot from the nitrate of soda, charcoal, and sulphur; the charge, where the vein of salt and the covering is thick, will frequently be three hundredweight, and this will dislodge upwards of twenty tons of salt. The pieces thrown up are broken with hammers, and a selection is made of the purest specimens. The crude product obtained in the manner described is, however, very seldom found in such a condition of purity as to be capable of immediate application in the arts; and the great difficulty of getting the salt from the *officinas* or *burks* to the coast, renders it imperative to purify the substance as much as possible in the localities that yield it. The process of purification usually adopted is, however, extremely simple, and is dependent on the difference in solubility between common salt—which is the principal foreign substance—and the nitrate of soda, at temperatures above the common.

The apparatus employed for this purpose consists of two dissolving vessels, a settling pan, and several crystallizing pans. The dissolving vessels are hemispherical pans of cast-iron, about six or seven feet diameter and three or four feet deep. They are dead-set in brick-work, and one fire plays round and between them. Into these vessels a quantity of mother-liquor, saturated with common salt from a preceding operation, is run, and a charge of nitrate calèche, consisting of fifteen quintals, is now thrown in, and the whole boiled for four or five hours, until the liquid is considered to be saturated with nitrate of soda. The solution is now ladled by hand into a settling pan, in which the liquid clarifies by subsidence. In a few hours the clear lie, still hot, is drawn off into shallow coolers, constructed of boiler-plate iron, and in these the nitrate of soda crystallizes out as the liquor cools. The crystals are shovelled out on to the ground, and dried by exposure to the sun, while the mother-liquor is made available for the solution of a further quantity of the crude material. The ordinary yield of crystals from fifteen quintals of nitrate calèche, is from eight to ten quintals, or about seven and a half hundredweight. A quantity of these dry crystals, sufficient for a load, is now introduced into two bags; these are slung on the back of a mule, and with this load the animal winds down the sides of the mountain to the sea-coast. The

mother-liquors, after being used for several operations, become charged to a considerable extent with iodide of sodium, when that substance is a constituent of the crude material, but little iodine is obtained from this source, although, with proper management and utensils, the working might be made a profitable investment. The use of steam has been tried in purifying the crude nitrate, but with only partial success. The apparatus employed for this purpose consists in an iron vessel constructed in the form of an inverted cone, both ends being open. This vessel is filled with nitrate calèche and steam blown in through the bottom of the cone. The great solubility of the nitrate of soda in water, and its powerful attraction for that substance, induces its separation from the common salt, and a saturated solution of nitrate of soda, made by the condensed steam, flows out through the bottom of the cone. But owing to the necessity for introducing the crude material in lumps, a great portion of the soluble part in the interior of these is protected by the undissolved portion on the outside from contact with the steam, and as a consequence, a large amount of nitrate of soda is left undissolved; the loss from this source is the cause that little favor has been extended to the process.

One of the greatest sources of inconvenience in the purification and export of nitrate of soda is the want of pure water all along the sea-coast. On the Pampas a brackish water is obtained by boring for a few yards, and this, although not agreeable, is yet drinkable; but at Iquique, which is the port whence almost all the nitrate of soda is shipped, no drinkable water is to be found; the whole supply being derived from the distillation of sea-water. There are two large distilleries established to supply the want in this respect. The water obtained is, however, too expensive an article to be used in quantities sufficient for the healthy sustenance of animal life, and the mules employed in bringing down the nitrate of soda to the port, obtain a supply only by bringing it down with them from the mountains. Their privations in this respect, and the consequent injury to healthy life, is one of the greatest obstacles to the cheap supply of nitrate of soda.

This salt, obtained by the method described, is now usually supplied in commerce in a condition of great purity; the foreign matters, including water, or the *refraction*, as these are collectively termed in commercial circles, seldom exceeding seven per cent., and being more generally below six per cent. The impurities consist principally of common salt and water, the latter being attracted from the atmosphere; but a small proportion of sulphate of soda and lime is also found in it, with variable quantities of sand. No other substance can be detected in the commercial article in sufficient quantity to influence its value; but the actual value of the salt is so high that it becomes a matter of importance to detect the proportion of impurities, however small in amount. The following rapid and effectual method of doing so is recommended for those who are unacquainted with the more delicate manipulations of analytical chemistry:—A small quantity of the sample—say one hundred grains—is weighed out, and dried in a water or oil bath until it no longer loses

weight. The difference will give the amount of water. Another quantity, about one hundred grains, is weighed out and dissolved in pure distilled water, a few drops of pure nitric acid added, and the liquid made up to a thousand grain measures with water. About a hundred grain measures of this solution are transferred to a glass tube, and tested by comparison with several dilute standard solutions of common salt, contained in similar tubes, by means of a solution of nitrate of silver. The amount of cloudiness in the precipitate is observed with great nicety, and by comparison with the precipitate observed in the standard solutions of common salt, the per centage of this substance in the sample tested may be ascertained with much exactness. A very important point to be observed in this method of testing, is to have the solutions so dilute that only a distinct cloudiness shall be produced by the addition of the silver salt. By attention to this matter very minute differences are readily observed.

The per centage of sulphate of soda is determined by a similar method, using hydrochloric acid to acidify the solution of the sample in place of nitric acid, and employing dilute standard solutions of sulphate of soda, to compare with the sample. The precipitation is effected with a few drops of a strong solution of chloride of barium; but while the indications of chloride of sodium afforded by a silver salt are immediate, the cloudiness produced by adding chloride of barium to sulphate of soda, contained in a large quantity of solution of nitrate of soda acidified, is not immediately perceptible to its full extent when the solutions are weak. It is therefore advisable to compare the results obtained with the standard solutions, and the sample tested, only after the lapse of some hours. With this simple precaution the estimation of the per centage of sulphate of soda is effected with great accuracy by the method described.

The sand is estimated by dissolving the salt in water, filtering the solution, and after thoroughly washing the filter paper, calcining the insoluble portion. The per centage of water, chloride of sodium, sulphate of soda, and sand, being subtracted from one hundred parts of the commercial sample, will give the per centage of pure nitrate of soda to a very close approximation.

Various methods of estimating the amount of nitrate by a direct process are practised; but accurate results are only obtainable by the exercise of considerable skill in analysis. These are described under the article, NITRATE OF POTASSA, page 735; and the same description will apply equally well to the estimation of nitrate of soda, with the simple alteration of the equivalent weight of the former to that of the soda salt; that is, by putting the equivalent weight of nitrate of soda—85—in place of 101, the equivalent of nitrate of potassa.

Nitrate of soda is distinguished from potassa-nitre by its deliquescent property, a character that renders it quite inapplicable to some of the purposes for which the latter is employed, as for instance to the manufacture of gunpowder. It is extensively employed in the manufacture of nitric acid, owing to its cheapness, and also because it affords nearly ten per cent. more nitric acid than the corresponding potassa salt. Its

principal consumption is in the production of nitric acid, and as a vehicle for conveying oxygen to the sulphurous acid of vitriol works, whereby it is converted into sulphuric acid. Of late years it has been used largely as a manure. The subjoined are analyses of the commercial salt; but besides the ingredients named, LEMBERT found also small quantities of iodide of sodium and iodate of soda:—

	Hoffstetter.	Lecanu.	Wittstein.
Nitrate of soda,	94.29	96.70	99.63
“ potassa,	0.43	—	—
“ magnesia,	0.86	—	—
“ lime,	—	trace	trace
Chloride of sodium,	1.99	1.30	0.37
Sulphate of potassa,	0.24	trace	—
Water,	1.99	2.00	—
Insoluble matter,	0.20	—	—
	100.00	100.00	100.00

The following table gives the amount shipped from Iquique, and which may be assumed to be the yield of the saliferous grounds of Peru.

SUMMARY OF NITRATE OF SODA SHIPPED AT IQUIQUE,
JANUARY 20, 1859, TO DATE, IN QUINTALS:—

For	1857.	1858.	1859.
England,	143,873	109,809	204,775
France,	127,767	138,465	197,980
Hamburg,	69,810	48,601	158,057
Orders,	141,220	204,927	175,957
United States,	13,600	24,900	29,780
Austria,	7,720	—	—
Holland,	6,038	—	11,866
California,	3,577	—	6,200
Spain,	20,300	—	—
Sardinia,	2,225	—	11,570
Chili,	—	11,666	—
Peru,	—	155	103
Total,	536,150	538,523	796,288

PHOSPHATE OF SODA.—This salt has long been known as one of the constituents of urine, having been discovered in that fluid by HELLOT in 1737. It was not, however, sufficiently distinguished from other salts till a much later period, when it was examined and analysed by PROUST, ROUELL, and KLAPROTH.

It is most conveniently prepared by adding carbonate of soda to the solution of acid phosphate of lime, obtained by treating bone earth with sulphuric acid. The liquor should be maintained at a boiling temperature; and the carbonate of soda must be added as long as effervescence continues, or until the solution has an alkaline reaction. The effervescence is due to the escape of carbonic acid; the soda unites with the free phosphoric acid and with a portion of the acid of the superphosphate, while at the same time phosphate of lime, or a mixture of this and carbonate of lime, is precipitated. This insoluble matter is removed by filtration, and the liquor is then boiled down and allowed to crystallize. To obtain an additional quantity of the salt from the mother-liquors, it is necessary first to examine if these manifest an acid or an alkaline reaction. In the first case, more carbonate of soda must be added to restore the alkaline reaction, and the liquor again evaporated and set aside to crystallize.

If, on the contrary, too much carbonate of soda has been added originally, the crystals obtained will require to be washed, a fresh portion of the acid phosphate of lime added, the solution evaporated, and again allowed

to crystallize. To obtain good crystals of this salt, it is necessary that a slight excess of carbonate of soda be present. In operations on the large scale, when it may be advisable to economize the phosphate of lime, FUNCKE directs that the precipitate obtained on adding carbonate of soda be dissolved in nitric acid; sulphate of soda is then added, and the nitric acid is removed by distillation. The residue is then treated with water, when a solution of phosphate of soda is obtained, with a deposition of sulphate of lime.

Properties.—Phosphate of soda crystallizes in beautiful transparent colorless rhombohedral prisms terminated by four converging planes. The crystals are represented by the formula, $2 \text{Na O, HO, PO}_5, 24 \text{HO}$. Their taste is cooling and mildly saline, not unlike common salt. They are soluble in four parts of water at 60° , and in two of boiling water. Exposed to the air, the salt undergoes efflorescence, but this takes place only at the surface; beneath, the form and transparency are preserved. Heated, the crystals fuse in their water of crystallization, and then water passes off. But one equivalent of water for every two equivalents of soda is obstinately retained, and cannot be expelled, except at a red heat. When two equivalents are driven off, the salt acquires peculiar properties, different from those it originally possessed, being converted into pyrophosphate of soda. The cause of the change of property, according to GRAHAM, is that in the common or rhombic phosphate, the acid is united in the proportion of one equivalent with two of soda, and one of water in the capacity of a base, constituting a tribasic phosphate of soda and water; and that when the basic water is expelled by a red heat, the salt becomes a bibasic phosphate, composed of one equivalent of acid and two of soda, and, therefore, a totally different compound. Phosphate of soda, consisting of two equivalents of soda, one of acid, and twenty-five of water— $2 \text{Na O, HO, PO}_5, 24 \text{HO}$ —contains—

	Centesimally.	
Soda,	62.6	40.00
Phosphoric acid,	71.4	45.62
Water,	22.5	14.38
	156.5	100.00

The uses of phosphate of soda are principally in medicine, and in the laboratory of the chemist.

Physiological Effects.—This salt is an excellent saline cathartic, equal to the most esteemed of the neutral salts in this respect, and superior to them in the mildness of its taste. As a purgative, it is employed in the diseases of children and delicate persons in preference to other saline substances, on account of its slight taste and mild action. It is well adapted for febrile and inflammatory disorders. It is one of the substances which have been applied in cholera, to restore to the blood its deficient saline matters. On account of the phosphoric acid which it contains, it has been supposed to be especially applicable in those diseases in which there is a deficiency of phosphate of lime in the bones. It has also been administered in diabetes.—*Pereira*.

Ordinary phosphate of soda—the variety above described, is known in combination with one equi-

valent only of water, the salt having this formula, 2Na O, HO, PO_5 ; and also with fifteen equivalents of water, represented by $2 \text{Na O, HO, PO}_5, 14 \text{HO}$.

Pyrophosphate of Soda— 2Na O, PO_5 —obtained by heating the simple phosphate, has already been mentioned. This is also known in combination with water, the crystallized salt being $2 \text{Na O, PO}_5, 10 \text{HO}$. **Metaphosphate of Soda**— Na O, PO_5 —is obtained by heating the pyrophosphate, and according to the degree of heat used in its formation, appears in three different forms which, though the same in composition, possess different properties, as if the pyrophosphoric acid passed by a gradual transition into metaphosphoric acid.

Phosphate of Soda and Ammonia, or Microcosmic Salt, is a compound much used in the chemical laboratory in blowpipe examinations. It is prepared by dissolving six parts of common phosphate of soda, and one part of chloride of ammonium, by boiling with two parts of water. As the solution cools the double phosphate separates in crystals, and by a second crystallization is freed from adhering chloride of sodium. In this salt one equivalent of soda in the common phosphate is replaced by ammonia, and the crystallized salt has the composition, $\text{Na O, NH}_4 \text{O, HO, PO}_5, \frac{1}{2} 8 \text{HO}$.

When subjected to the action of heat the ammonia escapes with the water of crystallization, and a compound of similar composition to borax remains, that is to say, a compound which contains both a free acid and a readily fusible salt. It is preferred in some cases to borax as a solvent or flux in blowpipe operations, the beads which it forms with many substances being more beautifully and distinctly colored than those of borax.

BORATES OF SODA.—There are several combinations of boracic acid and soda, such as the monoborate, baborate, and quadraborate of the alkali; but the most important of them is the baborate, a salt which has been already described fully in Vol. I., page 346, *et sequitur*. Allusion may, however, be made here to another source whence boracic acid and baborate of soda may be made. This is the baborate of lime—boracite—which has been discovered in large quantities on the Western coast of America, and called after its discoverer, HAYES, *Hayessine*. It is met with in the Peruvian province of Tarapaca, near the port of Iquique, and in the same locality as that which produces the nitrate of soda in such abundance. It is imported in moderately large quantities into Liverpool. It is in the form of fibroid lumps, which, when broken, appear in loose fibres or scales of a nacreous white color, intermixed or incrustated with crystals of carbonate of lime and finely divided white clay. Baborate of soda may be prepared from this mineral by reducing it to an impalpable powder, and dissolving in ordinary hydrochloric acid, filtering or clarifying the solution by subsidence, and adding carbonate of soda to the menstruum. The lime is separated by this process as carbonate, whilst baborate of soda is produced, and may be obtained from the filtrate or supernatant liquid by evaporation, *et cetera*.

CARBONATE OF SODA.—This important salt is met with in nature under various conditions, but never in a state of purity. It exists in the soda lakes of Egypt and

Hungary, and in other mineral waters, though not in sufficient quantities to remunerate for its extraction. KUHLMANN and VOGEL found it in admixture with the sulphate of the same base in an efflorescence on the walls in several towns, and considered its production to be owing partly to the presence of soda salts in the limestone used in the preparation of the mortar, and partly to the soda in the coal with which the limestone had been burned. In plants growing on the sea-shore oxalate of soda exists, and when these are burned, the oxalate, losing carbonic oxide, becomes carbonate.

Preparation.—In a state of purity, carbonate of soda is most conveniently prepared from the bicarbonate. To obtain it, the latter salt is washed with cold water until the filtrate, after being acidified with nitric acid, is not rendered turbid by chloride of barium or nitrate of silver. The washed salt is then dried, and by gentle ignition one half of the carbonic acid is expelled, and the pure neutral carbonate remains.

The bicarbonate of soda used should be as pure as can be obtained, and must, of course, be completely soluble in water. That most suitable is obtained by passing carbonic acid into a strong aqueous solution of crystallized carbonate of soda.

The process recommended by GAY-LUSSAC, for the preparation of pure carbonate of soda, is also a good one, and less troublesome than the former. He washes the ordinary commercial crystals of this salt with cold water; dissolves them in hot water, and cools the solution rapidly by surrounding it with cold water, stirring it all the time with a spatula, so that small crystals may be formed. These are to be collected on a funnel, and after the mother-liquor has been drained off, washed with cold water till the drainings mixed with excess of nitric acid no longer give a precipitate with nitrate of silver. The crystals are then to be dried, and when heated to low redness, the pure anhydrous carbonate remains.

Properties.—Anhydrous carbonate of soda is white, translucent, of specific gravity 2.4649; it is very soluble, and much more so in hot than in cold water; its reaction is alkaline, and its taste slightly caustic, much less so than the corresponding salt of potassa.

The annexed table shows the amount of the anhydrous salt contained in *solutions of different gravities at a temperature of 59°*:—

Specific gravity.	Per cent.	Specific gravity.	Per cent.
1.1816	14.880	1.0847	7.440
1.1748	14.508	1.0802	6.768
1.1698	14.136	1.0757	6.396
1.1648	13.764	1.0713	6.324
1.1594	13.392	1.0669	5.972
1.1549	13.020	1.0625	5.580
1.1500	12.648	1.0578	5.208
1.1452	12.276	1.0537	4.836
1.1404	11.904	1.0494	4.464
1.1356	11.532	1.0452	4.092
1.1308	11.160	1.0410	3.720
1.1261	10.788	1.0368	3.348
1.1214	10.406	1.0327	2.976
1.1167	10.044	1.0286	2.504
1.1120	9.672	1.0245	2.232
1.1074	9.300	1.0204	1.850
1.1028	8.928	1.0163	1.488
1.0982	8.556	1.0121	1.116
1.0937	8.184	1.0081	0.744
1.0892	7.812	1.0040	0.372

Carbonate of soda forms several crystalline com-

binations with water. When a saturated aqueous solution is evaporated at a boiling temperature, small crystals are deposited containing an equivalent of water, and consequently represented by the formula, $\text{Na O, CO}_2 + \text{HO}$. Monohydrated crystals are also formed when the ordinary commercial crystallized carbonate is kept in solution for some time in its own water of crystallization, or evaporated between 167° and 190; and when commercial crystals are exposed to the air at a temperature of 100°, the monohydrated carbonate remains as an effloresced mass. The form of the crystals is that of a four-sided table. It does not melt when heated, but at a temperature from 188° to 212° loses the whole of its water. Exposed to the air, it gradually absorbs moisture, to the amount of six or seven equivalents.

When ordinary crystallized carbonate is exposed to the air at a temperature of 54°, an effloresced salt remains, containing five equivalents of water, $= \text{Na O, CO}_2 + 5 \text{HO}$. This may also be obtained in crystals by melting the same salt and maintaining it at a temperature of 92°. PERSOZ states that crystals having this composition were accidentally obtained at the Buxweiler soda works, in transparent rhombic octohedrons, which effloresced slightly in the air, and when dissolved in water, and evaporated at 86°, again yielded the same salt. According to MITSCHERLICH, a solution of protosulphide of sodium exposed to the air, and frequently also a mixed aqueous solution of chloride of sodium and carbonate of potassa, yield crystals containing six equivalents of water, $\text{Na O, CO}_2, 6 \text{HO}$.

Crystals of carbonate of soda have also been obtained containing eight equivalents of water, $\text{Na O, CO}_2, 8 \text{HO}$, in the form of rectangular prisms, terminated by four-sided summits. These are produced when the ordinary crystallized salt cools from a state of fusion, or from a saturated aqueous solution at a particular temperature.

Common commercial crystallized carbonate of soda contains a still greater proportion of water than the salt last named. These crystals are a combination of one equivalent of carbonate of soda with ten equivalents of water, and are consequently represented by the formula $\text{Na O, CO}_2, 10 \text{HO}$. They are formed from a moderately concentrated solution, at a temperature below 92°. Their crystalline form is that of the oblique prism.

When gently heated this salt fuses, monohydrated carbonate crystallizes out, and the residual liquid, although containing more than ten equivalents of water to each equivalent of carbonate, solidifies at about 92°. When exposed to the air it loses a portion of its water, and becomes covered with an efflorescence containing eight equivalents of water.

NATIVE SODAS.—In France, Spain, and other countries where common salt is scarce, or where the duty upon this article is so great as to prevent its conversion into carbonate of soda, plants and alkaline waters are extensively consumed for the soda they contain. Besides these two great sources, carbonate of soda also occurs mineralized in some countries, though not in any great quantity, and is generally the residue of the evaporation of alkaline waters.

In Egypt, in the desert of Thiaït, to the West of the Delta, there is a pit four leagues long and a quarter of a league wide, which, during the winter months, becomes filled to the height of five or six feet with violet-colored water. In the summer this water evaporates, and an incrustation of carbonate of soda remains, half an inch in thickness. At Shegedin, in Little Cur- nania, a province of Hungary, WERNER found carbonate of soda as an efflorescence on the ground, and some years ago it was extensively collected and purified. The commercial demands for soda were supplied formerly, principally by the combustion of marine vegetals. These contain the soda, according to DUMAS, as oxalate, and by calcination this is converted into carbonate of soda. The plants, after being dried in the air, are burnt in rude furnaces, at a temperature just sufficient to cause the ashes to enter into a state of semifusion, so as to concrete on cooling into moderately compact cellular masses. The substance so obtained is known under various names, according to the country whence procured, and the kind of plant consumed for its production. Among these may be mentioned the *barilla*

of Spain, *kelp* of Scotland, *varec* of Brittany and Normandy, *blanquette* of Frontignan and Aiguemorte, and the *salicor* of Narbonne. The soluble portion of these ashes consists of carbonate, sulphate, and hyposulphate of soda, sulphide, iodide, bromide, chloride, and ferrocyanide of sodium, and sometimes also the corresponding compounds of potassium; and the matters insoluble in water are carbonate and phosphate of lime, sulphide of calcium, magnesia, alumina, silica, sulphide of iron, and charcoal. Of the several varieties, *barilla*, known also in commerce as Alicante soda, Carthagenia soda, and Malaga soda, is by far the most valuable. It contains from fourteen to twenty per cent. of soda in the state of carbonate. It has a greyish-blue color, and when exposed to the air for some time effloresces at the surface. It is hard and difficult to pulverize, and has a pungent alkaline taste. The plant yielding this ash is the *salsola soda*; it is carefully cultivated on the coasts of Spain for the purpose of this manufacture. The following table shows the composition of various kinds of ash, as given by GIRARDIN, RICHARDSON, and others:—

Constituents.	Alicante.	Cherbourg.	Cherbourg.	Unknown.	Unknown.	Spain.	Villeite.	Granville.
Sulphate of potassa,	—	22·19	42·54	18·80	22·00	15·85	20·35	13·50
Chloride of potassium,	—	16·00	19·64	—	—	10·55	10·53	15·60
Chloride of sodium,	65·00	45·78	25·38	73·20	68·00	68·35	54·11	65·68
Carbonate of soda,	2·00	9·53	3·71	6·00	6·00	traces	13·76	·22
Sulphate of lime,	—	—	—	—	—	1·10	—	—
Insoluble matters,	3·00	1·50	·73	—	—	—	—	—
Iodine compounds,	—	traces	traces	traces	traces	—	traces	traces
Sulphate of soda,	30·00	—	—	—	—	—	—	—
Water,	—	5·00	8·00	2·00	4·00	4·00	1·25	5·00
Loss,	—	—	—	—	—	·15	—	—
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

Kelp, which was formally prepared on a considerable scale on the coasts of Ireland and the Western coasts and islands of Scotland, is greatly inferior in value to *barilla*. This is the residue of the combustion of sea-weeds and various species of *fuci*, and similar plants. Its composition is very variable, not only as regards the proportion of alkaline carbonate, but of the other constituents; and hence the uncertainty that attended its employment in some of the chemical arts, and particularly in the manufacture of crown glass. Two specimens—the first from Heisker, the second from Rona, both in the Isle of Skye—analysed by URE, gave the following results:—

Soluble	{ Sulphate of soda,	8·0	19·0
	{ Soda as carbonate and sulphide, ..	8·5	5·5
	{ Chlorides of potassium and sodium, ..	36·5	37·5
		53·0	62·0
Insoluble	{ Carbonate of lime,	24·0	10·0
	{ Silica,	8·0	—
	{ Alumina, with a little oxide of iron, ..	9·0	10·0
	{ Sulphate of lime,	—	9·5
	{ Sulphur and loss,	6·0	8·5
		100·0	100·0

The native sodas obtained in France are distinguished under various terms, according to the district where extracted. The most valuable is that known as *salicor* or *Narbonne soda*, which is the residue of the combustion of the *Salicornia annua*. It contains from fourteen to fifteen per cent. of the alkaline carbonate. Another kind, also valuable, is *blanquette* or *aiguemorte soda*, extracted

from plants growing on the coasts, among which the most important are the *Salicornia europæa*, the *Salsola tragus*, the *Atriplex portulacoides*, the *Salsola kali*, and the *Statice limonium*. The first-named of these yields the most soda, and all contain abundance of common salt. The amount of carbonate of soda in *blanquette* varies from three to eight per cent. *Varec* or *Normandy soda*, like *kelp*, is the ash of plants belonging to the species *fuci*. This is the least valuable of the French native sodas, but it contains much sulphates of soda and potassa, chlorides of sodium and potassium, and a little iodide of sodium. It is principally extracted for the sake of its potassa salts, and is used in the manufacture of glass and saltpetre. It is also valuable as a source of iodine. The commercial demands for soda are now supplied almost exclusively by an artificial method of production. *Barilla* and *kelp* are used to a small extent in the soap manufacture, as a substitute for chloride of sodium, and in Scotland sea-weeds are still consumed as a source of potassa and of iodine. For the extraction of these the lie obtained from the ash is evaporated, when the potassa and soda salts separate one after the other, and the mother-liquor, distilled with sulphuric acid and peroxide of manganese, yields the iodine.

Generally, the ash of sea-plants, compared with that of those growing on the shore, is not rich in carbonate of soda, but contains much potassa. This fact is not, however, without exceptions, for in the various species of *fuci* soda largely predominates, and the fucoidal

plants are, doubtless, also the principal sources of iodine in those ashes.

Artificial Soda.—Soda Ash.—White Ash.—The production of artificial soda is now one of the most important branches of manufacturing chemistry, although the art was, little more than half a century ago, almost entirely unknown. It may indeed be averred, without fear of contradiction, that since the first application of chemical science to manufacturing operations, few discoveries have been made having such an important bearing, whether considered in relation to social life, to commerce, or to the progress and successful prosecution of the useful arts, as that of the production of carbonate of soda from common salt. It would, indeed, be difficult to exaggerate the immense importance of this manufacture; and probably no more striking proof of this can be given than the enormously increased consumption of this salt since its production at a moderate cost was effected.

The manufacture of soap and of glass; the fictile arts, as well as those of bleaching and dyeing; the production of paper; many metallurgical operations, *et cetera*—are dependent for their successful prosecution upon a supply of carbonate of soda, and the various other substances obtained as by-products in the manufacture; and to meet the consumption of this article, the transformation of chloride of sodium or common salt into carbonate of soda is almost entirely depended upon.

Historical Notice.—It has been already observed that the introduction of artificial soda dates only from a very recent period. It has also been previously mentioned that of all the varieties of native soda, that known as *barilla* is by far the most valuable, containing twenty-five to thirty per cent. of the carbonate. The plant yielding this ash grows most luxuriantly on the coasts of Spain, and was formerly cultivated on a most extensive scale for the purposes of this manufacture; and the ash was produced so abundantly as to supply, not only the native demand, but also that of other countries where either the plants yielding soda were scarce, or if a large quantity of ash was obtained, the amount of soda contained in it was comparatively small.

While it thus happened that other nations were almost entirely dependent upon Spain for a supply of soda, Great Britain produced large quantities of native soda under the form of *kelp*, the manufacture of which was carried on at a very early period on the North and West coasts of Ireland, and later on the Western shores and islands of Scotland. This branch of trade was especially brisk at the commencement of the present century when, to meet the exigencies of the war, high duties were imposed upon the Spanish *barilla*. The annual rental of the kelp shores of the island of North Uist alone amounted at this time to seven thousand pounds; and at one period the entire quantity of *kelp* produced in Scotland, and its adjacent islands, was estimated at more than twenty-five thousand tons annually. Still, the quantity of native soda thus obtained was not sufficient to supply the demands of commerce; and even in 1834, some years after the introduction of artificial soda, *barilla* was imported to the amount of upwards of twelve thousand tons. But more especially was France dependent upon Spain for supplies of

native soda; and when at the time of the French revolution of 1789, during the cessation of the commercial intercourse between France and Spain, the importation of *barilla* was suspended, the National Convention, incited by the proposition of a manufacturer of the name of CARNY, made, in a special proclamation, an appeal to the chemists of France to devise a process by which common salt might be rendered available as a source of soda, and to lay before them whatever plans they knew or could devise for the preparation of soda.

Not only was the importation of *barilla* discontinued, but the supply of potassa was also greatly diminished at this period. All the potassa that could be obtained in France was immediately applied to the production of saltpetre to be consumed in the fabrication of gunpowder; and those branches of trade requiring for their prosecution large supplies of alkali—either potassa or soda—were almost completely at a stand still. But necessity is ever the mother of invention; and the republic mastered the difficulty by an unprecedented development of internal power. To the appeal of the Convention due response was made, and numerous plans were proposed; but of all the processes communicated to the committee intrusted with the examination and execution of the various proposals, the only one deemed likely to be advantageous was that of LEBLANC, and the justness of this decision has been ratified by fifty years' experience; no essential improvement having since been made in the process. The first establishment for prosecuting the manufacture on a large scale, was erected in 1804 at Saint Denis by LEBLANC, and was carried out by him and his partners, DIZÈ and SHÉE. The great French chemist, after having spent all his means in perfecting his plan, was neglected by the government of his own country, and though handsomely rewarded by the British government, at last died in an hospital. In Greece and at Rome statues have since been erected to his memory.

The valuable properties possessed by carbonate of soda were too well known, even at an early date, in England, to allow experimenters to remain idle. In a patent granted to Dr. BRIAN HIGGINS as early as 1781, the Editor finds that he started with common salt, which he decomposed into sulphate of soda and hydrochloric acid by oil of vitriol, in the manner described under SULPHATE OF SODA. The dry sulphate or salt cake obtained was put into a reverberatory furnace, with one-eighth of its weight of coal, and heated till the ingredients were melted, and the sulphate reduced to the state of sulphide. At this stage twice its weight of lead was introduced, and when the metal was melted, the whole was stirred with an iron rod until the sulphur united with the lead, and the fused caustic soda floated in a distinct layer over the surface of the sulphide of lead. The furnace was then tapped to allow the alkali to flow out.

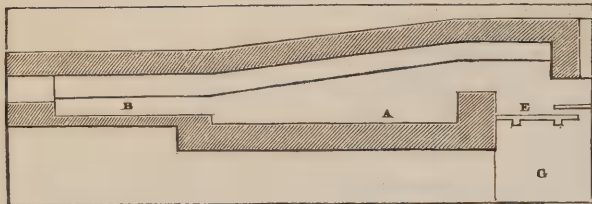
The great expense attending this plan, arising from the high price of lead, *et cetera*, rendered it valueless as a commercial process; but in the same patent HIGGINS states that *iron introduced into the furnace, or other metallic oxides, may be used equally well*. Here, therefore, is clearly developed the principle of LEBLANC'S

process, who merely replaced the *oxide of iron by oxide of calcium* or lime. HIGGINS, therefore, may be considered the *inventor* of the process.

LEBLANC's process, is substantially that practised in Great Britain at the present day. Its introduction into this country was, however, effectually prevented until a considerable period after it began to be adopted in France, by the enormously high duty imposed upon salt, amounting, from the year 1805 until about 1822,

drawings. Fig. 516 is a longitudinal section; Figs. 517, 517½ a plan; and Fig. 518 an end elevation. The furnace is similar in construction to a common reverberatory; but its floor, or *bed*, is divided into two parts, A and B—Fig. 516—B being raised half a brick above A. The former, or that farthest from the fire, is termed the *preparatory* bed, and upon this the materials are first placed and heated to low redness, so as to avoid cooling the furnace; the mass is often indeed in a state of partial fusion before its removal to the other hotter portion of the furnace bed, A. The latter is called the *fluxing* bed, and here the material is speedily brought to a liquid condition; the floor of A is lined internally with the most refractory fire-bricks that can be procured; it is not necessary to be so particular in respect to the floor of B. The arched roof is likewise built with fire-brick; E is the fire space, G the ash pit, and F the flue leading to the chimney.

Fig. 516.



to fifteen shillings per bushel, or about thirty times the cost of the salt. Shortly after the repeal of this impost, the manufacture was commenced on a considerable scale in England by Mr. JAMES MUSPRATT of Liverpool—*vide* SOAP, page 872. Until the year 1830, the soda produced, which was almost wholly consumed in the soap manufacture, was disposed of in the crude condition, under the form of *black ash*. After that period the carbonate of soda was extracted from the black ash produced by lixiviation, and sold, as at present, as a white or soda ash. For about six years after the commencement of the manufacture, the trade remained almost entirely in the hands of the Editor's father. In the year 1836 an important improvement was effected in the carrying out of the process, by the introduction, by Mr. GOSSAGE, of an apparatus for condensing the gaseous hydrochloric acid eliminated during the conversion of the common salt into sulphate of soda.

Many other improvements have been subsequently made, tending to render the process more complete and economical. These will be described in detail in the following pages. The first important operation in the manufacture—the conversion of chloride of sodium into sulphate of soda—has already been fully discussed. The next operation in the process is the production of *black ash*.

Black Ash.—Ball Soda.—The materials used in the production of this ash are perfectly dry sulphate of soda, charcoal, or small coal—slack—and carbonate of lime, either in the form of common limestone or as chalk. These substances require to be brought into a state of fusion together, and this operation is the most important part of the whole soda process.

The details of the furnace arrangements at present in use for this operation are shown by the annexed

When economy of space is a matter of much moment, the opening to the fire space is on one side of the furnace, and the bars reach across; but when it can be allowed, it is preferred to have two sets of fire bars, as shown in Figs. 517, 517½, and 518, and to fire the furnace at the end.

There are two openings into the furnace, C and D,

Fig. 517.

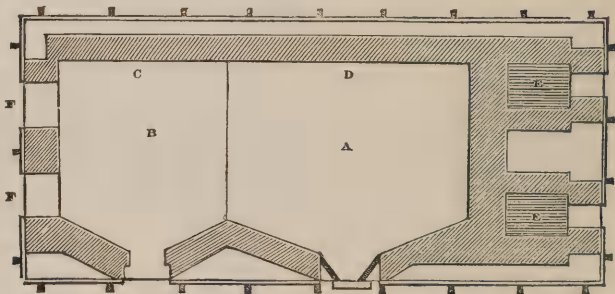
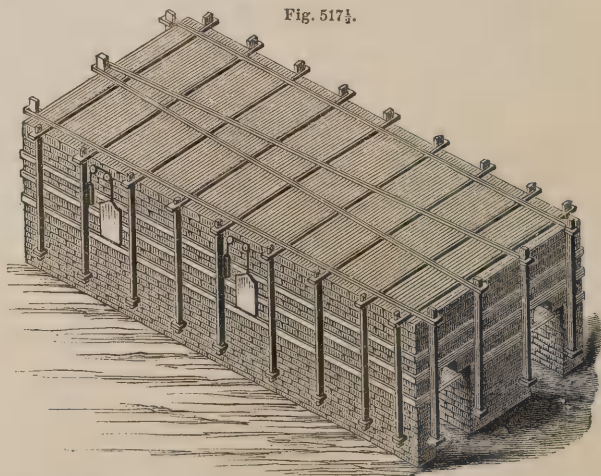


Fig. 517½.

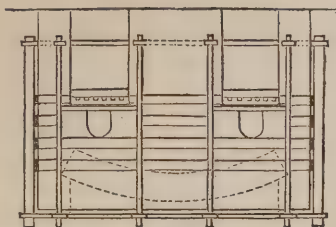


furnished with doors partially supported with weights passing over pulleys.

The walls of the furnace at c and d are bevilled off on the inside, so as to render the furthest parts of the furnace readily accessible by means of the iron rakes and utensils used in working it.

Immediately in front of the openings, c and d, is

Fig. 518.



suspended from the top of the furnace a stout iron rod, with a depression in the centre, so that the heavy rakes used may be supported upon it as a fulcrum.

The furnace walls are strengthened by iron plates, and firmly bound together by iron rods, as seen in the plan and end elevation.

The furnace having been heated to a suitable temperature, a charge, usually consisting of three hundredweights of sulphate of soda, three to three and a quarter hundredweights of crushed limestone or chalk, and two hundredweights of small coal, called *slack*, roughly mixed together, is then thrown on to the upper bed, A, and spread over it, so as to be evenly exposed to the flame of the furnace. A most important consideration is to have the ingredients of the mixture in proper proportions; although in compounding it, manufacturers may advantageously vary the amount of the ingredients, according to the purposes to which the black ash is to be applied. For instance, it is in some cases desired that the black ash produced should yield a considerable proportion of caustic soda, whereas in others, especially when the object of the manufacture is the production of soda crystals, the presence of caustic soda in large quantity is the occasion of great inconvenience.

It is a most difficult task to lay down precise rules for the guidance of the practical man in such cases, owing to the great difference in the materials used by different manufacturers. If the carbonate of lime employed be very fine, the proportions directed to be employed by *LEBLANC* yield a good black ash. These are a thousand parts each of dry sulphate of soda and chalk, and five hundred and fifty of charcoal.

Wood charcoal can rarely be obtained cheaply enough to be used for this purpose, and small coal, such as leaves but little ash, is substituted for it, in which case the quantity used should then be two-thirds of the weight of the salt cake, or even more.

If all the materials taken were perfectly pure the proportions required would be—of sulphate of soda forty-one parts, of carbonate of lime forty-four, and of charcoal fifteen. This accords with the explanation of the process of decomposition given by *DUMAS*; but his theory, as will be shown presently, has been more than once called in question. The proportions of salt cake and limestone or chalk employed, are properly one

hundred parts of the former to one hundred and five, or one hundred and ten, or even one hundred and twenty of the latter; while, as to the proportion of coal, probably not two manufacturers in this country use the same. *URE* recommends ten parts of salt cake, from eleven to twelve parts of chalk or limestone, and five parts of coal; and in a large manufactory near Liverpool, the proportions taken are, thirteen parts of salt cake, nine and a half parts of coal, and fourteen parts of limestone. Some chemists recommend that the materials should all be reduced to coarse powder, and afterwards most intimately mixed by sifting together. This is an unnecessary expense and waste, as the decomposition proceeds quite as successfully when the materials are simply broken into small fragments and mixed in that state.

The operation of fluxing is carried on in the following manner:—The furnace having been properly heated, the charge, differing in quantity according to the dimensions of the furnace, is thrown in upon the preparatory bed, spread evenly over its surface, and when it has become hot, transferred to the fluxing bed by means of an iron spatula or *slice*, shaped somewhat like an oar. The door of the fluxing bed is then closed, so that the heat may exert its full power, and a second charge is immediately placed upon the preparatory bed.

In a short time the charge upon the fluxing bed begins to soften at the surface and form into clots; it should then be turned completely over by the slice, and a fresh surface exposed, until the whole mass appears to have the consistence of dough. Jets of inflamed sulphide of hydrogen and carbonic oxide gases now issue from the various parts of the mass, and the whole should be continually worked about with the slice and an iron rake, so as to equalize the mass, and continually expose fresh surfaces to the action of the fire. When the jets of flame begin to disappear the mass is raked out into iron barrows, each capable of holding a single charge, in which it is allowed to solidify, and in this state it is termed a *ball*. In a furnace of the dimensions above given, the weight of each charge would be about seven hundredweight. Nine of these, the weight of which after decomposition will be about five hundredweight, may be introduced and withdrawn in eight hours, or twenty-seven in twenty-four hours. This is, indeed, the quantity usually worked in that period, but a still greater number of balls may be produced in the same time. The Editor has known nine charges to be introduced and completely decomposed in five and a half hours, and it is important to notice that the black ash so produced yielded its soluble portion with far greater ease than a ball that has remained in the furnace some minutes longer. It is, indeed, important that black ash should be withdrawn from the furnace the moment decomposition is completed, for in this case the mass, after solidification, remains so porous that the soluble portion may be extracted with colder water, and in a shorter period of time, than when closer and heavier black ash is produced. This is one of the characteristics of good black ash; another is that it should contain *no* sulphate of soda, and more especially should it be free from sulphide of sodium. It should be of a blackish-grey color;

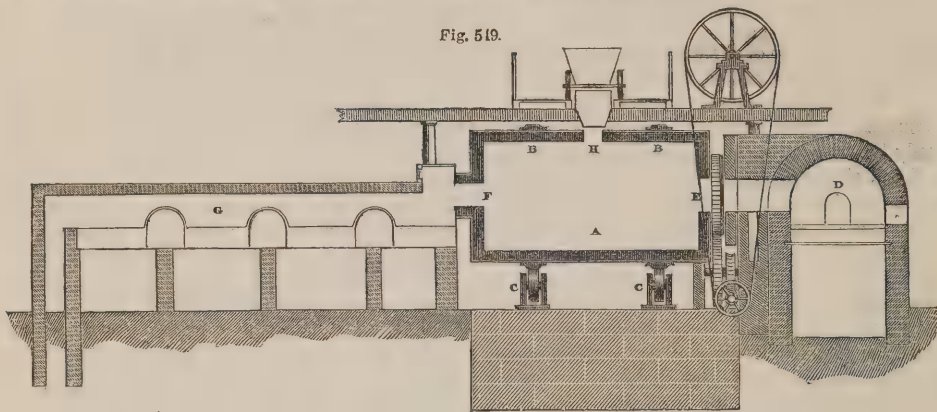
when treated with water the filtrate should be colorless, or with the slightest green tinge; and should yield about twenty-four per cent. of available alkali.

A patent was obtained in 1853 by ELLIOT and RUSSELL for an improved furnace, to be used in place of the usual black-ash furnace. This improvement consists in the substitution of a revolving cylinder of iron, lined with fire-bricks, for the chambers of the ordinary furnace, and with the later modifications by Messrs. STEVENSON and WILLIAMSON, of the Jarrow Chemical Works, South Shields, Newcastle-on-Tyne. Its advantages appear to be of sufficient importance to induce its general adoption by soda manufacturers.

In the annexed drawing—Fig. 519—A is the cylinder made of malleable-iron plates, lined with fire-bricks, some

portions of the lining being made to project in the form of shelves beyond the inner periphery of the brick cylinder, the shelves being intended to assist in mixing the charge. The malleable-iron cylinder is formed in two cast-iron rings, B B, which rest and run upon strong iron rollers, C C, supported in proper bearings. The cylinder is made to revolve slowly by means of a pair of pulleys and a train of wheels, as shown in the figure. The internal dimensions of the cylinder are—length thirteen feet, and diameter seven feet; D is the coal-burning furnace, from which flame escapes through a lateral orifice, corresponding with openings, E F, in the ends of the cylinder; and the flame, having traversed the chamber of the furnace, passes over the contents of a boiling-down pan, G, to the chimney.

Fig. 519.



When it is desired to charge the cylinder, the aperture, H, is raised to the position shown in the figure corresponding with a hopper containing the charge, and the charge is at once introduced. When the working of the charge is finished, the aperture, H, being unstopped, and the position of the cylinder reversed, it is run into a number of iron waggons, linked together, and brought consecutively under the aperture. With a cylinder of the above-stated dimensions the proper charge contains twenty-four hundredweights of sulphate of soda, with the usual proportions of chalk and small coal.

According to the invention of STEVENSON and WILLIAMSON, as described in their specification, the chalk is first introduced into the cylinder with a portion of the coal, and heat is applied from the coal furnace. During this period, which continues about an hour and a half, it is only needful to cause the cylinder to revolve about once in five minutes, and the same rate of speed is sufficient until the decomposition of the charge approaches completion, when it is found necessary to increase the number of revolutions to the rate of one in two minutes. The effect of the previous heating of the chalk and coal is to convert the greater part of the chalk into caustic lime. When this is effected, the charge of sulphate of soda with the remaining portion of small coal is added; and the rotating motion, together with the application of heat, being continued during a further period of about an hour, the decomposition is completed, and the charge

is ready for withdrawal. In this manner the furnace works off a charge every three hours, or decomposes nearly ten tons of sulphate of soda per diem, which is almost equal to the work of three ordinary black-ash furnaces.

The patentees state the advantages resulting from their improved furnace and mode of working to be—

1. The continual motion of the furnace causes its contents to become heated with perfect uniformity, so that no part of the charge ever attains an excessive temperature, and thus the loss of soda from volatilization is much diminished.

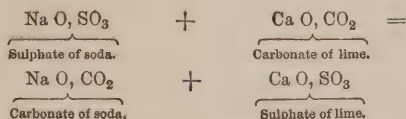
2. The mixing of the materials for the charge is effected without requiring the furnace to be opened for the introduction of implements, consequently without a current of air being drawn through the furnace during such mixing, thus providing for the atmosphere in the furnace being constantly devoid of free oxygen.

3. From the much larger quantity of work effected by the patent furnace at one time, a smaller number of skilled workmen is sufficient, and the risk of bad work is diminished, and a more complete decomposition of the sulphate of soda is insured by the more perfect mixing.

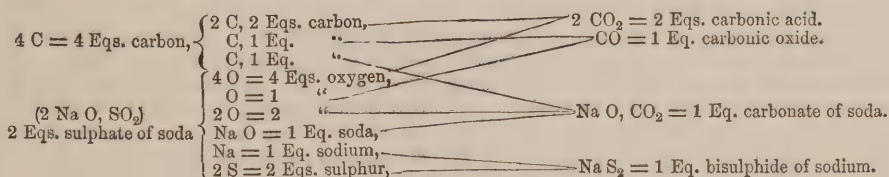
4. The waste of soda by absorption into the beds of the ordinary furnaces is avoided, and no tools being used in the process of mixing, the surface of the brick lining is less subject to injury from working than the bottoms of reverberatory furnaces.

Theory of the Decomposition.—The conversion of

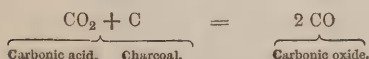
the sulphate into carbonate of soda by the above-described method of **LEBLANC** is a very complicated process of decomposition. Some French chemists, however, amongst whom **DUMAS** may be mentioned as the foremost, take a very simple view of the case. They suppose that when sulphate of soda, carbonate of lime, and charcoal are fused together in the proportions given above, in the first place the sulphate of soda and carbonate of lime react upon each other, producing carbonate of soda and sulphate of lime thus:—



The sulphate of lime, in contact with incandescent charcoal, yields its oxygen to the latter element, and carbonic oxide, or a mixture of this and carbonic acid is evolved, leaving protosulphide of calcium in admixture with the carbonate of soda previously produced.



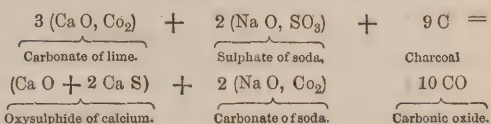
If carbon is present in greater proportion, it is taken up by the carbonic acid gas, which thereby passes into the state of carbonic oxide—



Supposing this to be a true statement of the transformations, the subsequent decomposition—namely, the reaction of carbonate of lime upon bisulphide of sodium—must also be far more complicated than is usually supposed. It is exceedingly difficult to arrive at any positive conclusion from the views of different chemists upon this subject. It is certain, however, that the calcination of sulphate of soda with both coal and carbonate of lime at the same time, is by no means essential to the process; if desirable, the sulphate might first be treated with coal alone, and the resulting sulphide or mixture of sulphide and carbonate be afterwards calcined with carbonate of lime.

Composition of Black Ash.—Probably in no other department of chemistry does a greater difference of opinion exist among theorists, than as to the true composition of black ash. The principal, but by no means the sole discrepancy in their statements, is found in their different views of the composition of the insoluble lime salt. When a mixture of sulphide of calcium and carbonate of soda in *equivalent proportions* is treated with water, insoluble carbonate of lime is formed, and sulphide of sodium is obtained in solution. But if to the mixture of carbonate of soda and sulphide of calcium a portion of lime be added, and the compound be then affused with water, the soda salt, partially

Other chemists take a different view of the decomposition. According to **GMELIN**, the sulphate of soda is reduced by the charcoal to the state of sulphide of sodium, with evolution of carbonic oxide gas; and the sulphide of sodium so produced is converted by the carbonate of lime into sulphide of calcium and carbonate of soda; and when three equivalents of carbonate of lime are used to two of sulphate of soda, the result is shown in the annexed equation:—



In the statement of the result of the decomposition, **DUMAS** and **GMELIN** agree precisely; they differ, however, as to the mode by which the result is obtained. **LIEBIG** shows the action of charcoal upon sulphate of soda to be far more complex than as stated by **GMELIN**, and gives the following diagram in elucidation of his views:—

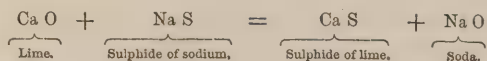
deprived of its carbonic acid, alone dissolves, and the sulphide of calcium remains unaltered.

The question to be solved, therefore, is—in what manner does the free lime prevent the decomposition that would otherwise ensue? Many chemists explain the difficulty, by supposing that the lime— Ca O —enters into combination with the sulphide of calcium. In the first place, however, it must be borne in mind that this supposed compound has never yet been isolated, so that its precise composition cannot, therefore, be ascertained.

DUMAS, and some others assume it to be a combination of two equivalents of sulphide of calcium with one equivalent of lime— $2 \text{ Ca S} + \text{Ca O}$. **UNGER**, reviewing **DUMAS**' theory of the process of its formation, considers it much more probable that it is a compound of three equivalents of sulphide of calcium with one equivalent of lime— $3 \text{ Ca S} + \text{Ca O}$ —a formula also assigned to it by **PAYEN**, and adopted by many others. **ROSÉ** regards it as composed of one equivalent of sulphide of calcium, with one of hydrate of lime— $\text{Ca S} + \text{Ca O, HO}$.

The conclusion that combination of sulphide of calcium with lime does ensue, appears to have been arrived at, not from an analysis of the pure compound, for, as mentioned above, it has never yet been obtained, but simply because, in the presence of free lime, the sulphide of calcium *does not dissolve* when treated with water. This is indeed the only argument stated by **DUMAS** to account for the existence of his $2 \text{ Ca S} + \text{Ca O}$; and certainly the fact that an additional proportion of lime in the preparation of black ash does render the sulphide of calcium more insoluble, seems a power-

ful argument for the existence of this or a similar compound. UNGER, however, reasoning analogically, argues that because ROSÉ obtained a salt having the formula $3 \text{ Ba S}, \text{ Ba O}, 28 \text{ HO}$, the compound— $3 \text{ Ca S}, \text{ Ca O}$ —though free from water, might also be supposed to exist. This, although affording a strong presumption, cannot be accepted as a conclusive proof; and still the question remains—If sulphide of calcium is more soluble in the presence of free lime than in the pure state, why is this the case? In an investigation into the composition of black ash performed a few months ago by Mr. J. W. KYNASTON in the Editor's laboratory, it was found that when the ash was treated with water, and allowed to remain for some time undisturbed, the lime previously existing in the ash in the free state, by acting upon the solution of carbonate of soda, eliminated caustic soda, *itself becoming wholly converted into carbonate*. This, if not conclusive proof of the non-existence of the hitherto assumed compounds of sulphide of calcium and lime, at least shows that the stability of the sulphide of calcium of black ash, when treated with water, is not to be ascribed to the production of any such compound. In this view Mr. KYNASTON is supported by the observations of GOSSAGE, than whom probably no one ever performed so numerous a series of experiments upon black ash, and more especially upon its insoluble portion. Mr. GOSSAGE states that he has long held this view, and, indeed, founded upon it a process for the recovery of the sulphur from the insoluble portion of the ash, to which further reference will shortly be made. Mr. KYNASTON suggests that, instead of the combination of sulphide of calcium with lime, a compound may exist of sulphide of calcium with carbonate of lime, and having the formula $2 \text{ Ca S}, \text{ Ca O}, \text{ C O}_2$. Were further evidence required, an additional proof that the whole, or at least the greater part, of the free lime of black ash is converted into carbonate, when the ash is treated with water, is the fact of the existence of so large a proportion of caustic soda in black-ash liquor, and the presence of which cannot be satisfactorily explained in any other way. Some chemists—indeed by far the greater number who have written upon the subject—do give hydrate of soda as a constituent of black ash. It will not, however, be difficult to show the fallacy of this. KNAPP accounts for the proportion of caustic acid, by supposing a portion of the carbonate of lime to be burnt and converted into the caustic state, before the decomposition of the soda salt is effected; the caustic lime, then acting upon the sulphide of sodium, produces sulphide of calcium and caustic soda:—



One may be permitted to doubt whether this reaction would take place under the circumstances. Carbonate of soda, treated in solution with caustic lime, gives rise to the formation of caustic soda and the insoluble carbonate of lime. But if caustic soda and carbonate of lime be fused together, carbonate of soda and caustic lime are produced. So if a mixture of caustic soda and sulphide of calcium be fused together, sulphide of

sodium and caustic lime are formed, $\text{Na O}, \text{ Ca S}, = \text{Na S}, \text{ Ca O}$; but if the resulting mass be treated with water, caustic soda and sulphide of calcium are reproduced. It cannot be reasonably supposed, that when in the case of the pure salts the above-mentioned reaction is well known to take place, in the production of black ash, exactly the reverse action should ensue with the same salts and by a similar mode of treatment. Yet it is well known that in the preparation of black ash, caustic lime may be, and in the early days of the manufacture in this country was, used instead of carbonate of lime. But in such a case a predisposing cause, if the term may be allowed, determines the reaction. When zinc and water are placed in contact, the water is not decomposed; but if an acid be added, decomposition of the water rapidly takes place. So when sulphate of sodium and lime are fused together no change occurs; but when charcoal is also present, and hot air is blown upon the mass as in the reverberatory black-ash furnace, decomposition immediately follows.

Carbonic acid is here the *predisposing cause*, just as sulphuric acid is in the case of zinc and water. The success of this soda process is, indeed, in no small degree owing to the remarkable affinity of soda in the fused state for carbonic acid; and this is so great, that even supposing caustic soda to exist in the black ash at any time during its preparation, it could not remain more than a few moments uncombined in the atmosphere so highly charged with that acid. It is further to be noticed that all those analysts who state hydrate of soda to be a constituent of black ash, also include *carbonate of lime* amongst the ingredients. But what an inconsistency to suppose that hydrate of soda and carbonate of lime can exist, after fusion together for such a length of time as in the preparation of black ash, when the two salts so readily decompose at a much lower temperature than that to which the mass is subjected. Still another argument against the existence of caustic soda in black ash presents itself, if the theory of DUMAS and others of the French school be accepted as the true one. These explain the reaction, by supposing that the sulphate of soda and carbonate of lime first decompose the bases, exchanging acids, and that the sulphate of lime so formed is afterwards reduced to sulphide of calcium by the charcoal. In this case *no caustic soda can have been formed*; and as carbonic acid once combined with soda cannot be again removed by simple heating, of course no caustic soda can be produced. In conclusion, the Editor must again assert, that as yet no sufficiently satisfactory proof has been put forward to show *hydrate of soda to be a constituent of black ash*; while, on the other hand, its existence in the black-ash liquors is quite consistent with the views expressed above. But if this be admitted, the theory that the sulphide of calcium owes its insolubility and permanence to its having entered into combination with free lime, is of course disproved. The fact does not indeed require such a far-fetched explanation. Protosulphide of calcium is itself *very insoluble*, bisulphide of calcium is *readily soluble*, and all that it appears necessary to guard against is the formation of bisulphide of cal-

cium, or rather perhaps of bihydrosulphate of lime, which is so liable to be produced.

Whether a sulphite and hyposulphite actually exist in black ash, is a question that hardly admits of proof. They are included in the analyses of several investigators, and the researches of Mr. KYNASTON certainly lead to the same conclusion. Still the probability of the formation of these, subsequent to the removal of the black ash from the furnace, is so obvious, that until the point has been conclusively determined, it is better not to express any positive opinion. Black-ash liquors certainly contain both salts. Sulphate of soda and ferrocyanide of sodium are frequently constituents of black ash, but these are not always present. The Editor has had numerous samples examined which were free from even a trace of either one or the other. The subjoined analyses of this highly complex mixture are by UNGER and RICHARDSON. Both, it will be seen, assume the existence of a compound of sulphide of calcium and lime, and also of caustic soda.

	From Newcastle. Unger.	From Newcastle. Richardson.
Sulphate of soda,	1.99	3.64
Chloride of sodium,	2.54	0.60
Carbonate of soda,	23.57	9.89
Hydrate of soda,	11.12	25.64
Carbonate of lime,	12.90	15.57
Oxysulphide of calcium (3 Ca S + Ca O),	34.76	35.57
Sulphide of iron,	2.45	1.22
Silicate of magnesia,	4.74	0.88
Charcoal,	1.59	4.28
Sand,	2.02	0.44
Water,	2.10	2.17
Loss,	0.22	—
	100.00	100.00

Mr. KYNASTON's analysis is also appended :—

Carbonate of soda,	36.879
Chloride of sodium,	2.528
Sulphate of soda,	0.395
Silicate of soda,	1.182
Aluminate of soda,	0.689
Sulphide of calcium,	28.681
Carbonate of lime,	3.315
Bisulphide of calcium,	0.435
Hyposulphite of lime,	1.152
Sulphite of lime,	2.178
Caustic lime,	9.270
Magnesia,	0.254
Sulphide of iron,	0.371
Sesquioxide of iron and phosphate of lime,	2.658
Alumina,	1.132
Charcoal,	7.007
Sand,	0.901
Ultramarine,	0.959
Water, hygroscopic,	0.219

100.205

Annexed is another analysis of black ash, just made by Mr. MARTIN MURPHY, the Editor's talented assistant, and whose aid in scientific and literary matters for twelve years he has found of the utmost service :—

Soda,	25.388
Lime, chiefly existing as sulphide,	35.484
Carbonic acid,	17.599
Sulphur,	14.747
Sulphuric acid,	0.421
Iron,	3.020
Alumina,	1.165
Silicic acid,	0.945
Chlorine,	0.794
Charcoal,	5.724
Ultramarine and sand,	1.659

The preceding numbers correspond with the following order of combination :—

Carbonate of soda,	41.489
Sulphate of soda,	0.748
Chloride of sodium,	1.308
Aluminate of soda,	0.392
Silicate of soda,	1.162
Sulphide of calcium,	33.193
Caustic lime,	9.320
Carbonate of lime,	0.857
Sesquioxide of iron,	3.020
Alumina,	1.020
Charcoal,	4.724
Sand, et cetera,	2.259

100.000

The characteristics of good black ash are as follows :—It should be of a blackish-grey color, and with open pores, similar to pumice-stone, so that a liquid may easily penetrate its substance. It should contain from twenty to twenty-four per cent. of available soda, and should be free, or contain only a slight trace of sulphate of soda. When the solution obtained by lixiviating a portion is acidified, merely a faint smell of sulphide of hydrogen should be perceptible.

Lixiviation of the Black Ash.—This is the next operation in the process of manufacture, and is the first step towards the preparation of pure soda from black ash. Its object is the separation of the soluble constituents from the calcareous and other insoluble matters present. To effect this the balls of crude soda, a day or two after preparation, are broken to fragments and thrown into iron vats. By some it is recommended, first, to crush or grind the ash under upright millstones, and afterwards to sift it, or else to crumble it by exposure to hot vapor. With this view, the ash is sprinkled with water in a tolerably hot furnace, where, in the atmosphere of vapor, it soon swells up and falls to pieces. If the ash has been properly prepared this proceeding is quite unnecessary, and indeed objectionable on other grounds than the expense and labor required. With ash that has been allowed to remain too long in the furnace it may, however, be necessary to heat it in such a manner, otherwise the extraction of the soluble ingredient occupies too long a period of time; and it must be borne in mind that the longer the liquor is allowed to remain in contact with the insoluble portion of the ash, or the *soda water*, the greater the amount of sulphide of sodium in the solution, and this must be subsequently got rid of, or the ash will be unfit for use.

The vats used in the process of lixiviation are of iron, and of considerable size, and are so arranged as to allow the separation of the soluble constituents of the ash with the smallest possible proportion of water.

But although, as KNAPP observes, it is desirable, on the one hand, to use as little water as possible, yet it is equally necessary on the other hand to dissolve out every particle of alkali from the residue. In this, as in all other similar cases, both objects have been obtained by one and the same ingenious method.

The difficulty is obvious; if too little water be used in the first instance, a portion will remain undissolved. In the contrary case all the alkali will be dissolved, but, as at first, the whole solution cannot be drawn off; for a considerable quantity is kept back by the spongy

residue. It is, therefore, impossible in any case to obtain the whole quantity of soluble matter with one portion of water; a second, third, and fourth portion will be required, each of which will contain a less quantity in solution, so that, altogether, there will be a vast excess of liquid. The contrivance by which this difficulty is overcome, depends upon an uninterrupted continuance of the process, and consists in using the same water which was employed for the first infusion, with fresh portions of crude ash, until the solution has acquired the proper strength for boiling.

Just in the same manner every second or subsequent infusion can be increased in strength, so that none but sufficiently concentrated lie is supplied to the evaporating pan. Suppose that a certain quantity of water has taken up eight per cent. from the first portion of the soda, it will take up as much more from the second, and leave it containing sixteen per cent.; from the third portion it will be drawn off with twenty-four per cent., and so on.

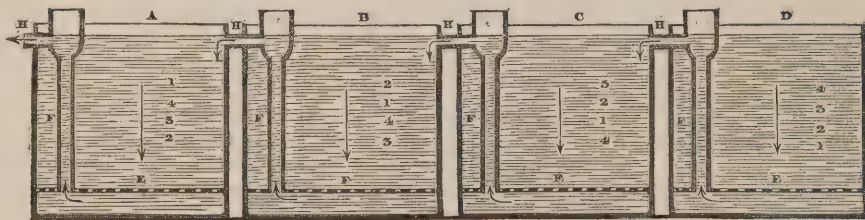
The lixiviation was formerly effected in vats so placed at different elevations, that weak liquors resulting from partly lixiviated ash flowed upon ash contained in a fresh set vat; but in using such apparatus, the manufacturer had to remove the partially lixiviated ash into higher vats, and yet the strongest liquors obtained rarely exceeded a specific gravity of 1150°, and consequently a very large quantity of water had to be evaporated to obtain dry salt. A very ingenious and scientific apparatus was invented and applied successfully by the celebrated French chemist, CLEMENT DESORMES. This apparatus provided for obtaining solutions of much higher gravity, but necessitated the employment of much manual labor, and also occupied a large space. The lixiviating apparatus which is now universally adopted by the manufacturers of soda in this country, the Editor knows to be a foreign invention, which was introduced

by Mr. C. T. DUNLOP into the St. Rollox Chemical Works, Glasgow, about the year 1843. This apparatus from its extreme simplicity, correct scientific principles, and the perfect manner in which the lixiviation is effected by its use, appears to fulfil all the conditions which can be desired in this process.

The apparatus is represented in Fig. 520, and may be described as consisting of a rectangular vessel about twenty-four feet long by twelve feet wide, and five deep, having three partitions, H H, dividing it into four vats, A, B, C, D, of twelve feet by six feet. Perforated false bottoms, E E, are supported about three inches above the bottom of the vats, on which the black ash is thrown in lumps. Each vat is furnished with a vertical pipe, F, five feet long, the lower end of which is open, and communicates with the space below the false bottom. About one foot six inches from the upper end of this pipe a short branch is provided, and this branch is bolted to the side plate of the vat; an opening being made in the side plate, to correspond with that in the branch. By these means a communication is effected between the lower part of one vat, and the upper portion of another. The upper part of the pipe, F, is enlarged; and at the lower part of this portion, a conical seating is provided, which admits of the passage being closed by a plug, or of a short pump being applied to withdraw the fluid contents of the vat.

When in regular use, the four vats will contain black ash at various stages of lixiviation, diffused in their corresponding liquors—one being filled with fresh balls; and another, furthest distant from it in the series, containing residuum all but deprived of its soluble matter. A supply of warm water is run upon the first and nearly spent vat; and this, after permeating through the residuum and becoming impregnated with alkali, rises through the pipe F, and flows into the upper part of the second vat, through the contents of

Fig. 520.



which it passes, taking up more alkali, and rising again by a similar pipe, gains access to the third vat, and so on into the fourth vat, in which the liquor becomes fully saturated by its contact with the fresh balls. The flow of liquor from the last vat may be intermittent, but it is preferable that it should be continuous; the supply of warm water to the first vat being also continuous, and this vat kept constantly filled. When it is found that the liquor proceeding from the first vat contains scarcely any alkali, this vat is shut off from the series; and the remaining liquor being pumped out, the residuum is removed, and the vat filled with fresh balls. This vat now becomes the fourth of the series, and receives liquor from that which was previ-

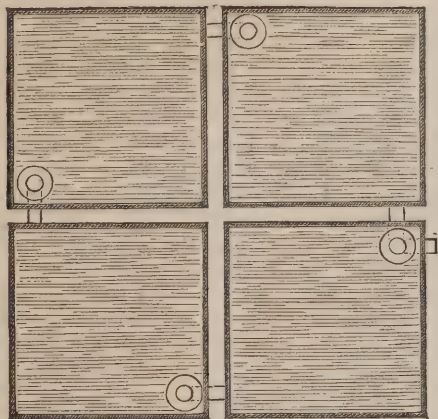
ously the fourth, by means of a pipe leading externally from the lower part of the latter to its upper part. When the vats are arranged in a square of four as shown in Fig. 521, in place of four longitudinally, this external pipe is not needed. In this manner each of the vats becomes consecutively the one to be discharged, and to be refilled with fresh balls.

In large establishments, a series of sixteen or more vats in a double row are employed, and these may be constructed by fixing longitudinal and transverse partitions in one large vessel.

By the provisions of this highly scientific apparatus, it becomes no longer needful to remove the black ash during the process of lixiviation; which removal was

previously attended with much labor, injurious exposure to the oxidising influence of the air, and great diminution of the permeability of the mass. The residuum in the above admirable arrangement, is constantly

Fig. 521.



supported by the fluid in which it is immersed, and thus kept in a condition highly favorable to its permeability; and the solvent is caused to percolate through the contents of the whole series without the cost of pumping. Practically, the advantages have been found to comprise a much more perfect abstraction of the soluble parts of black ash, and the obtaining of solutions requiring less than half the evaporation formerly necessary; indeed, so perfect is the process of lixiviation, that scarce one-tenth per cent. of soda is left in the residue.

In some alkali works, to assist the solvent power of the water employed in the lixiviation of black ash, it is usual to heat it to about 90° to 100° . This end may be conveniently attained by passing the water through a coil of pipes contained in a steam boiler. The practice of heating the water, though it undoubtedly aids the process of lixiviation, is nevertheless very objectionable, principally because sulphide of calcium is dissolved and decomposed by hot water, giving rise to the formation of sulphide of sodium, and the hotter the water the greater will this proportion of sulphide be, or rather of the double sulphide of sodium and iron contained in the vat liquor.

The temperature of the water, it must also be observed, always rises considerably— 20° to 30° or more—on coming in contact with the fresh black ash in the fresh vat, owing to the powerful affinity of caustic lime for that liquid to produce hydrate of lime. In summer the liquor frequently becomes so hot as to render necessary its withdrawal considerably below the point of saturation, otherwise the ash obtained on evaporation would be so strongly impregnated with sulphide, that it would be quite inapplicable to many purposes.

If the temperature of the liquor should not rise higher than from 110° to 120° , it may remain in contact with the ash until of specific gravity $1.225 = 45^{\circ}$ Twaddell; in the contrary case it should be withdrawn

at a density of $1.200 = 40^{\circ}$ Twaddell, or even still lower. Water is allowed to run into the weak vat until the density of the liquor passing through is reduced to 1.10 to $1.15 = 2^{\circ}$ to 3° Twaddell, and the insoluble matters remaining should, after being dried, contain not more than 0.2 or 0.3 of available soda. This last portion, if extracted, would contain so large a proportion of sulphate and other salts of lime, that on coming into contact with the ash in the next vat, it would decompose and render valueless more than an equivalent proportion of soda.

The composition of vat refuse—soda waste—according to UNGER's analysis is as follows:—

Carbonate of lime,.....	19.56
Oxysulphide of calcium, $3 \text{ Ca S} + \text{Ca O}$,	32.80
Sulphate of lime,.....	3.69
Hydrosulphite of lime,	4.12
Hydrate of lime,	10.69
Bisulphide of calcium,	4.67
Sulphide of calcium,	3.25
Sulphide of sodium,	1.78
Oxide of iron,	3.70
Silicate of manganese,	6.91
Charcoal,	2.60
Sand,	3.09
Water,	3.45

100.31

The sample of waste examined by UNGER must have been some time exposed to the air. When fresh it contains, according to the Editor's observations, *no bisulphide of calcium*, and but little hydrate of lime either free or in combination. The sulphate of lime also is wholly formed, subsequent to the removal of the soluble constituents of the ash. After being kept for some time only partially dried, a large quantity of sulphite and hyposulphite of lime is also produced, and the mass becomes of a dirty white color, with streaks of a beautiful blue color, running through it. The liquor containing in solution the salts of soda removed from the black ash, as it is withdrawn from the vats, is conducted into a series of settlers or iron vats. In these it is allowed to rest for some hours, to deposit any impurities that may be held in suspension. It is then pumped into a spacious cistern or reservoir, so elevated that, by means of pipes, the liquors may be distributed to the concentrating pans and furnaces.

EVAPORATION OF THE LIE.—The process of concentration is carried on in two different ways. Most commonly the solutions are evaporated and the residue calcined in the same reverberatory furnace, known as the *white-ash furnace*, whose extreme length should be about eighteen feet, and the breadth about nine feet. Its interior is lined with fire bricks, between which and the external masonry is placed a partition of sheet iron. By the application of heat in this manner, the evaporation proceeds rapidly, quietly, and at a very moderate expense of fuel. The waste heat from the black-ash furnaces is frequently applied to the evaporation of vat liquors. In this case, an iron pan termed the *salting pan*, in shape similar to the furnace above described, is placed at the end of the black-ash furnace next to the raised bed. The evaporation proceeds rapidly as with the ordinary white-ash furnace; but the mass of ash is not allowed to become completely dry. As soon as the contents of the pan have attained

the consistence of mortar, they are raked out into a large iron called the *drainer*, furnished with a false perforated bottom, to allow the mother liquor to drain from the crystals. The drained mass is next collected and introduced into a reverberatory furnace, named the *finishing furnace*, in which it is moderately calcined, and at the same time dexterously worked about in all directions so as to bring every part of it in contact with the air, and within the action of the flame. The mother liquor or draining from the *salts*, which contains nearly all the caustic soda and sulphide of sodium and iron, as well as the excess of foreign salts, sulphate of soda and chloride of sodium, *et cetera*, is in some works returned to the salting pans with the next charge of fresh liquor; in others it is evaporated *per se*, and the residue is afterwards heated to redness, mixed with saw-dust or coal-dust in reverberatory furnaces. During the process of calcination the sulphur of the sulphide of sodium escapes in some form of combination, and carbonate of soda is produced; the caustic soda also quickly combines with carbonic acid to produce the same salt, and the sulphate of soda is reduced at the same time to sulphide of sodium, and undergoes a similar change.

In manufactories where caustic soda is produced in a marketable form, it is principally extracted from the mother liquors above-mentioned.

The other method of conducting the evaporation of vat liquors is by means of iron pans, with the fire and heated air applied beneath. These—named *fishing pans*—are of considerable size, and shaped somewhat similar to a boat. They may be heated by a fire used solely for the purpose; in which case to prevent injury to the pan, the arch of the furnace should be continued for some distance beneath, or the pan may be placed at the end of the black-ash furnace farthest from the fire, just as with the salting pan, except that the heated air is made to pass under instead of over the pan. The evaporation is rapidly conducted by this method; and when the lie becomes concentrated to a certain strength, small crystals of monohydrated carbonate of soda— $\text{Na O, CO}_2, \text{HO}$ —constantly fall to the bottom, and as quickly as they fall are raked together to the end of the pan farthest from the source of heat, and then scooped or *fished* out by means of perforated iron shovels. After being allowed some time to drain, the salts so obtained are washed with fresh vat liquor, and then removed a reverberatory furnace, and all worked about until sufficiently dry. The deep-red mother liquor is either applied to the production of caustic soda or evaporated, and the residue heated with sawdust as before directed.

In some alkali works the evaporation of black-ash liquors is conducted in a series of pans, three or four in number, or rather in one pan separated into three or four compartments; in the first, that is, the one at the greatest distance from the source of heat, the solutions are heated to the point of ebullition; in the next, or the two next, the liquors are concentrated until saturated while hot; and in that immediately in contact with the fire, the concentrated liquors are evaporated either to dryness, or until nearly the whole of the carbonate of soda is deposited from solution, and this is afterwards dried in a reverberatory furnace as before.

In the year 1853 an improved mode of concentrating black-ash liquors for the purpose of obtaining salts therefrom suitable for the manufacture of soda ash, was invented by Mr. GOSSAGE, and secured by patent. The following description of the method is in the words of the patentee, and is extracted from the specification:—A long iron pan is provided and heated, either by means of a special fire underneath the same, or by waste heat proceeding from the alkali furnaces. A second long pan is placed contiguous to the first, but to this no heat is to be applied; a channel of communication is provided, and having introduced a suitable quantity of black-ash liquor into both pans, heat is applied to the first pan, so as to produce concentration of the liquor. A continued circulation of the solution through the two pans is effected by pumping or otherwise transferring liquor from the second into the first pan, at the end opposite to that at which the channel of communication exists. By this arrangement the liquors become so concentrated in the first pan as to contain more salts when in a heated state than they can retain in solution at a lower temperature, and therefore as the liquors flowing through the second pan become reduced in temperature, salts are deposited in this pan, and the liquors circulate again through the first pan as required, so as to keep a suitable quantity in the apparatus.

In the process of concentration by the ordinary method in a single pan, the salts, as they are deposited from the solution, collect at the bottom, and form a compact mass of a greater or less thickness, and the heat being continued owing to the bad conducting power of the deposited salts, the part of the pan immediately over the fire, if constant attention is not exerted, frequently becomes heated almost to redness; and if by any means the colder liquid comes in contact with this at so high a temperature, not only is the solution violently thrown from the pan, occasioning considerable loss of liquor, but often the latter becomes cracked, and, of course, is rendered useless until repaired. The advantages of Mr. GOSSAGE's apparatus will therefore be at once apparent, since by his mode of arrangement none, or at least only a small deposition of salts, can take place in the pan to which heat is applied. The patent to which reference has just been made, also includes an improved mode of concentrating black-ash liquors, when it is desired to obtain therefrom in a remarkable state the caustic soda they contain. The apparatus employed consists of an oblong vertical tower, made of iron plates, to the inside of which tower is adapted a number of iron shelves, placed at such an inclination that fluid will flow freely down the same. One of these shelves is attached to one end and to both sides of the tower, leaving a space of about three inches in width between it and the other end. The next shelf is attached a few inches below the first to the opposite end and to the two sides of the tower, leaving the same space between it and the other end. In this manner each alternate shelf is attached to an opposite end of the tower, and the arrangement is such that a supply of fluid introduced on the upper part of the first inclined shelf flows down the same, and is delivered on the upper part of the second shelf, and after flowing over

this reaches a third, and so on consecutively over the whole number of shelves contained in the tower. By these means the fluid employed may be exposed, in thin sheets or films, to the evaporating action of heated air passing through the tower. A supply of heated air is provided by any of the ordinary methods, and the apparatus is connected with the previously mentioned tower, at or near its lower part; and to occasion a large quantity of heated air to pass through, the upper part of the tower is connected with a strong chimney draft. The liquid to be evaporated is introduced into the tower in such a manner that it becomes distributed nearly equally over the uppermost shelf, from which it flows in the same manner over the succeeding shelves, and, exposed to the evaporating action of highly heated air during its course, becomes so heated and concentrated as to contain more salts than it can retain in solution at a lower temperature. A channel of communication from the lower part of the tower is provided, through which the hot concentrated fluid is conveyed to two iron pans; in flowing through these it becomes cooled so as to deposit salts, and the remaining fluid is then elevated by means of a pump from the coolest part of the pans and caused to pass again through the tower.

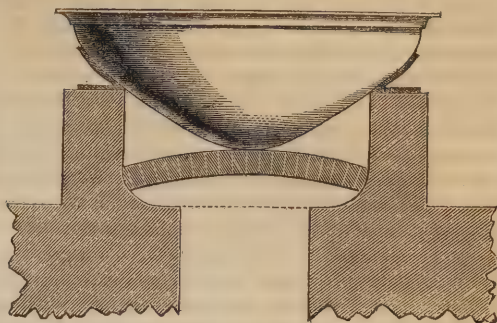
The inventor prefers to apply this mode of concentration for obtaining soda from vat liquors, to such liquors as have been already deprived of a considerable portion of the carbonate of soda previously contained therein. The circulation of these liquors through the tower is continued until it is found that the whole, or nearly the whole, of the carbonate of soda is removed, when the liquor is separated from the deposited salts, and by further evaporation in an iron pan solid hydrate of soda is obtained. The separated salts, after being washed, are transferred to a reverberatory furnace and completely dried. The product of these operations, whichever of the foregoing be adopted, is the *white ash* or *soda ash* of commerce. When properly prepared it contains fifty-three or fifty-four per cent. of available soda, two or three of which exist in the form of hydrate, and the rest as carbonate of soda. A little sulphide of sodium is also present, and some sulphate of soda, chloride of sodium, and minute quantities of other salts.

A new arrangement or apparatus for effecting the evaporation of black-ash liquors has been invented and successfully applied by Mr. D. GAMBLE, at St. Helens, Lancashire. It has been adopted very generally by the Lancashire manufacturers, particularly by those who are makers of solid caustic soda from black-ash liquors by GOSSAGE'S process. Mr. GAMBLE employs a pan of malleable iron, of the form indicated in Fig. 522, having a length of thirty feet, a width of seven feet, and greatest depth two and a half feet. The pan is placed above, or at the end of a black-ash furnace, and is heated by conducting the waste heat of the furnace by flues under the sides of the pan. The form of these sides is such as to afford facilities for separating the salts from the sides of the pan, when these adhere. During the boiling down, the salts are transferred in ladles into perforated drainers.

Mr. GAMBLE was also the first to use centrifugal machines, or hydro-extractors, for separating mother

liquors from salts obtained from black-ash liquors, and by such an apparatus soda ash of fine quality has been

Fig. 522.



obtained, by the first process, without being redissolved and evaporated.

The analyses of soda ash appended were performed by Mr. KYNASTON in the Editor's laboratory. The ash was obtained by evaporating the liquors at once to dryness, and calcining the residue.

	Centesimally represented.	
Carbonate of soda	67.891	73.626
Hydrate of soda	14.245	13.600
Sulphate of soda	4.579	6.127
Chloride of sodium	6.061	4.431
Sulphide of sodium	0.556	0.361
Aluminate of soda	1.214	..
Silicate of soda	0.389	0.511
Insoluble matters	0.217	1.579
Water	5.005	..
Ultramarine	0.140	..
	100.297	100.235
Available soda	50.75	54.00

The soda ash prepared by the processes described is, without further treatment, sufficiently pure for almost all the ordinary manufacturing applications of soda. For some purposes, however, and especially for the fabrication of plate glass, or for the production of the crystallized carbonate of soda—soda crystals—the ash made as above requires to be still further purified; and this is most commonly effected by giving it another calcination in a reverberatory furnace, moderately heated, sometimes by a charcoal fire. Or the salts obtained by evaporation of the vat liquors, either in the reverberatory furnace, or in the *fishing pans*, after being thoroughly drained and washed as completely as possible from adhering impurities, either with fresh liquor or with water, are mixed with saw-dust or coal dust, and calcined in a reverberatory furnace.

This calcination is intended to effect the separation of the sulphur from the small proportion of sulphide of sodium still remaining in the ash, and also the combination of all the particles of caustic soda in the ash, with carbonic acid derived from the burning carbonaceous matters introduced.

The heat applied in the first part of this process should not greatly exceed the melting point of lead.

At that temperature the sulphur goes off freely; but at a dull red heat the sulphur, instead of being volatilized, seems to enter into more permanent combination with the alkali.

The ash requires to be worked about with the oar and rake during the whole course of the operation, which usually takes about three or four hours. After the sulphur is expelled as completely as possible, the fire should be gradually urged until the mass attains a dull red heat, and this is continued until every particle of carbon is removed. The product of this operation is usually of a slightly yellowish or bluish-white tinge, and is excellent material for the manufacture of plate glass. The available soda exists wholly in the state of carbonate, and if any, only the most minute trace of sulphide of sodium. It must not be supposed, however, that this result is arrived at without the most careful manipulation, and constant attention to keep the furnace at the proper temperature required in the several stages of the operation. Ash so prepared should not, on exposure to the air for some time, undergo any alteration in hue, and when dissolved in water should yield a perfectly colorless solution. If it answers to these tests, the plate glass manufacturer may rest assured of its applicability to his purpose.

This ash being wholly in the state of carbonate, the amount of available soda contained in it is not quite so great as in some other varieties.

CRYSTALLIZED CARBONATE OF SODA—*Soda Crystals.*—This salt is prepared by dissolving soda ash, obtained as above, in hot water to the point of saturation, and the solution after reposing for some time is run into shallow pans of cast-iron or of wood, lined with sheet-lead, and allowed to remain at rest until the crystallization is completed. That the operation may be successful in a pecuniary point of view, it is essential that the salt be obtained perfectly colorless by a single crystallization. It is, therefore, necessary to observe particular care in the several operations, and especially in the selection of the ash to be dissolved. Nor is it by any means unimportant that the water used should be as free as possible from carbonate of iron and the salts of the alkaline earths. The ash most suitable is that prepared by the method last described. The alkali contained in it must exist wholly as carbonate. Sulphide of sodium must not be present, even in the smallest proportion; it should be as free as possible from carbonate of lime, and on exposure to the air should not undergo the slightest alteration in color. The solution is effected in different ways by different manufacturers. In the mode now most commonly employed, the lie is heated by means of steam blown into it. The dissolving pan, which is of iron, should be of such a size that sufficient ash may be treated at one operation to yield two, three, or four tons of crystals. Water being run in to about two-thirds full, it is heated to nearly ebullition, and ash is then thrown in, the injection of steam being continued until the solution has a specific gravity of $1.225 = 45^\circ$ Twaddell. It is then siphoned into a capacious iron vessel termed the settler, where it is allowed to remain twelve or fourteen hours to deposit any insoluble matters that may be present. The clarified liquor is

now conducted to a boiler placed over an open fire, where it is heated and kept in a state of ebullition until the density becomes about $1.275 = 55^\circ$ Twaddell. At this point it is again run off to the settlers, a pailful of solution of bleaching powder, or of chalk and water, or a mixture of these, is thrown in to aid the deposition of the impurities, and the whole is allowed to remain until the temperature is reduced to about 92° . At a little lower degree of heat crystals begin to be formed; but before this can take place the liquor is conveyed by means of sluices to the crystallizing pans or *cones*, which are of such a size as to contain sufficient liquor to give from a ton to a ton and a half of the crystallized salt. The annexed engraving shows the manner in which they are arranged in the crystallizing house.

To determine the formation of a larger quantity of very pure crystals, iron rods or bars are laid across the cones, and the crust that forms at the surface of the liquid, adhering to these, is prevented from falling, and will sustain also the mass of crystals that grow immediately beneath it. After nine or ten days—the length of time varying with the season—the crystallization may be considered complete. The mother liquor is then siphoned off, and by evaporation and calcination of the residue, a very white ash is obtained, containing about sixty-five per cent. of carbonate of soda, the other thirty-five being principally sulphate of soda and chloride of sodium. The crystals are allowed to remain a short time in the cones after the removal of the mother liquor, so as to drain and become dry, and are then taken out to be packed.

In some alkali works the soda ash, instead of being treated as above, is dissolved at once by the aid of steam, until the solution has attained a density of $1.275 = 55^\circ$ Twaddell. It is then drawn off to the settlers, a quantity of bleaching powder or chalk added, and when the temperature is near 92° , conveyed to the cones. From some varieties of ash, however, the impurities are not so readily separated, and it is necessary to substitute the process above given. The slimy deposit from the settlers with the adhering liquors, is either returned to the dissolving pan, or when collected in quantity is mixed with fresh water, boiled by means of steam; and the solution, after depositing the gross impurities, is added to the mother liquor from the crystals, and evaporated with it to dryness.

Though the process for the manufacture of soda ash, as detailed above, is very complete, and will probably never be superseded by any other method essentially different, still no one would think of asserting the impossibility of effecting any improvement. Many other modes of manufacture and several improvements of the old methods have been suggested, some of which deserve a brief notice.

A process invented by Mr. GOSSAGE, and for which he obtained a patent bearing date May, 1853, has for its object the purification of the black-ash liquors; firstly, by the oxidation of the sulphide of sodium; and, secondly, the separation of ferrocyanide of sodium from such liquors. During the ordinary process of evaporating black-ash liquors to dryness, and

roasting the product so obtained, the sulphide of iron and the iron of the ferrocyanide of sodium become converted into oxide of iron; and this substance communicates an objectionable color to the soda ash produced, rendering it unfit for certain applications.

The sulphide of iron being held in solution by sulphide of sodium, if the latter salt be converted by oxidation into hyposulphite— NaO , S_2O_2 —sulphite— NaO , SO_2 —or sulphate of soda— NaO , SO_3 —the sulphide of iron set free from combination becomes insoluble, and may be separated from the liquors by subsidence or filtration. In Mr. GOSSAGE'S process, as stated in the specification of his patent, the oxidation of the sulphide of sodium in black-ash liquors is effected by causing them to absorb atmospheric oxygen. To effect this as quickly as possible the liquors are made to pass through a high tower, termed by the inventor an *oxidising tower*, which is filled with small pieces of coke, or other suitable material; and while the liquors are percolating, a current of air is at the same time caused to pass through the interstices between the pieces of coke, by connecting the upper part of the tower with a chimney. By this arrangement an immense number of surfaces moistened with the liquors is presented to the current of air drawn through the tower, and the absorption of oxygen is thereby greatly facilitated. After passing through the tower, the liquors are collected in a pan to which heat is applied, and are afterwards pumped up, and caused to flow again through the tower. These operations are repeated until the sulphide of sodium in the liquors has become completely oxidised. The sulphide of iron, now in an insoluble form, is to be separated from the liquors either by subsidence or filtration; and the menstrua being rendered perfectly colorless, are freed from all iron, except such as exists as ferrocyanide of sodium. When the black-ash liquors are to be used for the production of soda crystals, or of soda ash, the conversion of the caustic soda present into carbonate of soda, is, by a modification of the process, effected collaterally with the separation of the sulphide of iron. All that is necessary for this purpose is to cause carbonic acid gas to pass through the tower with the atmospheric air. The liquors so purified are to be concentrated by the usual method employed in the preparation of soda crystals, or so as to obtain salts therefrom. In the further treatment of these salts and the residual liquor, and also the salts obtained in a similar manner by evaporating the mother liquor from soda crystals, the second part of Mr. GOSSAGE'S purifying process, namely, the separation of ferrocyanide of sodium, comes into operation. The first portions of the salts so deposited are but little impregnated with ferrocyanide of sodium; the second portions contain more of this compound; and the last portions are strongly impregnated with ferrocyanide, whilst the mother liquors still remaining contain a large proportion of this salt in solution. To separate it from these salts, they are to be washed with water or a solution of carbonate of soda.

For this purpose a series of four vats is employed, and the process is conducted exactly as in the lixiviation of black ash. In this mode of washing, the salts contained in each vat successively become those

least impregnated with ferrocyanide, and are subjected to the first action of the water, or of the washing solution. The solutions obtained by such washings are mixed with the mother liquors of the salts; and if it be found by testing that the mixed liquors contain more than ten parts of carbonate of soda for each part of ferrocyanide of sodium present, they are to be concentrated so as to obtain a further quantity of salts therefrom; and this concentration and separation of salts is to be continued, as long as the proportion of ferrocyanide of sodium to the carbonate of soda is less than ten per cent. The salts obtained by this last concentration are to be introduced into the concentrating apparatus with fresh black-ash liquor. The liquors above referred to as containing ten per cent. less of carbonate of soda for each one part of ferrocyanide, are collected and mixed with sufficient water and caustic lime to convert the carbonate of soda present into caustic soda, and the solution so obtained is to be concentrated until the greater part of the ferrocyanide becomes separated as salt; or the separation of the ferrocyanide may be effected by allowing the concentrated solution to crystallize; or, instead of converting the carbonate of soda contained in the liquors into caustic soda, the solution may be impregnated with carbonic acid, when bicarbonate of soda, a compound of sparing solubility, will be formed, and the greater part of the ferrocyanide may be obtained by filtration of water through the same, and drainage. The solution of ferrocyanide now contains only a small proportion of soda, which is converted by means of lime into caustic soda, and from this the ferrocyanide is separated either as salts or by crystallization. By resolution in water and repeated crystallization, the ferrocyanide is obtained sufficiently pure to be suitable for use.

Mr. GOSSAGE'S patent further includes a process for the production of caustic soda in a marketable state, in addition to white soda ash and ferrocyanide of sodium from black-ash liquors. In this operation, also, the liquors are first submitted to the oxidising action of atmospheric air as already directed. Any hyposulphate of soda contained in the purified liquors is then converted into sulphite or sulphate of soda by further oxidation; and this is effected by the gradual addition of solution of chloroxide of calcium, or bleaching powder. The liquors are now concentrated by the ordinary method so as to obtain salts therefrom; and these are washed as before described, to separate all the caustic soda and ferrocyanide of sodium. The mixed mother liquors and washings are then again concentrated, until the whole or nearly the whole of the carbonate of soda and ferrocyanide of sodium have become deposited as salts, and the solution or mother liquor remaining contains scarcely any saline matter but caustic soda. In this state it is suitable for many purposes to which caustic soda is applicable, and is a marketable product. The mixture of carbonate of soda and ferrocyanide of sodium in the form of salts, is washed with water by filtration; and the residue and washings are further treated exactly as before directed, for the preparation therefrom of pure soda ash and of ferrocyanide of sodium. By further concentration of the solution of caustic soda in cast-iron pans, it may be

so far deprived of water as to become solid hydrate of soda when allowed to cool, and in this state it presents great facilities for transportation.

At a later date, namely in 1857, Mr. GOSSAGE patented another invention, the object of which is to obtain an increased proportionate quantity of caustic soda or caustic potassa, or of carbonate of soda or carbonate of potassa, in the usual manufacture of soda or potassa. In the case of soda, this is effected, firstly, by using an increased proportionate quantity of small coal in the mixture employed, when decomposing sulphate of soda by fluxing. The proportions of these usually employed are three parts of sulphate of soda, three parts of carbonate of lime, and one and a half or two parts of small coal; but Mr. GOSSAGE uses nearly equal weights of each of these materials, reserving some part of the small coal to be added as the decomposition proceeds. The decomposition of some part of the carbonate of soda produced is alleged to be effected in this way, and an increased proportionate quantity of caustic soda is obtained when the fluxed mass is lixiviated. It would appear, however, from what has been stated regarding the composition of black ash, that an increased ratio of the calcareous substance would be much more effectual.

The second part of the process consists in the addition to the solutions obtained, of hydrated oxide of iron, of zinc, of manganese, or of lead, whereby the sulphide of sodium present is converted into caustic soda, with simultaneous production of sulphide of the metal employed. The decomposition is effected by adding to the solution obtained by lixiviation at a boiling heat, such a quantity of the metallic oxide as is found, by testing the solution with a salt of lead, to be sufficient to remove the sulphur from the whole of the alkaline sulphide present. The metallic sulphide thus produced, after being washed with water, is decomposed by means of muriatic or some other suitable acid, and the metal is obtained in solution. This, decomposed by means of hydrate of lime or magnesia, yields the hydrated metallic oxide in a condition applicable to the decomposition of a further quantity of alkaline sulphide.

To obtain an increased proportionate quantity of carbonate of soda, instead of caustic soda, in the process of manufacture, the alkaline sulphide is to be decomposed by the addition of the carbonate of iron, zinc, magnesia, or lead, and the metallic sulphide produced is reconverted to the state of carbonate by the addition to the solution of the metal obtained, as before directed, of carbonate of lime or of magnesia. This process, it should be observed, is one of a series of improvements in the manufacture of soda patented by Mr. GOSSAGE at the same time.

The primary object of these improvements is to render again available in the manufacture the sulphur contained in alkaline waste, which in the ordinary method is totally lost. As these relate more especially to the economical production of sulphuric acid, they will be further noticed in connection with the article to be specially devoted to that substance.

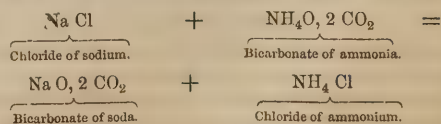
A process for impregnating black ash and white ash with carbonic acid, in order to convert the caustic and silicate of soda contained therein into carbonate, was

patented some years ago by Mr. JAMES SHANKS. In applying this process to black ash, the latter is to be broken into fragments and disposed in several layers, each of three or four inches in depth, in a stone or iron vessel named the *carbonator*. The layers having been moistened with water, carbonic acid gas is admitted into the carbonator by a pipe, the air being allowed to escape by another one. When the odor of sulphide of hydrogen is strongly perceptible at the exit pipe, the whole of the soda is considered to be carbonated; the introduction of carbonic acid is then discontinued, and the black ash is removed to the vats and lixiviated in the ordinary manner. The lie prepared from black ash may be exposed to the action of carbonic acid instead of the ash. In this case the carbonator used should have a capacity of sixteen cubic feet for every ton of white ash, or six cubic feet for every ton of soda crystals, to be made daily. Across the bottom of the carbonator is thrown an open arch of brickwork, and the space above is filled with small pebbles, over which the solution to be carbonated flows, being admitted at the top. The carbonic acid is introduced below the arch, and allowed to rise in the carbonator between the pebbles, the air of the vessel escaping by a pipe at the top. The greenish-yellow or brown color of the liquor disappears when properly carbonated.

With the same object in view, Mr. JOHN WILSON obtained a patent in 1840 for a process in which the caustic soda contained in either black or white ash is converted into carbonate by the application of as much bicarbonate of soda as might be necessary.

The entire loss of all the sulphur consumed as sulphuric acid in LEBLANC'S method of converting common salt into carbonate of soda, is justly considered a great objection to that process. Still, although numerous suggestions have been made, none of the new processes have succeeded so well as to supersede LEBLANC'S method; and the Editor is of opinion that it never will be supplanted. At the same time some of the plans recommended are so interesting in a purely theoretical point of view, that the Editor would scarcely be justified in omitting all notice of them.

One of the most economical of these processes is that proposed by Messrs. HEMMING and DYER, which is founded on the behavior of a solution of common salt with one of bicarbonate of ammonia. When carbonate of ammonia of commerce, which is in reality a mixture of carbonate and bicarbonate, is added in a state of fine powder to a solution of about an equal weight of salt in three parts of water, the mixture being well stirred, a white crystalline precipitate appears in a few hours, causing the liquid to become thick. This precipitate is bicarbonate of soda, and there is contained in solution chloride of ammonium, produced as shown in the annexed equation:—

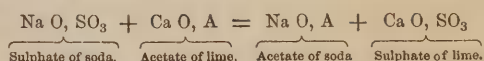


In the manufacturing process founded on this reaction, common salt is mixed with an impure carbonate

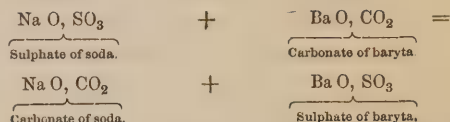
of ammonia, such as the liquor furnished by the purification of coal gas, or the distillation of bones; and, having separated the solid bicarbonate by pressure in a screw press, the chloride of ammonium remaining in the mother liquor is reconverted into bicarbonate of ammonia, by evaporating it to dryness, and treating the residue in a distillatory apparatus with carbonate of lime, as in the ordinary mode of preparing carbonate of ammonia. The advantage gained by this process is the production of soda without the use of sulphur, and therefore free from this element; the objection to it is the loss of ammonia, and also that the portion of chloride of ammonium necessarily remaining with the bicarbonate of soda, is in the heat *reconverted* into the cheap chloride of sodium. In referring to this method, PARNELL observes, that unless particular precautions be adopted, the loss of ammonia must be very great and inevitable, from two reasons:—First, when a mixture of chloride of ammonium and carbonate of lime is heated, a portion of the ammonia is always disengaged in the free state, the product not being a neutral carbonate, but a sesquicarbonate, having the formula $2\text{NH}_4\text{O}, 3\text{CO}_2$. In this process, therefore, one equivalent of ammonia in every three is disengaged in the free state and lost, unless particular means be adopted to retain it. Again, when the sesquicarbonate of ammonia is dissolved in water, it is resolved into the neutral carbonate and the bicarbonate; but chloride of sodium is decomposed by the bicarbonate only, and the neutral carbonate remaining in the mother liquor is decomposed during the evaporation into free ammonia and the bicarbonate, both of which are volatilized. The adoption of some patented improvements in the manufacture of carbonate of ammonia, in which the mixture of chloride of ammonium and carbonate of lime is impregnated with as much carbonic acid as it will absorb, whereby the sesquicarbonate of ammonia is wholly converted into bicarbonate, would also be a decided improvement on the preceding process of manufacture.

Other processes have been proposed for producing carbonate of soda directly or indirectly from common salt, and some of these were even known and practised before the discovery of LEBLANC'S method. Thus, in 1788, a French priest named MALHUBE proposed a process which was afterwards put in operation by ALBAN, and was practised in France during the Revolution. In this, one hundred parts of sulphate of soda are first reduced to sulphide of sodium by heating to redness with twenty parts of charcoal; and while the mixture is in the liquid state, twenty parts of iron turnings are added, then eight parts of charcoal or small coal, next twelve and a half parts of iron, and lastly three parts of charcoal. The caustic soda thus obtained is exposed to the air, to absorb carbonic acid. DUMAS considers it probable, that in this operation there is formed a double sulphide of sodium and iron, and that the sodium converted into caustic soda is not more than half that contained in the fluxed product. In another process, sulphate of soda is reduced to sulphide of sodium by heating it to redness with charcoal, and having dissolved the sulphide in water, carbonic acid is passed through the solution till sulphide of hydrogen

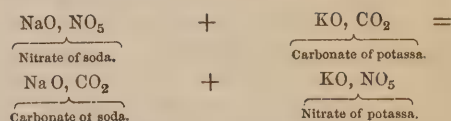
ceases to be evolved. The carbonic acid is produced by burning charcoal or coke, or by calcination of limestone. According to DUMAS, to decompose sulphide of sodium by carbonic acid it is indispensable to use a considerable excess of the latter, so as to produce the bicarbonate of soda. Mr. GOSSAGE, however, states that he has succeeded in effecting the decomposition with such a proportion of carbonic acid as to produce the ordinary monocarbonate of soda. MARGRAAF suggested that carbonate of soda might be produced from the sulphide, by first converting the latter into acetate of soda by means of pyroligneous acid. When this is heated to redness, a residue remains, consisting of carbonate of soda and charcoal. LAMPADIUS proposed to form the acetate of soda by the addition to a solution of sulphate of soda, of one of acetate of lime, when insoluble sulphate of lime and acetate of soda are formed:—



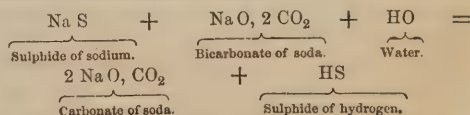
KÖBUNTER proposes to form carbonate of soda by decomposing sulphate of soda with carbonate of baryta:—



and KNAPP suggests that in districts where potassa is obtained at a moderate price, the production of salt-petre may be combined with that of soda, by decomposing Chili salt-petre—nitrate of soda—and carbonate of potassa into soda and ordinary salt-petre:—



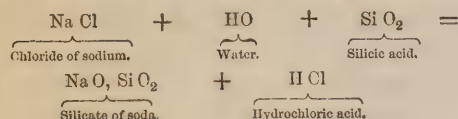
In treating of caustic soda, several methods for producing that salt, both from chloride of sodium and other salts of soda, have been detailed. These have also been applied in the manufacture of carbonate of soda, the caustic having been subsequently combined with carbonic acid, either by exposure to the air, or by heating it with coal or sawdust, or in some other way. In the patent of Mr. JOHN WILSON for improvements in the manufacture of carbonate of soda, already quoted, there is included a mode of preparing carbonate of soda from sulphide of sodium. He effects the conversion by mixing a solution of the sulphide with one of the bicarbonates, in the proportion of forty-eight parts of the former to eighty-five of the latter salt. The change is shown in the annexed formula:—



If the sulphide of hydrogen gas thus disengaged is to be collected, the materials may be mixed in a covered

iron pan, furnished with a pipe to conduct the gas to a gas-holder; but if the gas is not required the operation may be carried on in a common white-ash furnace. The mixture is evaporated to dryness, the residuary carbonate dissolved in water, and the clear solution is decanted and re-evaporated.

The soda process proposed and patented by MM. BLANC and BAZILLE, differs from nearly all the above-mentioned, inasmuch as the use of sulphur for the production of either sulphate of soda or sulphide of sodium is totally dispensed with. This method is founded on the decomposition of common salt by silica at a high temperature, and in the presence of steam. When the vapor of water is passed through an intimate mixture of common salt and silicious sand, contained in a porcelain tube heated to bright redness, the salt is decomposed, the chlorine unites with the hydrogen of the steam to form hydrochloric acid, which escapes as gas, while the sodium combines with the oxygen of the steam and with the silica or silicic acid, to form silicate of soda. The annexed equation represents the change:—



The decomposition, it will be observed, cannot take place unless water be present. In carrying out this process on a manufacturing scale, the patentees propose to introduce the mixture of salt and silicious sand into cast-iron cylinders, arranged in furnaces in a manner similar to gas retorts, so that the flame may play around and raise them to a cherry-red heat. A large perforated tube for the introduction of steam, as long as the cylinder, is to traverse the axis of each cylinder; and at one extremity of the cylinder the tubes must be each fitted to a large earthen or stone-ware tube for the purpose of conducting the evolved hydrochloric acid to the condensers. The latter tube should be of considerable size, to prevent its being choked up with volatilized salt; and it should lead first into a large empty chamber in which the volatilized salt might be deposited; a communication between this chamber and the condensers may afterwards be established.

The cylinders thus arranged are to be loosely filled with an intimate mixture of twenty-eight parts of salt and twenty parts of fine sand, and raised to a cherry-red heat; steam being at the same time slowly and steadily admitted into the perforated tube from a boiler.

To remove the undecomposed salt from the mass so obtained, it is to be lixiviated with water, in which the silicate is scarcely soluble; and to procure this in a state of solution, it is first calcined at a red heat with about one sixteenth of its weight of soda ash, until the mixture is vitrified. The subsilicate of soda thus formed is dissolved in water; and from the solution carbonate of soda may be obtained by impregnation with carbonic acid, which causes the precipitation of gelatinous silica; the soda salt remaining in solution. The patentees

prefer to procure the carbonic acid gas from the limestone by calcination in continuously acting limekilns. To the top of the kiln is adapted a dome-top, from which a tube passes into the vessel containing the solution to be carbonated; and it is alleged that the draught of the kiln is quite sufficient to maintain a proper degree of combustion to the end, if a single large vessel be employed to contain the solution instead of several small ones.

It is probable, as PARNELL remarks, that the manipulations required in these operations would be too tedious, and the decomposition of the salt in the cylinders too slow and incomplete, to allow of the process being prosecuted successfully on a large scale.

A plan was proposed by MAUGHAM for the production of silicate of soda, somewhat similar to the above, but with the additional aid of hydrofluoric acid. He then decomposes the silicate of soda by means of carbonate of lime.

SESQUICARBONATE OF SODA.—This salt exists as a natural product in solution in water. The mineral waters of Vichy and of Vals in France, of Bilin in Hungary, of Carlsbad in Bohemia, and the Geyser fountains in Iceland are remarkable examples. It is also produced as a mineral termed *trona* or *urao*, round the margin of some lakes in Northern Africa, Hungary, and South America. Its existence in nature is accounted for by some, on the supposition that chloride of sodium is decomposed by carbonate of lime, as BERTHOLLET observed that whenever these two salts were found mixed together there was also an efflorescence of sesquicarbonate of soda. DUMAS, however, dissents from this, and considers its formation to be owing to the decomposition of the sulphate of soda, which is always found in admixture with chloride of sodium. The sulphate of soda he supposes to be first reduced to sulphide of sodium by the action of organic matters in solution in the water; and the sulphide of sodium is afterwards converted into sesquicarbonate of soda by means of the carbonic acid also held in solution in the water of soda lakes. The lakes are usually called *white*, from the circumstance that, during the summer months, the water evaporating leaves a snow-white efflorescence on the surface at the bottom. This is sesquicarbonate of soda.

The plains on the shores of the Black and the Caspian Seas, Persia, Arabia, India, Thibet, China, and Siberia, and even the great desert of Africa—all furnish this variety of carbonate of soda.

This salt may be prepared artificially by several methods.

According to WINCKLER, if four ounces of alcohol be poured on the surface of a solution containing one hundred grains of simple carbonate of soda, and one hundred and fifty-two grains of crystallized bicarbonate of soda in four ounces of water; fine, clear, circular crystals of the sesquicarbonate are formed after several days at the surface of separation of the two liquids, and at the bottom of the solution large crystals of the simple carbonate are formed, together with a crust of bicarbonate of soda.

According to HUMANN, sesquicarbonate of soda

cannot be prepared pure by crystallization from any aqueous solution, as it decomposes when in solution into the bicarbonate and carbonate of soda, which crystallize apart. When a concentrated solution of the bicarbonate is evaporated quickly, so as to avoid the dissipation of the whole of the second equivalent of carbonic acid; when the bicarbonate and crystallized carbonate are mixed in single equivalent proportions, and the mixture is caused to undergo the watery fusion; and, lastly, when the bicarbonate of soda is exposed to heat, the temperature not being allowed to exceed 482° , products are obtained, which consist for the most part of sesquicarbonate. If these masses are exposed for a few weeks to a humid atmosphere, they assume a perfectly crystallized structure; and their cavities and fissures become lined with groups of crystals, which are pure sesquicarbonate of soda. The form of the crystal of this salt is that of the rhombohedral prism, terminated by quadrangular pyramids. It dissolves in water more readily than the bicarbonate, but less easily than the simple salt, and the solution possesses an alkaline reaction. It is unalterable in the air, a remarkable proof of which is given by DUMAS, who asserts that the walls of Cassar, a fort in Africa actually in ruins, have been constructed with natural masses of this salt, originally obtained from some of the native lakes which abound in the country. It was formerly imported into this country, and sold under the name of *tronse*, and hence probably originated the error of the London college in substituting the sesquicarbonate for the bicarbonate of soda.

BICARBONATE OF SODA.—This salt may be obtained by passing carbonic acid through a concentrated solution of the simple carbonate; but the process is tedious and attended with much waste of gas, unless pressure be employed. Some manufacturers economize carbonic acid, by exposing the solution for a long period in shallow vessels to the atmosphere of a fermenting vat. In both cases bicarbonate of soda separates after some time in minute grains, owing to its comparatively sparing solubility; and the mother liquor, by cautious concentration at a temperature not exceeding 120° , yields a further quantity. In the process of SCHÖFFER, from three to four parts of crystallized carbonate are intimately mixed with one part of commercial sesquicarbonate of ammonia; the semifluid mass thus obtained, which evolves ammonia, is allowed to stand twenty-four hours, and then exposed to the sun on a clear surface. The last trace of ammonia escapes with the water, and bicarbonate of soda remains as a chalky mass. As the ammonia evolved in this method is lost, and as it is difficult to evolve in close vessels, SCHORZ proposed to mix fifty parts of dry carbonate of soda in fine powder with fifteen parts of the crystallized carbonate and forty-one parts of carbonate of ammonia, and to heat the mixture in a distilling vessel immersed in water.

The first nine-twelfths of the ammonia are readily evolved; the second two-twelfths with greater difficulty; and the last one-twelfth is removed by exposing the mass to the air. Manufacturers on the large scale have generally abandoned all the liquid processes for producing bicarbonate of soda, in favor of the dry

way; and this is certainly preferable both as regards economy, convenience, and despatch.

The process commonly followed is that suggested by SCHÖFFER, and introduced into the Parisian codex of 1840. It consists in packing fragments of crystallized carbonate of soda upon a series of perforated shelves in a box, or in large air-tight iron cisterns without shelves, but with an airhole at the side, and a small pipe at the bottom to carry off the water of crystallization, which separates during the process. After the introduction of the salt, carbonic acid is admitted in a stream regulated according to the rate of its absorption. The carbonic acid may be derived by the decomposition of chalk or limestone by hydrochloric acid, or, with proper precautions, from a charcoal or coke fire, or from a liquor undergoing the vinous fermentation. The latter method may be advantageously practised in distilleries, where a great quantity of liquor is kept in a fermenting state for a considerable time.

As carried on in alkali works, the first method is the one usually practised; the muriatic acid obtained in the production of sulphate of soda being made to act upon chalk or limestone.

The evolution apparatus employed consists of a large stone cistern laid in clay and well bedded. It is provided with a pipe, continued to within a few inches of the bottom of the cistern, and through this the acid is admitted from the condensers. The cistern being filled with chalk, the acid is allowed to flow in, and, rising through the mineral, it disengages carbonic acid in the passage; and the solution of chloride of calcium formed escapes through another pipe, similar to that by which the acid is admitted. The escaping liquors flow off through a third pipe, and the carbonic acid issues through an opening, whence it is conducted to the cisterns or boxes containing the crystallized carbonate of soda. The gas coming in contact with the crystals is very rapidly absorbed; and at the same time a liquid, charged with carbonate of soda or sesquicarbonate, trickles down to the bottom of the cistern, owing to the carbonate containing more water of crystallization than is required to constitute the bicarbonate. This liquid is usually withdrawn from time to time, as may be necessary. During the absorption of the gas a considerable amount of heat is evolved; and at the end of ten days or a fortnight the whole is converted into bicarbonate of soda, which is, however, very damp. This moisture is removed by heating the mass in stoves fitted with wooden shelving, by air passed through hot iron pipes.

A great improvement on this method in small operations, and which has also been adopted on the large scale, is the process suggested in its details by MOHR. In this method, the crystallized and anhydrous carbonates are mixed in such proportions as to leave a slight excess of water over what is necessary for the water of crystallization of the whole salt, when it is converted entirely into bicarbonate; and carbonic acid is admitted to the bottom of the mixture by a tube proceeding from a pneumatic apparatus similar to a gasometer, so constructed that there can never be any waste of gas. The absorption is completed every twenty-four hours.

MOHR proposed to mix anhydrous carbonate so as to leave no excess of water over that required for the water of crystallization of the bicarbonate. CHRISTISON, however, who carefully investigated the subject, found that absorption does not take place at all with the proportions proposed by MOHR; that with nothing but crystallized carbonate the absorption is slow, and the disengaged water contains carbonate or sesquicarbonate; but that with such proportions of the crystallized and anhydrous carbonates as will leave a slight excess of water, absorption is prompt, a slightly damp salt results, and there is not an appreciable quantity present of any other carbonate besides the bicarbonate.

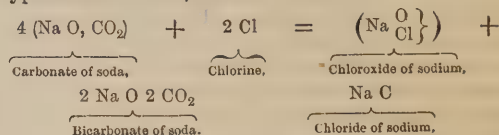
The rapidity with which effloresced carbonate of soda, or what is practically the same, a mixture of crystallized and anhydrous carbonate, absorbs carbonic acid, is stated by ARTUS to be considerably increased by mixing with the salt recently calcined and powdered charcoal, made from soft wood, which possesses the power of condensing gases within its pores to an extraordinary extent. When it is desired to obtain the bicarbonate in crystals, advantage may be taken of this property of charcoal. The mixture, which may be made in the proportion of two parts of effloresced carbonate and one part of charcoal, is moistened and exposed to the gas for twenty-four hours, then taken out, powdered, and moistened, and again exposed to the gas. These operations having been twice repeated, the mass is mixed with eight parts of hot water; the solution is filtered while hot, and left for the bicarbonate to crystallize. Carbonate of soda is known to be fully saturated with carbonic acid when it no longer reddens turmeric, or gives a precipitate with a very dilute solution of chloride of mercury or corrosive sublimate, but with a concentrated solution a white precipitate, which becomes red in a few minutes, and afterwards purple; with the least admixture of simple carbonate of sesquicarbonate of soda, the precipitate is reddish-brown.

Bicarbonate of soda is known only in combination with water, its formula being— $\text{Na O}, 2 \text{ CO}_2, \text{HO}$. It crystallizes in oblique four-sided tables, which have a slightly alkaline taste and a very feeble alkaline reaction on vegetal colors. As met with in commerce, it is usually in the form of powder, or in small, white, opaque, irregular scales. At a moderate heat, it loses half its carbonic acid and the whole of its water, and is reduced to the state of anhydrous monocarbonate. Cold water dissolves about one-tenth of its weight, and hot water considerably more. When the solution is heated somewhat above 120° , carbonic acid begins to be eliminated; and, according to BERZELIUS, at 212° the salt becomes sesquicarbonate.

Physiological Effects.—Bicarbonate of soda possesses diuretic properties, but less actively than the corresponding salt of potassa. It is also an excellent antacid and antilithic, and is employed in great quantity for making effervescent powders. A mixture of this salt with the tartrate of soda and potassa, or Rochelle salt, with the addition of tartaric acid, constitute seidlitz powders. Many have thought that the long-continued use of alkaline carbonates in gravel and acidity of the stomach entails injurious consequences; and diseases of the kidneys as well as organic disorders of the

stomach have been referred to the practice. These suppositions are probably imaginary, as there can be no question that many have employed alkaline remedies habitually for years, without apparently any deleterious effects being produced; the Editor can affirm this from his own experience.

HYPOCHLORITE OF SODA—CHLORIDE OF SODA—CHLOROXIDE OF SODIUM.—A solution of this salt in an impure state constitutes the well-known disinfectant liquor of LABARRAQUE. Its disinfecting power was discovered about the year 1820. The process for preparing this solution given in the London Pharmacopoeia is as follows:—A pound of crystallized carbonate of soda is dissolved in two parts of water, and the chlorine eliminated by heating a mixture of four ounces of common salt, three ounces of binoxide of manganese, four of sulphuric acid, and three of water, is conducted into the solution. The changes that ensue are represented in the subjoined formula, the result of the decomposition being a mixture of bicarbonate of soda, hypochlorite of soda, and chloride of sodium:—



The above is the method followed in the preparation of this salt by LABARRAQUE; PAYEN proposed another, which was adopted by the French pharmacists. It consists in the decomposition of chloroxide of calcium, or bleaching powder, by carbonate of soda. The proportions employed are one part of bleaching powder and thirty of water, and for the carbonate of soda solution two parts of the crystallized carbonate and fifteen of water. In this process hypochlorite of soda and chloride of sodium are formed, and remain in solution whilst carbonate of lime is precipitated. By using the proportion of the French Codex, the solution obtained is much weaker than that prepared as directed by the London College. Pure hypochlorite of soda can only be obtained by neutralizing a solution of hypochlorous acid with one of soda.

LABARRAQUE'S disinfecting compound may be obtained in the solid state, according to MAYER and SCHINDLER, by transmitting chlorine, evolved from ten parts of common salt, eight parts of binoxide of manganese, and fourteen parts of sulphuric acid, into nineteen parts of dry powdered carbonate of soda, moistened with one part of water only. The absorption of chlorine goes on slowly with the disengagement of heat.

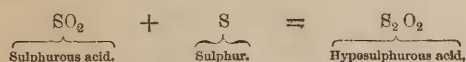
Properties.—The solution known as LABARRAQUE'S disinfecting fluid is colorless or slightly yellow, has an odor of chlorine and an astringent taste. Upon vegetal coloring matter it first reacts as an alkali, and afterwards effects its destruction. By evaporation needle-shaped crystals are obtained, which when redissolved in water reproduce the bleaching fluid. Acids added to the solution disengage chlorine and carbonic acid gas, and by exposure to the air decomposition is also effected, and crystals of carbonate of soda are formed.

Physiological Effects.—This salt, as well as the soluble hypochlorites, is supposed to exercise a specific

influence over the nervous system, causing depression and tetanus. In small doses it has been considered to possess tonic, alterative, and febrifuge properties, and has, consequently, been proposed as a remedy in strumous diseases, chronic affections of the liver, ague, and the typhoid form of continued fever. Its utility as an external remedy is, however, much better established than its alleged therapeutic properties as an internal agent. When considerably diluted it is an excellent stimulant for ill-conditioned sores on the surface of the body, and especially for promoting cicatrization.—*Christison*,

According to PEREIRA it is most valuable as a disinfectant antiseptic, and as an antidote in cases of poisoning by the sulphides and by hydrocyanic acid; and he remarks, that in several cases where he had carefully compared it with chloroxide of calcium he gave the decided preference to the chloroxide of sodium. LABARRAQUE recommends its employment as an antiseptic, on the ground that by the process of disinfection it becomes chloride of sodium, which is not a deliquescent salt, whereas the chloride of calcium existing in and generated by bleaching powder, attracts water from the atmosphere, and thereby furnishes one of the conditions necessary to the putrefactive process. Hence, in his opinion, while chloride of lime will serve equally well for mere disinfection, chloride of soda is preferable when one wishes at the same time to prevent a renewal of putrefaction.

HYPOSULPHITE OF SODA.—There are several modes of procuring this salt. It is very conveniently prepared by first forming a solution of neutral sulphite of soda, by passing sulphurous acid gas into a strong solution of the carbonate of this base. The sulphite so obtained is then digested with sulphuric acid for several days at a moderate heat. In this case sulphurous acid, by taking up sulphur, becomes hyposulphurous acid, thus—



Or a solution of soda may be first saturated with sulphur by boiling, and sulphurous acid may then be passed through this menstruum, when hyposulphite of soda is formed. In either case the solution obtained is rapidly evaporated to a sirupy consistence and then set to repose, when the hyposulphite separates in large colorless crystals.

A very convenient process for the production of this salt on the small scale is that recommended by WALCHNER. A pound of pure crystallized carbonate of soda is dried as perfectly as possible, and then intimately mixed with five ounces of pure sulphur; the mixture is gradually heated in a glass or porcelain basin to the melting point of the sulphur, and kept at that temperature for some time, stirring constantly in order to bring every part in contact with the air. The sulphide of sodium formed at first absorbs oxygen from the air, and is converted with feeble incandescence into hyposulphite of soda. The mass, when cold, is dissolved in water boiled with sulphur for some time, and the filtrate is evaporated, when very fine and pure crystals separate. If the heat employed be too strong, part of

the sulphur is burned off, and carbonate of soda remains undecomposed. In this case a second crystallization is necessary.

Properties.—Crystallized hyposulphite of soda— $\text{Na O, S}_2\text{O}_2, 5\text{HO}$ —is an inodorous salt with a taste first cooling, and afterwards bitter. The crystals are oblique prisms, belonging to the right prismatic system. They are deliquescent in the air, but *in vacuo* lose their water of crystallization. When heated, the salt at first undergoes the aqueous fusion, and then dries up into a white mass; the heat being continued, it takes fire, burning vividly and with a clear yellow flame. Hyposulphite of soda is readily soluble in water, but not in alcohol. In close vessels the aqueous solution deposits sulphur till nothing but sulphite of soda remains in the liquid; exposed to the air it deposits sulphur, and the sulphite is converted into sulphate of soda.

Hyposulphite of soda, and other soluble salts of hyposulphurous acid, possess the remarkable property of dissolving all the compounds of silver, even the chloride, and the solution thus formed has a very intense sweet taste, with a metallic after-taste. This property has been made available in the daguerreotype, for the purpose of dissolving the sensitive coating of iodide from the plate of silver after exposure to light, and thus fixing the image already formed. For this purpose hyposulphite of soda is now prepared on a very considerable scale.

ANALYSIS.—The compounds of sodium may be distinguished from all other salts in a most unmistakable manner, though the tests are almost of a purely negative character. In the pure state, the mode of recognition is as follows:—When dissolved in water, no precipitate or other change is produced by the addition of hydrochloric acid, sulphide of hydrogen, sulphide of ammonium, carbonate of ammonia, or bichloride of platinum; but if the solution be evaporated to dryness, or if a little of the original substance be taken and exposed on a platinum wire to the inner flame of the blowpipe, the outer flame becomes of an intense yellow color, owing to the reduction of the soda and the subsequent oxidation of the reduced sodium.

This test is a safe, and mostly in itself sufficient proof of the presence of soda, provided always a fixed alkali alone be present and in the form of chlorides; the one hundredth part of soda may by this means be detected in presence of potassa. A precipitant has been proposed for soda, which is not, however, of any great value, and is very rarely employed; this is the antimoniate of potassa. It produces, in neutral or alkaline solutions of salts of soda, a white crystalline precipitate of antimoniate of soda, which in concentrated solutions is formed immediately, but in dilute solutions, only after the lapse of some time. Its formation is promoted by vigorous shaking of the mixture. This test gives decisive results only when applied with a careful and attentive consideration of the attendant circumstances. The most indispensable condition of its applicability is, that besides soda and potassa, no other bases must be present in the solution, since the salts of the heavy metallic oxides, those of the earths proper, and of the alkaline earths, and finally those of ammonia, are also

thrown down by antimoniate of potassa. The solutions, too, must be neutral or alkaline, since otherwise the reagent suffers decomposition, and hydrated antimonie acid or acid antimoniate of potassa is precipitated from it. Soda is usually estimated quantitatively as sulphate of soda or as chloride of sodium.

Other compounds of soda are converted into sulphate by adding to their aqueous solution a quantity of sulphuric acid more than sufficient to saturate the whole of the soda; the solution is then evaporated to dryness, and the excess of sulphuric acid expelled by ignition, adding now and then a portion of carbonate of ammonia.

Every one hundred parts of sulphate of soda so obtained represent 43·66 of soda. Of chloride of sodium obtained in a similar manner, one hundred parts represent 39·34 of sodium, or 53·02 of soda. Salts of soda are also sometimes determined as carbonate of soda; and for soda salts with organic acids this method is preferable to all others.

Caustic soda is converted into carbonate by adding to its aqueous solution carbonate of ammonia in excess, evaporating at a gentle heat, and igniting the residue. The bicarbonate of soda is converted into the simple carbonate by ignition; and the salts of soda with organic acids are converted into the carbonate by heating gradually in a covered crucible, the charcoal being afterwards removed by igniting the residue in a gentle current of air. Every one hundred parts of carbonate of soda obtained represent 58·49 of soda.

Lastly, the determination of the commercial value of

some soda compounds, as soda ash, caustic soda, borax, *et cetera*, is effected by noticing the quantity of acid of known strength required to neutralize a given weight of the salt. The process recommended by Mr. FARADAY is as follows:—Into a tube of about three-quarters of an inch in diameter, and nine and a half long, and as cylindrical as possible throughout its whole length, one thousand grains of water are to be weighed, and the space occupied marked on the tube with a fine file; this space is then divided from above downwards into one hundred equal parts. At 23·44 or 76·56 parts from the bottom an extra line should be made, and soda marked opposite to it; at 48·96 potassa should be marked in the same way; at 54·63 carbonate of soda; at 65 carbonate of potassa. A diluted acid is now to be prepared, which shall have a specific gravity 1·127, and this is made by mixing intimately together nineteen parts by weight of oil of vitriol and eighty-one of water. The method to be followed in the employment of this acid is as follows:—The dilute acid is to be measured in the tube up to the line opposite to which the alkali sought for is marked; if barilla, which contains carbonate of soda, 54·63 measures are to be taken. The one hundred measures are then made up by the addition of water, and is then ready for use. But these processes, which constitute a very important branch of commercial analysis, have been fully discussed under *Alkalimetry* in connection with the article POTASSA, Vol. II., page 729 *et seq.*, to which the reader is referred for details.

STATISTICAL REPORTS OF THE ALKALI TRADE OF THE UNITED KINGDOM FOR THE YEAR 1852, DRAWN UP BY
J. WILLIAMSON, ESQ., JARROW CHEMICAL COMPANY, SOUTH SHIELDS,

From full returns by sixteen manufacturers, representing 46% of the trade.
From partial returns by eleven manufacturers, representing 35% “
No returns by sundry manufacturers, representing 19% “

RAW MATERIAL CONSUMED, IN TONS.

	Newcastle- on-Tyne.	Lancashire.	Glasgow and the Clyde.	Wales, Ireland, and South of England.	Midland.	Total.
Sulphur,.....	7,580	none	3,000	none	940	11,520
Pyrites,.....	33,750	40,220	9,000	12,000	5,292	100,262
Salt,.....	57,905	40,152	19,120	12,000	8,370	137,547
Coals,.....	232,020	136,400	80,000	36,500	34,500	519,420

QUANTITY OF PRODUCE, IN TONS.

Alkali,.....	23,100	26,343	12,000	7,000	2,750	71,493
Crystal soda,.....	42,794	3,500	6,000	3,500	5,250	61,044
Bicarbonate of soda,.....	4,046	1,200	none	none	516	5,762
Bleaching powder,.....	5,000	1,250	5,000	1,850	none	13,100
Number of men employed,.....	3,067	1,519	900	470	370	6,326
Amount expended in apparatus,.....	£344,000	172,000	100,000	50,000	36,000	702,000
Amount annually expended in repairing the same,.....	£69,500	23,000	20,000	11,000	6,200	129,700
Tonnage of shipping employed,.....	189,100	71,200	70,000	35,000	8,000	373,300

71,193 tons alkali, at £10,.....	£711,930
61,044 “ crystal soda, at £5,.....	305,220
5,762 “ bicarbonate of soda, at £15,.....	86,430
13,100 “ bleaching powder, at £10,.....	131,000

Total value of products,.....£1,234,580

VALUE OF MATERIALS IMPORTED FROM OTHER COUNTRIES.

11,520 tons sulphur, at £6,.....	£69,120
4,800 “ nitrate of silver, at £15,.....	72,000
12,000 “ manganese, at £2 10s.,.....	30,000

£171,120

Amount contributed by the alkali trade to the annual income of this country,.....£1,063,460.

This report is the only accurate return ever made of the alkali trade. The manufacture in Lancashire has, however, greatly increased of late years; but if the total amount given be doubled, the figures will represent pretty nearly the present yield of the manufacture.

STARCH.—*Amidon*, French; *Sterke*, German; *Amylum*, Latin.—Starch exhibits to the naked eye the appearance of a white glistening powder, which, under a higher visual power, is found to be composed of a number of very minute, colorless, and semitransparent grains. It is a secretion educed from most plants and seeds, though contained in some in much greater proportion than in others; and it would appear that its end is to produce cellular structure under the vital power of the plant, as well as to give support to the embryo seed till it is able to gather sustenance from extraneous sources.

HISTORY AND SOURCES.—This substance has long been known: the ancient Greeks called it *αμυλον*, from the circumstance of its not being prepared by grinding in mills like other farinaceous matters. PLINY attributes to the inhabitants of the island of Chio the discovery of the method of extracting it from wheat flour. Very little is said concerning it in any historical work down to modern times. FOSBROKE states that starches of various colors were imported into England from Holland in 1564—that which was yellow being esteemed the best for ruffs and other articles.

The starches more commonly known as products of particular seeds or parts of plants, are in a measure restricted to a definite number of organic productions, which secrete them for the purposes already alluded to; but if by starch be meant the analogues of this substance, having the same or a closely allied composition, then it may be said to form a constituent of all plants at one stage or another of their existence. The fact that starch of one form or other enters at some particular period into the composition of plants, is the more certain from the consideration of the variety of starches and their congeners. Of these there are three kinds known, namely, *common starch*—such as is extracted from the monocotyledonous and bicotyledonous seeds, and from several roots, tubers, *et cetera*—also *lichen starch*, and *inulin*. The first is the primary link between cellulose and dextrin or artificial gum; the second is intermediate between cellulose and dextrin; and inulin is the connecting link between common starch and sugar. On examining the transformations which the seeds of many plants, such as the cereals, the tubers, or leguminous plants—seeds which are rich in starch—undergo when germinating, it is evident that they effect the solution of the substance of the amylaceous matter into gum, or dextrin, or sugar, whence the carbon necessary for the increase of the young germ is extracted; and so likewise the starch which is abundant at one period of the growth of plants, but which at a more advanced stage disappears, must have passed through an analogous modification necessary for the development of another secretion. This department of vegetal physiology is, however, not sufficiently investigated to admit of explaining with certainty the intermediate stages of the secretion and decomposition of the starch granules in plants; but the fact that starch appears at one period of the growth of a plant or the formation of a fruit, and disappears at another, warrants the supposition that where sugar or gum is discovered, starch, organized in the form of granules or in some other

stages, has probably preceded these, or will result from them.

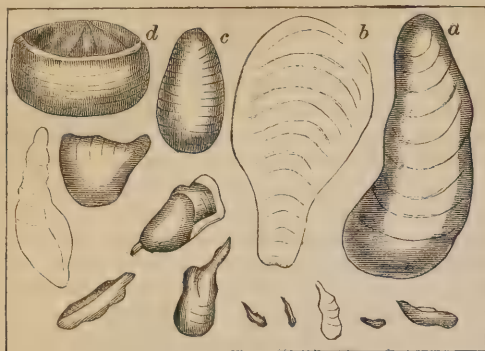
The term starch may be used here in a generic sense to designate the variety of organized structures educed from seeds, roots, and stems of plants belonging to different orders and families, in consequence of such educts offering marked analogies of properties and composition, though differing in physical characters. When it is requisite to distinguish the particular kinds, the source is mentioned; hence wheat, potato, arrow-root, sago, rice, and other starches. Wheat starch is generally called *amidon*, which term is applied not only to the amylaceous matter educed from wheat, but likewise to the similar products of the other seeds of the cerealia in the grains of the leguminosæ, the chenopodiaceæ, *et cetera*. Potato starch has its synonym in *fecula*, and this also is the term by which the starch from the carrot, beet, yam, and the like, are distinguished from the foregoing, as likewise arrow-root, sago, and other kinds. Arrow-root starch is found in the roots of many plants belonging to the family of *Scitamineæ zingiberaceæ* and *euphorbiaceæ*, as the *maranta arundinacea*, and *indica*, from which it is extracted in Jamaica; and the *curcuma angustifolia* from which it is prepared in the East Indies. Sago starch exists in the pith of the palm tribe, especially the *Sagus Rumphii*, *Cicasinermis*, *C. revoluta*, *Coryza urens*, *Borassus gomato*, and several species of *Zamia*, *Corypha*, and *Mauritia*, and can be extracted from them. Besides these, there is another variety of amylaceous secretion, which, differing from them in physical characteristics, is still allied to the preceding in chemical composition, and this is known as *inulin*. It is the immediate principle extracted from the roots of many plants, as the *dahlia*, *elecampane*, *inule*, *helenium*, *colchicum*, *dandelion*, *chicory*, *Iceland moss*, *Carrageen moss*, and several of the lichen and fucus tribe of plants. The latter is little used in the industrial arts of Europeans, though employed in China for the manufacture of transparent lamps and tablets similar to the gelatin articles of the French.

PHYSICAL PROPERTIES.—Particles of starch viewed under a high magnifying power, appear in well-defined grains, in most cases more or less oval; in others polygonal. Notwithstanding an evident analogy between starch particles, from whatever sources obtained, there still remains such difference in their shape and size as to enable any person acquainted with them to identify any particular species even when mixed with others from a different source. Size is the most important criterion, and PAYEN'S researches in measuring the relative magnitude of the starch granules from various sources, constitute perhaps the best guide for the student; hence the following measurements and engravings of the appearance of the various starches, from his *Chimie Industrielle*, will be found useful. The details are of forty-one varieties:—

Fig. 523.—*Fecula* of the *Canna gigantea* measure in length 175 thousandths of a millimetre—equal seven thousandths of an inch, the millimetre being 0·03937 of an inch; *a*, *b*, *c*, *d*, *e*, represent the normal starch granules; *f*, *f'*, *f''*, granules partly exfoliated by vegetation which wastes them. The grains of the

Columba roots—*Minispermum palmatum*—measure 180 thousandths of a millimetre, and those of the

Fig. 523.



Case 1.

large ripe potato—of Rohan—185 thousandths of a millimetre.

Case 2.—Fecula of the arrowroot of commerce—*Maranta arundinacea*—attains a length of 140 thou-

Fig. 524.



Case 2.

sandths of a millimetre; *a*, *b*, *c*, *d*, represent the normal external coating separated from the inclosed matter by pressure. Fecula from the bulb of the lily has the same dimensions.

Fig. 525.



Case 3.

Case 3.—Bean starch, the maximum length of which is 75 thousandths of a millimetre—three thou-

sandths of an inch. At *a a'*, *b b'*, *c c'*, *d d'*, the granules are seen in two positions, exhibiting length, breadth, and depth, and also the median canal impression.

Case 4.—Starch from the tubercles of the *Oxalis crenata*, 85 thousandths to 100 thousandths of a millimetre. Fecula from the largest *Echinocactus erinaceus* imported, 75 thousandths of a millimetre.

Cases 5 and 6.—Detached and agglomerated grains of the pith of the *Cycas circinalis*—sago—the length

Fig. 526.



Case 4.

Case 5.

Case 6.

of the largest of which measures 50 thousandths of a millimetre.

Case 7.—Wheat starch granules, *a*, *a'*, *a''*, in three positions, the largest of which are from 45 to 50 thousandths of a millimetre.

Case 8.—The same starch, the orifice or hilum of

Fig. 527.



Case 8.

Case 7.

which is rendered visible by heating to 396°, and examining the granules subsequently in alcohol of 0.85 specific gravity.

Case 9.—The same starch viewed after the evaporation of the alcohol, showing where the residual water has dissolved a portion of the exterior of the globule.

Fig. 528.



Case 9.

Case 10.

Case 10.—The same starch after the internal matter has been dissolved by an excess of water.

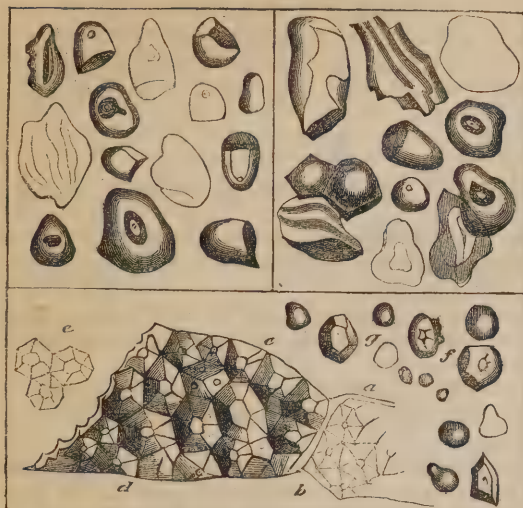
Case 11.—Fecula of the red sago of commerce, the grains of which are partly swollen and deformed by heat.

Case 12.—Fecula of white sago, showing the alterations suffered in the preparation by the effects of a high temperature and the presence of a large quantity of water; this variety, as also lentil starch, measures 75

Case 11.

Fig. 529.

Case 12.



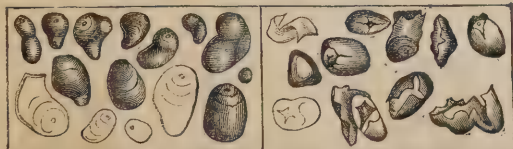
Case 13.

thousandths of a millimetre; kidneybean or haricot starch 67 thousandths; and that of large peas 36 thousandths of a millimetre.

Case 13.—Indian corn starch. Here *a b, c d*, represent the grains encased and compressed in two contiguous cells of the horny part of the perisperm; *e, e, e* represent three compressed grains; *f, g*, detached grains, 25 to 30 thousandths of a millimetre.

Case 14.—Fecula of the bulb of the hyacinth, showing several double grains; the greatest length is 45 thousandths of a millimetre.

Fig. 530.



Case 14

Case 15.

Case 15.—The same, showing the exfoliation of the granules in an old shell.

Case 16.—Fecula of beet, showing several double grains and appearing conical; length 40 thousandths of a millimetre.

Case 17.—Shows the same heated to 360° to develop more plainly the hilum or aperture.

Case 18.—The same fecula as it appears at the commencement of its hydration after the evaporation of the alcohol.

Case 19.—Fecula of the *Orchis bifolia*, many granules of which have two apertures or hila, and double lateral conical protuberances.

Case 20.—Fecula of the *Orchis latifolia*, the grains of which are ovoidal, pear-shaped, *et cetera*, with a

Case 16.

Fig. 531.

Case 18.



Case 17.

Case 19.

double hilum. Both these kinds of starches measure 45 thousandths of a millimetre.

Case 21.—Starch grains found in the tubercle of the potato, the growth of which was arrested. The granules are seen forming two or more smaller corpuscles at the expense of the larger ones; also the more developed

Fig. 532.



Case 20.

Case 21.

Case 22.

grains, several of which are adhering two and two together, with a few grains acted upon with a solution of soda containing 0.005 of the caustic alkali, and swelling the matter in the interior so as to cause it to exude.

Case 22.—Fecula extracted from the stem of the *Cactus Peruvianus*, showing the single, double, and triple grains. It measures from 25 to 30 thousandths of a millimetre.

Case 23.—Represents the starch of the red sorgho, most of the grains of which exhibit a polygonal outline,

Fig. 533.



Case 23.

Case 24.

Case 25.

Case 26.

and measure 30 thousandths of a millimetre. The amylaceous organization of the *Cactus pereskia grandiflora* are of the same size, as also that of the *Naïas major*.

Case 24.—Starch grains of the *Aponogetum dis-*

tachyum of a truncated polygonal form; they measure 22 thousandths of a millimetre. Such also is the dimension of the starch contained in the stem of the *Ginkgo bilobi-saliburia adianthifolia*.

Case 25.—Exhibits the same swollen by a solution of soda.

Case 26.—Shows the starch of the *Cactus cereus grandiflora*, and which measures 20 thousandths of a millimetre.

Case 27.—Fecula of the *Cactus Braziliensis*, showing the double and triple grains; it measures 18 thousandths of a millimetre.

Case 28.—Starch of the *Panicum Italicum* in polygons; measures 16 thousandths of a millimetre.

Case 29.—Fecula of the *Cactus flagelliformis*, measures 15 thousandths of a millimetre. The pollen of the *Globba nutans* has the same dimension.

Case 30.—Starch of the *Echinocactus erinaceus*, measures 12 thousandths of a millimetre. Pollen of the *Rupia maritima* is 11 thousandths of a millimetre.

Case 31.—Starch of the *Cactus opuntia tuna* is 10

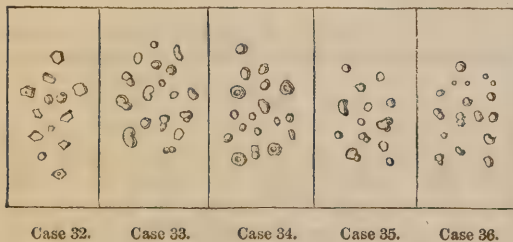
Fig. 534.



thousandths of a millimetre. The starch of the *Ficus indica*, as also that of the *Cactus curassavicus*, have the same dimensions.

Case 32.—Starch of the *Aylanthus glandulosa* measures 7 to 8 thousandths of a millimetre.

Fig. 535.



Case 33.—Represents the starch grains of the *Cactus curassavicus*.

Case 34.—Starch from the parsnip, measuring 7 thousandths of a millimetre.

Case 35.—Shows the granules of the *Ficus indica*.

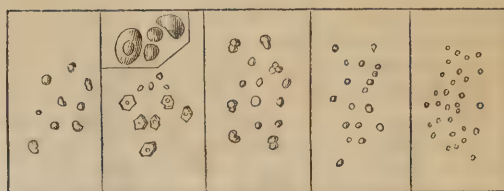
Case 36.—Shows the double starch granules of the *Cactus serpentinus*, 7 thousandths of a millimetre.

Case 37.—Fecula of the *Cactus monstrosus*, measuring 6 thousandths of a millimetre.

Case 38.—Millet starch—*Panicum miliaceum*—exhibiting the polygonal form; they measure 9 thou-

sandths of a millimetre. The inclosed grains are those that have been swollen with a solution of soda.

Fig. 536.



Case 37. Case 38. Case 39. Case 40. Case 41.

Case 39.—Starch of the *Cactus mamillaria discolor* exhibiting several double grains; length 8 thousandths of a millimetre.

Case 40.—Starch grains of the sugar beet, exhibiting a globular form; the largest measure 4 thousandths of a millimetre.

Case 41.—Starch from *Chenopodium quinoa*, of rounded form, measuring only 2 thousandths of a millimetre.

Thus it will be seen, that the most general forms of starch corpuscles are ovoidal, conical, and polygonal; the first and second shapes prevail when the cellular structure, in which the granules are inclosed, offers sufficient space and retains as much moisture as to confer elasticity upon the coats and interior substance of the grain; but sometimes the granules are collected in large numbers in the cells of the seed or plant, which in turn are closely bedded in the *testa* or outer covering; in such cases—as shown in Case 13 in preceding plate—the compression causes the walls of the amylaceous bodies to assume polygonal forms.

SCHLEIDEN and others describe the formation of a starch corpuscle as commencing from a spheroidal granule, the nature of which is assumed to be different from the matter subsequently secreted. This matter, according to PAYEN, is assimilated through a funnel-

Fig. 537.



Case 1.

Case 2.

shaped opening in the granule, usually, though improperly, called a *hile* or *hilum*. This aperture is visible in many varieties, and sometimes grains are found to have two or three of them, especially when the

corpuscles are large; and even when imperceptible under the usual magnifying powers, they may be rendered visible by submitting the starch to careful desiccation, when the internal matter contracts, and thus causes an enlarged opening, which, sinking into the granule, exhibits the rings or discs usually observed in starch grains abutting against it, as seen in the annexed figure, exhibiting in Case 1 the starch granules with the hilum, and, in Case 2, the same after desiccation. These concentric rings or bands have led to much controversy as to the true organization of the starch corpuscle. It is generally supposed that it is made up of layers superimposed on one another, from the nucleus to the outer wall, and that the bands contracting towards the hilum result from the upper verge of such layers cropping out. Those maintaining this view hold that the matter in each differs neither in its nature nor composition, beyond being a little denser as the outer surface is approached. Those who maintain the opposite opinion assert that the corpuscles are true cells filled with the true amylaceous matter, and that the bands are simple plications of the walls of the cell.

When starch is moistened with alcohol of 0.85 specific gravity, and then slightly heated, the spirit evaporates readily, and leaves a slight particle of water

and gradually expand, developing at the same time a frill-like plicated margin, which slowly opens out; the plications on the globule may then be seen slowly unfolding, and may be traced in many cases into the rugæ of the frill. Ultimately the granules swell up to twenty or thirty times their original bulk, in which state they appear as flaccid sacs, though no extrusion of matter can be observed during the experiment.

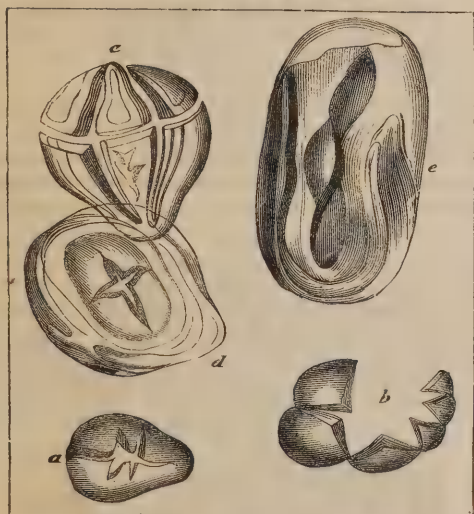
The Editor finds REID argues, from the following endosmotic experiment, that the starch has an exterior covering or cellular membrane coating the inner substance, and that the latter is not organized in successive layers as if a number of sacs were arranged one within the other. He saturated starch granules with glycerin, and placed them while in this state in contact with water, when endosmotic changes followed, the less dense liquid being absorbed. After the absorption the grains were found to have burst in the direction of their axes, the rupture indicating a membrane that had been corrugated by release from unusual tension, whilst the covering of the remaining portion of the granule was visible in distinct longitudinal wrinkles from the hilum downwards. He submits that, were the corpuscle composed of superposed laminæ only, the addition of water in the manner described ought not to rupture it, or if this happened, the fracture would be in the direction of the laminar surfaces and not at right angles to them or their supposed order, as happened in his experiments. He further holds that the bands or lines observed in starch grains are mere plications of the outer membrane, because they entirely disappear on swelling the corpuscles with any liquid.

In direct opposition to this view may be placed the facts already stated of the combined effect of heat and solvents. Thus, if a little potato starch be heated on a metal plate to 360° or 390°, and then examined after treatment with a little water, the several layers will be found swollen, and by adding an aqueous solution of iodine they will be made to appear with considerable distinctness. The question, however, is not yet thoroughly answered, though the mass of evidence is in favor of the view that an outer cuticle surrounds the inclosed matter, from which, as well by the iodine reaction as by its less solubility, such coating differs in many of its properties.

In the annexed woodcut—Fig. 539—*a*, *a'*, *a''*, *c*, *d*, represent granules of starch heated to 320°, 392°, and 410°, as seen in alcohol; *f*, *g*, the same swelled in water after being heated to 320°, showing the hilum opening inwardly; *g*, granules of the same starch submitted to the last-mentioned temperature and afterwards plunged into alcohol, which, on evaporation, left a little water on the external part of the grain, and which dissolved a portion of the exterior matter; *h*, grains of starch heated between 392° and 420° and then put in water, when they swell to such a degree as to exhibit the different folds of their matter in the form of so many layers. These folds are more easily distinguished by adding a little of an aqueous solution of iodine to the liquid, in order to give them a violet tint.

Before passing to the consideration of the chemical properties of starch it may be well to give, in addition

Fig. 539.



on each grain, which, at the increased temperature, is acted upon more or less; and if the grains be placed in an excess of the liquid so as to remove the entire mass, nothing but a thin pellicle remains. Fig. 538 exhibits granules of potato starch thus treated; the granules, *a*, *b*, *c*, show the effect of the action of the drop of water; *d* shows the partial solution of the substance leaving the insoluble portion; and *e*, the swollen insoluble pellicle. According to BUSK, the best method for exhibiting the starch corpuscle under the microscope is, to saturate it with a concentrated solution of chloride of zinc containing a little free iodine. No change appears from these agents; but as soon as water is added, the grains assume a deep-blue color,

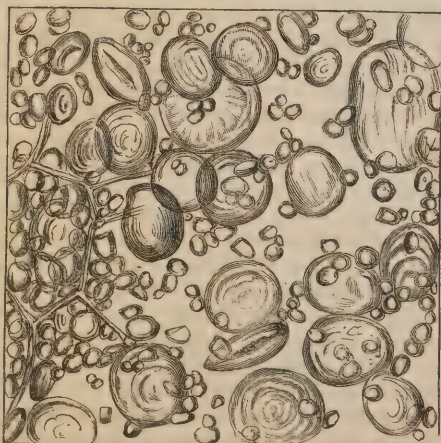
to the descriptive references in the preceding drawings, a few additional facts concerning those starches which form articles of commerce.

Fig. 539.



WHEAT STARCH.—The amylaceous corpuscles of wheat differ somewhat among themselves in appearance and size of grain, but generally they are composed of

Fig. 540.

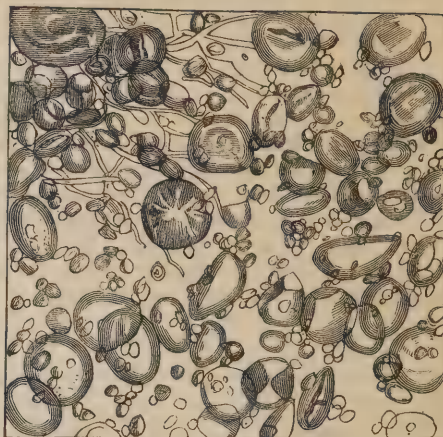


large and small granules, with very few of an intermediate size. The smaller grains are chiefly round, rarely oval, and for the most part provided with the dark central spot or aperture designated the hilum; the large granules are rounded and flattened, so as to give them a lenticular appearance. In most of the grains neither the hilum nor the concentric rings can be distinguished with a magnifying power under four

hundred and sixty linear diameters. Viewed edgewise between glass plates, some of the grains seem misshapen, and present the appearance of a longitudinal furrow, occasioned by the partial folding or curling of the grain on itself; this has been erroneously described by PEREIRA as the hilum. In Fig. 540 are represented the structure and appearances of the starch granules of wheat flour, as also the characters of the cellulose, drawn with the camera lucida, and magnified four hundred and twenty diameters.

BARLEY STARCH—Fig. 541—is somewhat similar to

Fig. 541.



that of wheat, being composed of large and small grains; but the latter are three to four times less than the corresponding ones of wheat starch. This engraving represents the structure and characters of barley starch, together with the cellulose. It is drawn with the

Fig. 542.



camera lucida, and magnified one hundred and forty diameters. A considerable number of the large corpuscles has distinct rings and the furrow already referred to.

RYE STARCH.—This variety—Fig. 542—is similar to wheat starch in the form of the granules, but the smaller grains appear to be less than the analogous ones in wheat starch, and the others somewhat larger. In

addition to these differences, there is seen on the flattened surfaces of the larger grains of rye starch a three or four, or even five-rayed hilum or spot, which serves at once to distinguish the two varieties. This engraving represents the structure and characters of the starch granules of rye flour. It is drawn with the camera lucida, and magnified four hundred and twenty diameters.

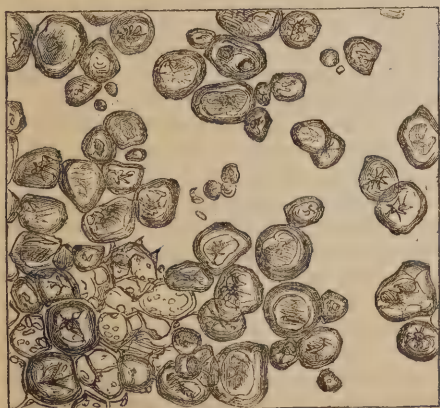
OAT STARCH.—The corpuscles of this variety—Fig. 543—are much smaller, but more homogeneous, than those of wheat or barley; and instead of being circular, they have a polygonal outline, and are devoid of visible rings or hila. Many of the granules remain connected, presenting rounded or oval bodies, with a reticulated

Fig. 542.



surface, indicative of their structure. Another well-marked difference is, that the granules of oat starch do not show the usual crosses when viewed with polarized light that the other cereal starches exhibit under the

Fig. 544.



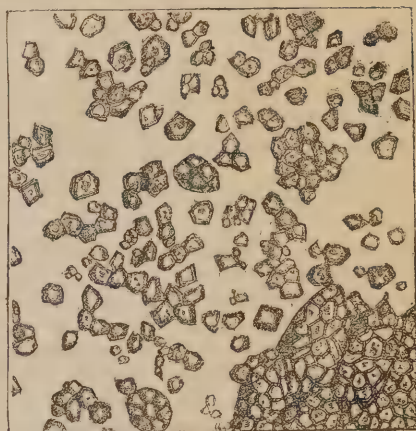
same circumstances. This engraving represents the structure and characters of the starch corpuscles of oat flour, as also of the cellulose. It is drawn with the camera lucida, and magnified four hundred and twenty diameters.

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MAIZE OR INDIAN CORN STARCH.—This—Fig. 544—resembles in a great measure oat starch in the polygonal outline of its granules, but the corpuscles are much larger, and do not aggregate to form compound bodies, as is the case with oat starch. Under the polariscope maize starch presents well-defined crosses, and, like all the other amylaceous organization of the cerealia, exhibits the central depression of the grains very well marked. This engraving represents the structure and characters of the starch granules of Indian corn flour, including the cellulose, drawn with the camera lucida, and magnified four hundred and twenty diameters.

RICE STARCH.—This variety—Fig. 545—representing the starch corpuscles of rice flour, drawn with the camera lucida, and magnified four hundred and twenty diameters—presents the appearance of very small polygonal grains, more angular, however, than that of the

Fig 545.



oat or maize; it has a well-marked central depression in the grain, the edges of which appear raised. They resemble the starch from the oat grain, by their aggregating together and forming in rounded masses. The preceding figures, representing the starches referred to, are taken from HASSALL'S *Adulteration of Food*.

CHEMICAL PROPERTIES OF STARCH.—Viewed chemically, starch may be regarded as a definite compound of water and the true principle of organic formation bearing this name, or *amylum*. If the substance, after extraction from the plant which yields it, be allowed to deposit from the water in which it is held in suspension and then dried by pressing between absorbent media, such as plaster of Paris, till no further loss is sustained, it will be found still to retain forty-five per cent. of its weight of moisture. On exposing this product to moist air at a temperature of 68°, the weight of water will ultimately be reduced to thirty-five per cent. At this degree of desiccation the starch appears of snow-white brilliancy, possessing remarkable cohesive properties, so much so as to allow its being readily pressed into plates possessing a considerable degree of tenacity, and capable of receiving an impression from hard bodies without, however, yielding any moisture to an envelope

6 D

of bibulous or other paper in which such plates may be inclosed. It is impossible to sift it whilst in this state, and when projected upon metal plates, heated to 300°, the particles agglutinate into compact masses. This property is turned to account in the manufacture of tapioca, sago, and the compounds sold as patent soluble starches, from ordinary fecula or wheat starch.

When the starch which has been desiccated in moist air for several days, is exposed to the circulation of a dry atmosphere, it parts with a further quantity of water, which reduces the per centage of that ingredient to eighteen, and in this state it possesses a very slight adhesive property, but not to such an extent as would prevent it from passing through the meshes of a fine sieve; neither does it swell up or agglutinate as before. Thus dried, it constitutes the ordinary commercial starch. Air-dried fecula of this nature loses a further quantity of moisture when kept in a vacuum at a temperature of 60°, so as to leave only fifteen per cent. combined; and if the heat be sustained at 260°

the moisture is reduced to a minimum, or eight and a half per cent. Starch so dried constitutes a monohydrate of amylin or of the true starch principle, from which mere desiccation cannot remove more water without altering or destroying the order of combination of the elements entering into its composition. It is only by combining the matter of starch with metallic bases, such as lead or baryta, that it can be obtained in a perfectly dehydrated state, in which it exhibits upon analysis the following composition, corresponding with the formula $C_{12}H_9O_9$:—

	At. Weight.	Centesimally.
12 Eqs. of Carbon = $12 \times 6 = 72$	72	47·059
9 „ Hydrogen = $9 \times 1 = 9$	9	5·883
9 „ Oxygen = $9 \times 8 = 72$	72	47·058
	153	100·000

By tabulating the results above referred to, the relation between the amylaceous matter and the combined water will be more easily comprehended :—

Condition of Starch.	Formula.	Atomic weight of Starch.	Per centage of HO in thoroughly dried Starch.	Per centage of monohydrate of Starch.
Anhydrous amylin,.....	$C_{12}H_9O_9$	153	0	0
Starch dried at 212° to 280° <i>in vacuo</i> ,.....	$C_{12}H_9O_9HO$	162	0	100
Starch dried at 60° <i>in vacuo</i> ,.....	$C_{12}H_9O_9HO$, 2 aq.	180	10	90·0
Starch dried at 68°, in air containing 0·6 per cent. of moisture,.....	$C_{12}H_9O_9HO$, 4 aq.	198	18·18	81·82
Starch dried in air saturated with moisture,.....	$C_{12}H_9O_9HO$, 10 aq.	252	35·71	64·39
Starch thoroughly drained by absorbents,.....	$C_{12}H_9O_9HO$, 15 aq.	297	45·45	54·55

When subjected to a heat ranging from 395° to 410°, starch is readily converted into dextrin, but some kinds are more easily acted upon in this way than others. If a certain amount of water be contained in the starch, the heat necessary for its transformation is not so great. Thus, when starch dried in a vacuum at 260° is subjected to a temperature of 320° in an oil bath, it does not suffer much change, and retains its property of insolubility in cold water; but when the temperature is raised to 395°, and sustained at this degree for half an hour, the starch becomes altered to an amber color, without, however, giving out much water, and the chief part is dissolved by cold water. It is different with fecula containing four equivalents of water, which, if suddenly brought to 320° to prevent the evaporation of the moisture, passes at this degree into dextrin, so that the effect is in all things nearly the same as if the substance were quickly heated in the air to 395° or 410°. According to JACQUELIN, the changes that follow an increase of temperature applied to starch merely air-dried are these :—From 212° to 284° the hilum is more and more developed, appearing in the end like a large rent or tear; at 320° the granules lose their ordinary form; at 338° the inclosed starchy matter becomes soft and slightly colored; at 356° it turns black, and is soluble; and at 372° to 395° the walls of the grains burst asunder.

Such are the changes which heat alone effects upon starch; they are somewhat different from those that are produced by other agents.

Potato starch or fecula suspended in twelve to fifteen times its weight of water suffers no change, not even when the temperature is raised to 131°, with the exception of a slight increase of the younger or more

tender grains; at 135°, however, the corpuscles perceptibly swell, and continue to do so as the heat advances; at 162° the increase of the granules becomes more evident, and the liquid assumes more or less consistency, which goes on increasing up to 212°, when it forms a paste of greater or less thickness. If the proportion of the fecula and water be as one to a hundred and the mixture be boiled, the white color of the corpuscles disappears and the whole presents a perfect solution, so much so as to traverse a compact filter; yet a finer filtering medium can separate the starch so as to make it appear that, instead of being dissolved in the liquid, the corpuscles were only largely distended and diaphanous. PAYEN, by immersing the bulb of a hyacinth in such a filtered solution, succeeded in separating the apparently dissolved starch; for there appeared, as the rootlets absorbed the water, particles of starch adhering to them, which were turned blue by iodine, whilst a section of the roots of the bulb gave no indication with this test of the presence of amylaceous matter. Hence it is evident that the fine capillaries of the plant, being too small to permit the passage of the particles of starch, caused their accumulation on the surface—a circumstance which, it may be supposed, would not occur if the starch were perfectly dissolved. Not only is the starch separable from its apparent solution by the means just mentioned, but it is precipitated by cold even when the quantity of water is more than double that mentioned in the last experiment. By submitting starch paste made with fifteen parts of water and one of starch at 212°, to cold sufficient to freeze it, and then allowing it to thaw, a contraction of the paste takes place, and it parts with a portion of its water. By repeating the operation, the

starch, which was apparently soluble in water whilst in the form of paste, becomes quite insoluble, and precipitates from the liquid in flakes. Advantage is taken of this property to obtain a felt-like substance suitable for certain kinds of cartridges, and for other purposes to which paper is inapplicable. The paste, after being cooled below zero, is then heated slightly above the freezing point and submitted to pressure, when most of the water is expelled and a dense felt-like matter remains, applicable for the above uses. Even when the quantity of water in which the starch is boiled is two or three hundred times greater than the weight of the starch, it is found that by repeatedly freezing and liquifying, the menstruum and the starch separate in flakes. From all these circumstances it appears doubtful whether starch is entirely soluble in hot water.

Solutions of the fixed alkalis have the effect of swelling the corpuscles of starch, and causing it to form a paste even without the aid of heat. Mixed with an alkaline solution containing from one and a half to two per cent. of alkali, the starch granules appear to swell, when viewed under the microscope, to the extent of seventy-five times their original bulk. By previously drying the starch *in vacuo* till it becomes a monohydrate, the absorbent qualities seem to be considerably increased, for when such fecula is treated with a liquid containing only one per cent. of alkali or less, the enlargement is so great as to rupture the cell walls of the grains, and cause the starchy substance or amylin to protrude and become diffused in the liquid.

When the quantity of alkaline water is not in too great abundance, it converts the starch into a semi-transparent paste, in the same manner as water. It would appear that a salt of the alkali is produced in this operation, in which the starch forms the radical, and from which the insoluble amylates of the alkaline earths or metallic bases may be obtained by simple double decomposition, upon the addition of a neutral soluble salt of those bases. The decompositions in these cases are so complete that, when an equivalent of the precipitant is employed, the filtrate from the precipitate does not, upon the addition of iodine, give the slightest indication of the presence of starch; the iodine will not give the usual reaction of starch with the precipitates till after their decomposition with a weak acid, such as acetic.

From the analysis of the amylates of lime, baryta, lead, and silver, the composition of the true matter of starch, as previously stated, has been deduced.

Sulphuric, hydrochloric, and nitric acids in a diluted state have also the power of swelling starch and converting it into a paste. When sulphuric acid is employed, the proportion of acid in the liquid should form at least three per cent. of strong acid. If, in addition to the effect of dilute acids, the temperature of the solution in which the starch is held be raised to 212°, several changes follow, the first of which is the production of dextrin, a substance isomeric in composition to the true amylaceous matter that is soluble in cold water, and in its properties analogous to gum; the next change appears to be the formation of glucose or grape sugar, a body which differs from starch merely by two equivalents of water, or rather of oxygen and

hydrogen; for these elements are assimilated so that they constitute an integral part of the new compound. Its formula is $C_{12}H_{12}O_{12}$, but as it crystallizes from the liquid it takes two equivalents of water of hydration, in which state it may be represented as $C_{12}H_{12}O_{12} \cdot 2HO$ or $C_{12}H_{14}O_{14}$. These changes take place to a large extent with starch paste made simply with water by the aid of heat, by mere exposure to the air. Thus one hundred parts of wheat starch made into a paste with twelve hundred of water, and the mixture exposed during thirty-eight days, was found by SAUSURE to yield—

Sugar,.....	47
Dextrin,.....	23
Starch granules,.....	8
Starch,.....	4
„ altered,.....	10
	92

The difference in this instance must be attributed to the change in the composition of the substance. This was shown by taking the same weight of starch, treating it as above, and allowing the same period of exposure; it was then analysed, and the results showed a loss of one fifth, thus :—

Sugar,.....	50
Dextrin,.....	10
Starch granules,.....	5
Starch,.....	4
„ altered,.....	9
Carbonaceous matter,.....	0.3
	78.3

A disengagement of carbonic acid accompanies this decomposition when it takes place in the air; if on the contrary, the reaction take place in close vessels, bubbles of hydrogen are evolved from the mixture. In these cases it is probable that the small proportion of gluten in the starch, generating diastase by decomposition, renders the change more active; for it is well known that diastase will convert starch into dextrin and sugar, to the extent of two thousand times its weight.

The starch granules mentioned in the preceding analysis are such as settle down from a solution of starch in water at 300° when the liquid is left to cool; these granules are dissolved in water at 160°, or better when the heat is so high as 212°, and the liquid affords the ordinary reaction with iodine. It appears from the experiments of JACQUELIN that they are permanent, and may be reproduced from their solution in boiling water by simple evaporation in their original form; they are insoluble in cold water, as may be proved by iodine, but when rubbed in a mortar and then diluted with water it is probable that some of the grains are fractured, for on testing the liquid it manifests the presence of starch. The best method for obtaining this permanent form of starch is to digest a mixture of one part of fecula and five of water in a PAPIN'S digester at 300° for two hours, and afterwards to allow the mixture to cool. Should the heat rise to 320° the fecula would be converted chiefly into dextrin, with a little sugar giving a violet color with iodine; on the other hand, if the heat approaches 355° the sugar predominates and very little dextrin is found, so that iodine has no effect upon it.

It has been already mentioned that dilute nitric acid converts starch, equally with dilute sulphuric acid, into dextrin and sugar, after swelling the granules and transforming them into a pasty mass, when the water is not in excess. The result of the action is very different when strong nitric acid is employed. BRACONNOT found that fuming nitric acid, specific gravity 1.5, when poured upon starch or fecula, dissolves it, and on the addition of a large quantity of water a substance was precipitated, which, when freed from excess of acid by washing and dried, proved to be highly inflammable and soluble in ether; this is the xyloidin or nitramidin of PELOUZE, who found it to be composed of one equivalent of starch with one of nitric acid. With the same acid, and the application of heat, starch is converted into a number of indefinite substances, which ultimately resolve themselves into oxalic acid. This operation, with slight modifications, is followed in the manufacture of the latter article as will be seen by referring to page 637 of this volume.

Hydrochloric acid causes the alterations of starch already mentioned into dextrin and glucose, first forming a jelly, or dissolving the substance according as the quantity of water present is greater or less. Its action is far less energetic, however, than chlorine. The latter element has invariably a decomposing action upon starch, which results in the production of water and carbonic acid. These changes take place even when a solution of hypochlorite of lime—bleaching powder—is put in contact with starch in the cold, but the decomposition is gradual. With an excess of the reagent the transformation is more rapid. Oxalic, tartaric, and other acids have the power of swelling the starch grains, and ultimately converting them into dextrin or glucose. Acetic acid is devoid of this power, and therefore the fecula remains quite unaffected by it. The same inertness is exhibited by ammonia towards this body, and hence the following method by PAYEN, for the valuation of vinegar and ammoniacal salts:—He adds about a five-hundredth part of the sample of ammoniacal salt to be tested, of starch to the solution in which the former is contained, and then drops in a standard liquid of caustic-soda till the menstruum indicates the swelling of the granules and the formation of a paste. Previous to this result, the soda displaces the ammonia by combining with its acid; but after the whole of the ammoniacal salt is decomposed, the soda that is added in excess reacts upon the starch, and converts it into a paste. Vinegars unadulterated with mineral acids have no action upon starch, so that when a mixture of the two is boiled, the peculiar reaction of starch and iodine is exhibited unchanged; but if the acid be adulterated with sulphuric or any other mineral acid, the change of the fecula to dextrin and glucose will be proportionate to their quantity, and this alteration will be exhibited by the iodine reaction. The tests, however, considered analytically, are of little value.

The most remarkable property of starch is the combination it forms with iodine, and which is characterized by the well known blue color of the compound.

This reaction, besides being the most sensitive test yet discovered for the mutual detection of starch and

iodine, has many other important applications with reference to the changes which the fecula undergoes under the influence of other agents. When a weak solution of iodine is added to starch the blue coloration takes place, but it is so superficial that the granules appear transparent when observed under the microscope. If the quantity of iodine added be greater, the coloration becomes more intense, and to such a degree as to cause the corpuscles to appear black; this blackness and opacity take place when only one two-thousandth of a millimetre in thickness. As the combination proceeds through the entire mass of the granule, the whole appears of a beautiful blue. Between this characteristic blue shade, every gradation of tint is observed till a reddish or orange color manifests itself, according as the starch is disaggregated and changed into dextrin and sugar under the influence of a hot solution acidified by sulphuric acid, or any other body capable of producing the like effect. Thus, a solution of starch in boiling water, when iodine is added immediately, forms a fine blue precipitate; and then by pouring in some sulphuric acid, and maintaining the heat, it gradually changes to various shades of violet, afterwards to wine-red, then to a crimson-red, and finally to an orange-hue. Some of these shades are produced when iodine is added to starch in its progressive stages of development. Young or imperfectly formed starch granules, in which the matter is not properly aggregated, produce with iodine a reddish-fawn color; and as the particles become more united and compact the tint changes through the several stages of violet, in which the blue predominates, till ultimately, as the granules are fully formed, the tint resembles that of indigo.

There are many evidences that the result of this action is a true combination of the starch and iodine. If the compound be kept at 60° *in vacuo*, it retains nearly as much water as the starch itself under the same treatment. When the compound is partially desiccated in the vacuum, and the heat is afterwards raised to about 425° to 430°, a portion of the iodine is expelled, but on cooling the substance again by contact with the air, the shade of color still remains very deep. On adding a little water to the compound, and repeating the experiment under the same circumstances, a further amount of the iodine is displaced though the color is not eliminated. Treated with water at this stage of the experiment, only about two per cent. of the starch is dissolved, and this soluble portion even strikes a violet color upon the addition of a little iodine. Upon examination, many of the granules of the insoluble portion are so highly tinted as to appear black, and these resist the action both of the alkalies and concentrated sulphuric acid in the cold, thus showing that a very strong combination has taken place.

Starch dried at 212° to 266° in a vacuum, and suspended in absolute alcohol, does not unite with iodine dissolved in the same menstruum; but if a little water be added, a violet coloration, which deepens in shade by standing, is immediately produced. From this behavior it might be anticipated that alcohol would abstract iodine from the amylaceous compound. This is to a great extent the fact, for on agitating the blue

compound with about twenty times its weight of absolute alcohol, and decanting the liquid after the matter subsides, a portion of the previously combined iodine will be removed; and by a repetition of the process, fresh quantities will be taken up, though less each time, till as much as four-fifths of the combined iodine is separated. When the solvent is employed at the boiling temperature, the decoloration is much more rapid; and if a portion of the substance be viewed under the microscope whilst the reaction is taking place, it will be noticed that the least aggregated of the corpuscles, or in other words, the younger ones yield their iodine first, and turn to a violet and red color. The granules of starch do not lose their distinctive character by combining with iodine, for if the blue iodide, dried thoroughly at 212° in a vacuum, be examined under the microscope in the presence of absolute alcohol, the corpuscles will, as they become decolorated, appear intact. If, however, a few drops of water be added to the alcohol employed whilst the substance is under examination, or after it has been dried, several of the grains appear as if burst; the inclosed matter being disseminated in the liquid and colored reddish-violet, the coats of more aggregated matter acquiring by the hydration a shade approaching to a blue.

The blue iodide of starch is decomposed by several agents. Exposed to the light of the sun, it gradually loses its blue color in the presence of water; the effect is more rapid when the menstruum is raised to a temperature of between 86° and 105° . In either case the changes result from the decomposition of water, the hydrogen of which enters into combination with the iodine to produce hydriodic acid, the oxygen forming iodic acid with another portion, so that the mixture becomes colorless. When starch is freshly treated with iodine, the alkalis readily decolorize the compound, owing to an iodide and iodate of the alkali being produced, leaving the starch almost intact in the solution. It is a very curious characteristic of the iodide of starch that, by a change of temperature alone, the blue color may be made to disappear and return several times in succession. If an excess of iodine be poured into the solution of starch the blue iodide will be retained for some time, even at 212° ; but when the excess of this element is volatilized by the heat, the compound fades, and even a heat not exceeding 160° will be found capable of reducing the color of the mass completely. On allowing the vessel to cool, however, the blue tint, strangely enough, reappears, and this alternation of color can be repeated by heating the solution, and allowing it to cool again. By degrees, the tint weakens each time the solution is cooled, owing doubtless to the loss of iodine sustained either by expulsion in the form of vapor, or by conversion into hydriodic acid. The blue tint is retained with much greater tenacity when the amount of starch present is greatly in excess of the iodine.

Iodide of starch precipitates very readily from its solutions however dilute; but the coagulation of the matter takes place much more readily in presence of the neutral salts of the alkalis and alkaline earths, and of dilute acids, and even by a reduction of temperature. In all of these conditions the separation is to

be attributed to a very marked contraction which the iodine by its union causes in the corpuscles of starch.

It has been stated that water at a high temperature, acid, and alkaline solution have the power of swelling the granules of starch to such an extent as to render them apparently soluble when the volume of water is very large, or to produce a semitransparent jelly, when its quantity does not exceed a certain limit. In the latter case the increase in the granules is greater than the volume of the liquid in which they are held; and, consequently, instead of moving freely as in a solution, the swollen grains are compressed and ramify into one another till the whole becomes as it were soldered—at which stage the mass appears a jelly. When iodine is added to such a mass a reverse change succeeds; and the contraction of the grains enables the compound to precipitate readily, so that, in a short time, the blue iodide will be retained on a filter from the liquid portion. In a very dilute solution of starch the precipitation of the iodide is not so rapid as in menstrua of greater density. Congelation, in such cases, causes the blue compound to form in flocculi in the liquid; and in time they settle to the bottom, leaving the rest of the liquid colorless. Cold has an analogous effect upon fecula which has been distributed in a large quantity of water, and subjected to a temperature of 212° ; for, by repeated freezings and solutions of the frozen mass, by successive applications of cold and heat, the starch grains which before had seemed as if dissolved, owing to their great extension, now appear in flocks in the liquid, and can be separated from the latter by simple filtration. In both cases a considerable amount of contraction takes place, to which the separation of the starch, in one instance, and of its iodide in the other, is to be attributed. One equivalent of iodine can fully saturate seven of starch in producing the blue iodide; the ratio of combination between them is therefore as seven to ninety-two by weight, and by volume as one to twelve.

Tannic acid seems to form combinations with solutions of starch, giving a greyish-white flaky precipitate, which becomes transparent in the heat, but reappears in the usual form as the liquid cools. This acid decolors the blue iodide of starch, and when present in sufficient quantity it prevents the entire decomposition of fecula by means of diastase. The reaction contributes in part to the formation of artificial leather on CLAUSEN'S principle, as already detailed in this work.

Amount of Starch contained in different substances.

—The quantity of starch in different grains and bulbous roots yielding this substance, varies considerably, both in the per centage, amount, and gross total yield per acre; and these two circumstances must be taken into consideration by the manufacturer in selecting one in preference to another of the many sources whence the starch is extracted. Thus while the potato affords centesimally only from fifteen to sixteen parts of starch, wheat affords as much as sixty per cent.; still the total amount per acre is in favor of the potato in the ratio of 2400 to 996; the produce being estimated at six tons in the first instance, and sixteen hundred-weight in the latter.

Different varieties of the same species of grain likewise exhibit a marked difference in the amount of starch, as appears from the following table :—

AMOUNT OF STARCH IN DIFFERENT KINDS OF WHEAT DRIED AT 212°.

	Per cent.
Talavera wheat from Hohenheim,.....	56.25
Whittington " ".....	52.45
Sandomierz " ".....	53.37
Wheat from Giessen,.....	54.63
Do. from Vienna, No. 1,.....	65.68
Do. " No. 2,.....	67.17
Do. " No. 3,.....	67.45

A difference as remarkable is exhibited in various kinds of potatoes. Thus JOHNSTON found in—

	Per cent.
Red potato from Lanarkshire,.....	14.08
Small Americans,.....	17.80
Orkney potatoes,.....	17.42
Buffs from Forfarshire,.....	20.71
Kidneys,.....	14.93
Cups from Argyleshire,.....	15.41

Mr. HEMING gives the following numbers as the per centage of starch from different varieties of potatoes grown on the same soil in Renfrewshire, namely :—

	Per cent.
Irish blacks,.....	16.5
Connaught cups,.....	21.0
White dons,.....	13.0
Red dons,.....	10.75

This variation is the more remarkable when considered with reference to the quantity produced per acre :—

	Quantity per acre.	Amount of starch.
	Tons.	Tons.
Cups,.....	13.25	2.9
White dons,.....	18.50	2.4
Red dons,.....	14.25	1.5

It may be presumed that much of the discrepancy in the quantity of starch indicated by the foregoing analyses is to be attributed to the age of the tubers; but though the amount of fecula certainly varies at different periods in the growth of the plant, still the experiments that have been made to elucidate this question conclusively demonstrate that even at maturity the quantity of the starch is unequal. The per centage of starch which any given variety yields, depends very much likewise upon the nature of the soil and the weather which has prevailed during harvest, the yield being much less in dry than in wet seasons. Potatoes that have been allowed to remain a considerable time in the ground, or being improperly stored, have become heated and budded, will not be found to contain as much fecula as others of the same kind which have been timely collected and carefully stored; for the sprouting effects the decomposition of a considerable portion of the starch. This is well known in potato-starch factories; for whilst, in the months of October, November, and December, as much as seventeen per cent. is obtained, in January, February, and March, the amount diminishes to fifteen and even twelve per cent.

There is no difficulty in inferring from these facts the advantage gained by extracting the fecula from potatoes during the three months after they have arrived at maturity, rather than at a more advanced

season. Analysis of the potato shows that it is composed centesimally of—

Water,.....	74.00
Fecula,.....	20.00
Epidermis, cellular tissue, pectose, pectine, pectates of lime, soda, and of potassa,...	1.65
Albumen and analogous nitrogenous matters,.....	1.50
Asparamide,.....	0.12
Fatty matters,.....	0.10
Sugar, resin, essential oil—solanine,.....	1.07
Citrate of potassa, phosphates of potassa, of lime and magnesia, silica, alumina, oxide of iron, and manganese,.....	1.56

100.00

The following numbers indicate the per centage of starch in the various cereal grains, which can be employed for the manufacture of starch, and in the potato according to KROCKER's analyses :—

	Cereal grains.	
Wheaten flour,.....	65.21	66.16
Rye,.....	61.26	60.56
Oats,.....	37.93	36.90
Barley,.....	64.63	64.18
Buckwheat,.....	43.80	44.45
Buckwheat meal,.....	65.05	
Indian corn,.....	65.88	66.80
Indian cornmeal,.....	77.74	
Rice,.....	85.78	86.63
Beans,.....	37.71	37.79
Peas,.....	38.81	38.70
	Potatoes.	
	I.	II.
Blue potatoes,.....	23.20	22.80
White potatoes,.....	16.14	17.98
" ".....	16.48	16.09

The potato has long been resorted to for the preparation of the cheaper kinds of starch; but, in addition to this source and wheat, from which the finer kinds are made, other matters—such as rice, maize, and barley—are employed in the manufacture. Wheat and other cerealia having been first employed, claim precedence in describing the process on the large scale, notwithstanding that at present these materials are not so generally resorted to as in former times, unless when to some extent damaged, and, therefore, not so well adapted for human food.

MANUFACTURE OF STARCH.—In the manufacture of starch from the cerealia two methods are followed, which may be distinguished as the fermentative or old process, and the chemico-mechanical, or modern and improved method. That the improvements introduced of late years in the manner of making starch possess a decided advantage over the old system, cannot for an instant be doubted, and yet in many factories the old process by fermentation is still followed; a method both noxious and wasteful. By this process, the wheat is first steeped till softened, and then coarsely ground in a malt mill, or crushed between rollers; the crushed mass is made into a thickish creamlike consistence with water, generally the acid water from a previous operation, and allowed to remain in vats or tuns for a period varying with the temperature of the weather from ten to thirty days. The effect of this prolonged steeping is to disintegrate the starch from the glutinous envelope in which it is contained in the grain; an effect produced by the gluten being partly

decomposed by fermentation, partly dissolved by the acids formed in the course of the operation, and partly by its property of becoming partially soluble on entering upon the putrefactive change. At first any sugar in the grain, or dextrin produced in the first stages of the process, is dissolved in the water, accompanied by a slight alteration of a portion of the gluten, whereby diastase is formed in more or less quantities; this sugar and dextrin are converted into alcohol and carbonic acid, and by prolonging the operation the spirit is changed to acetic acid. To equalize the action it is necessary to agitate the mass once or twice a day, and likewise to beat into it those portions which the escape of carbonic acid during fermentation may bring to the surface. After a few days the glutinous portion of the grain begins to undergo the putrefactive change more or less rapidly, and this proceeds till it is considered sufficiently advanced to allow the starch corpuscles to be separated in a state of comparative purity. By such changes, ammonia, sulphide of hydrogen, and other disagreeable products are formed, which renders the operation noxious, and often a most offensive nuisance. After the fermentation is supposed to be completed, any excess of water that may happen to be in the fermenting tun is drawn off, and the magma or thin pulpy mass is filled into bags of stout canvas, or other material, the mouths of which are afterwards well secured; they are then placed in water, and trodden upon till the water is quite loaded with starch, when it is drawn off, and its place supplied by fresh liquid; the treading is then repeated till the solution again becomes quite creamy with starch, and this, in like manner, is let off as before. Three or four such washings exhaust the bags of the starch, leaving only the husk of the grain and the altered albuminous matter, which is almost useless. The starchy liquids are made to pass through hair-cloth or wire sieves in their course to the settlers, to deprive them of any portion of husk or fragments of glutinous matter, after which they are allowed to repose in the settlers for several days; the starch sinks and forms a cake of solid matter on the bottom, whilst the more glutinous portion afterwards constitutes a deposit of a brownish color above it. Frequently, in order to delay the deposition of the glutinous matter, very light and finely-divided fibrous matters are introduced, and agitated with the liquor; the glutinous particles by attaching themselves to the fibres of the extraneous substance employed, are retained in the water a much longer time than the starch, so that the under layer of the deposit is almost in a state of purity whilst the gluten and fibre settle down upon it. After drawing off the clear water by a siphon, the impurity on the top of the deposit is separated and set aside to be washed with the next batch; the underlying portion is stirred up with fresh water, and purified by settling and decantation; this operation being repeated twice, thrice, or oftener if necessary. When the starch is sufficiently white, it is put to drain into small boxes, the sides of which are lined with flannel; or it is dug out in lumps from the bottom of the depositing vessel, and placed upon blocks of plaster of Paris, which absorb the

moisture, and thereby cause the starch to harden. The deposit in the drainer boxes is similarly desiccated before it is sent to the drying-room.

Bran, and other refuse matters of the wheat, *et cetera*, are generally mixed with the grain in these operations, and increase the amount of the product.

When the gluten is of such a nature as to agglutinate easily, it can be separated by careful manipulation, but not so, without additional labor, when it disintegrates and passes off with the starch into the water. The extraction of starch from the cereals and leguminous seeds is now much simplified by the aid of chemical substances, and consequently the older system is but rarely practised. The length of time which it required, the labor involved in the process, the loss of starch occasioned by its transformation into dextrin and sugar, and finally, the disagreeable and unhealthy effluvia which were evolved, all concurred to render the old process far inferior in every respect to the modern one. In fact the new process introduced by MARTIN offers so many advantages that one might expect it to be universally adopted by the manufacturers of starch from wheat or flour; yet the old system is still practised in a number of factories, the conductors of which allege that the product obtained from the fermentative process has a better color than that prepared by the chemico-mechanical system.

In MARTIN'S process flour is employed in preference to wheat grain or the same coarsely crushed. It is made into a stiff dough with water, and allowed to remain in that state till every part becomes thoroughly saturated with moisture. A mechanical kneader may be employed with advantage to effect this part of the work. The time allowed for the water to permeate the mass varies from half an hour in summer to two hours in the winter season. The inventor employs a trough covered with a wire-gauze sieve, No. 120, to which a pipe and tap supplies a constant stream of water for washing the dough, the water being thrown upon the mass from a rose of forty minute apertures. The workman takes a mass of dough, averaging ten pounds, and placing it under the small jets of water, kneads it on the sieve till the water ceases to flow off milky, using at first only a gentle pressure, which is increased towards the end of the operation. By this careful working, the gluten, which at first is finely divided in the dough, is made to agglutinate into a pasty elastic mass, which becomes more consistent in proportion as the starch is removed, till ultimately nearly pure gluten remains. Another mass of the dough is then operated upon in the same manner, the gluten being each time separated and removed. In this way almost the whole of the gluten is disengaged from the starch. To remove the particles of gluten which accidentally pass through the sieve, the amylaceous washings are allowed to remain for twenty-four hours at a temperature of 70° or thereabout, together with the scum which formed upon the produce of a preceding washing, with the view of inducing fermentation, and thus altering the small portions of gluten still retained. The purification of the product is effected in the ordinary way by successive washings and decantations, taking the precaution, however, to draw off the liquor when

the dense portion has subsided, and before it becomes contaminated with the lighter particles held in suspension by the glutinous matter. On allowing these washings to settle for three or four days the suspended starch falls, and is recovered after the liquor is drawn off, drained in flannel-coated boxes, and finished on plaster and the drying stove. It constitutes about ten per cent. of the starch, and, although unfit for fine white goods, it forms a very good paste for colored stuffs, dressing, and the like.

MARTIN'S process is being daily more extended, especially in Germany, with decided advantage over the old system, not only in respect to the gluten which is extracted in the fresh state, and which constitutes a fourth of the weight of the flour, but likewise as regards the starch itself; for from average wheat flour as much as fifty per cent. is obtained, whereas on the old method not more than forty per cent. could be recovered. The cause of this loss is to be found in the change which the glutinous fermentation produces on the starch, and by which it is converted first into dextrin and then through the successive stages into glucose, alcohol, and acetic acid. These changes take place more rapidly in hot weather. By the new process, the gluten separated from the starch forms the basis of another profitable business, namely, the preparation of articles of food, such as macaroni, vermicelli, semolá, and such like; or it may be compounded with other articles, such as flour or potato meal, and made into a wholesome and substantial bread. In summer the gluten separated from the starch retains its freshness fully twenty-four hours; but after this it begins to lose its tenacity, enters into partial solution, and then decomposes; in the winter season it may be retained for two days without injury.

At first it was proposed to utilize the gluten by mixing it with potatoes or inferior flour, and making the compound into bread; but subsequently it was found preferable to mix it with boiled potatoes, in consequence of the insipidity of the compounds with potato starch. The manufacture of vermicelli and macaroni did not at first succeed, in consequence of the proneness of the gluten to decomposition; but this obstacle has now been overcome, and the gluten is made into a highly nutritious and palatable food, for which purpose the patent process of VERON of Vienna is the most applicable. In this method the gluten, after the separation of the starch, is mixed with twice its weight of best flour, and placed in a machine consisting of two concentric cylinders, the inner one of which is furnished with projecting pins, and is made to revolve much more quickly than the outer; the glutinous substance is thereby divided into a mass of elongated grains, which are placed upon trays and dried in the hot-air compartment along with the starch for the space of one and a half to two hours. The whole is then sifted to separate the finer from the coarser particles, and the latter is ground in a mill and resifted. The very rich nitrogenous compound thus prepared offers advantages over macaroni and semolá, owing to the readiness with which it may be prepared into food.

Such are the main features of the process followed in manufacturing starch from wheat, grain, or flour;

the details of the manufacture will be more fully given when treating of potato starch or fecula. At present it may be remarked, however, that the different qualities of starch to be met with in the market are simply the successive deposits, or the portions which subside in succession in the tuns or vats within a given period. It may be likewise stated that, with the view of giving a purer whiteness to the product, it is submitted, either in vats or in close chambers, to the action of chlorine or of sulphurous acid, either dissolved in water or as gases. By a slight elevation of the temperature in the primary stages of the hot-air desiccation, the starch undergoes a change which causes it to dissolve in water at a lower heat than it otherwise would; the product so heated bears the name of *soluble* starch.

STARCH FROM POTATOES.—For a long time the manufacture of starch or fecula from potatoes has been rapidly extending in France, and has now assumed so much importance that it ranks, in money value, next to beet-root sugar. In England the practice is not so general, and its development has been much checked by the potato disease. It has been already shown that this esculent yields a large quantity of starch, and the product so obtained possesses all the qualities adapted for ordinary application in calico printing, *et cetera*; it is also extensively mixed with farina, for increasing its whiteness; it is employed in the confection of vermicelli, semolá, tapioca, polenta, and a number of other alimentary substances, distinguished by various designations; also in the formation of dextrin or artificial gum, grape sugar, sirups, molasses, wine, beer, alcohol, vinegar, and several other uses.

In large potato-starch factories it is necessary to have considerable storage room for retaining the tubers during the most part of the year; and care must be taken to obviate, as far as possible, the conditions under which the starch in the potato is liable to undergo alteration. Thus all affected or diseased potatoes should be carefully removed from those which are sound, and the latter ought to be kept in a dry atmosphere, and at a temperature as low as possible. Dry cellars or pits formed in the ordinary way, if dry at the base, and securely covered with straw and earth, serve for some time; but a well-ventilated barn or shed with grated floorings, one over another, whereon the potatoes may be laid to the depth of two feet, or thereabouts, will answer the end much better. In any case it is necessary that, during the spring and first of the summer months, the potatoes be turned frequently, so that any shoots which may be forming be broken, and the progress of decomposition in the substance of the bulbs be thereby intercepted.

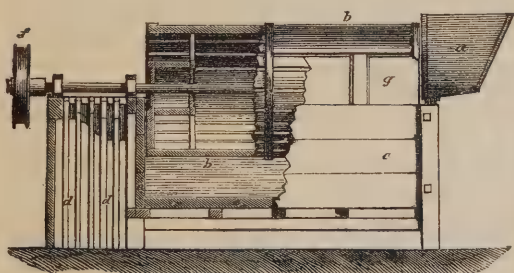
Few operations are simpler than the extraction of fecula from potatoes; nothing further is necessary than the rupture of its cellular matter either by rasping or grating, so as to liberate the starch granules, and the washing of this pulp upon a metallic plate or stage by a stream of water, such washings being afterwards passed through a fine sieve. The solid matter of the potato is thus left on the plate, whilst the starch is carried off in the water, and separated from any grosser impurities by the straining or sifting.

Finally, the fecula is purified by washing and decantation, *et cetera*. Simple as this process may appear, it is divided into several distinct operations, which will be described in the order in which they are carried on in the French and other manufactories of fecula.

STEEPING THE POTATOES.—This operation, which is preliminary to the washing, and has in view the softening of the clay and other adhering gross matter, that they may be more easily removed, is performed in a large trough or vat, filled with water, in which the potatoes are allowed to steep during six to twelve hours, according to the quantity of the impurities.

THE WASHING.—The next operation is the washing

Fig. 546

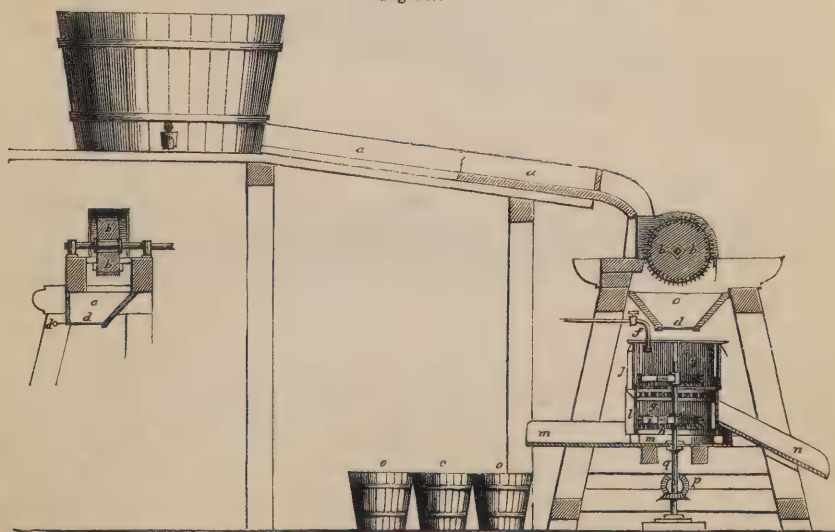


which is effected by mechanical means and the aid of steam. Fig. 546, represents an elevated view of the machine employed, which consists of a hollow cylinder, *b b*, constructed of laths of wood or iron,

laid longitudinally from one end to the other, the distance between each being such as to permit of the escape of the dirt, stones, *et cetera*, whilst the tubers are retained. The cylinder is charged from a hopper, *a*, at one end, and being slightly inclined, the washed potatoes are discharged at the opposite end, down the inclined plane, *d d*. About a third of the cylinder is immersed in the water of the trough, *c c*, wherein it revolves, and from the sides of which spring the boards, *g g*, slanting to the upper part of the cylinder, and intended to prevent the splashing of the water during the movement of the machine. This cylinder is worked by a band passing over the wheel, *f*, at the end of the axis, and a drum-head of another shaft in connection with the main shaft of the engine. The inclined plane upon which the potatoes fall when thrown out conducts them to the rasping machine.

RASPING OR GRATING.—The object of the rasping is to reduce the tubers to a pulp, by which the cells containing the fecula are ruptured; and the finer this rasping is effected, the more freedom will the starch have in escaping. In some instances, this operation is performed by means of a hand-machine; but generally, the larger factories adopt a machine by which the rasping and the washing of the pulp are effected consecutively. The circular drum bearing the rasp is turned by a winch handle, and while revolving meets the tubers in the hopper, reducing them to a pulp which falls by the aid of inclined boards into a vessel moving on wheels, and on which it is carried to the washing stage. A small stream of water is conducted on the upper surface of the rasp, with the view of keeping it clean from accumulation of pulp. The rasp itself

Fig. 547.



is made of plate iron, punched from the reverse side with an angular, semicircular, or round tool on a yielding support, which allows the angular fractures of the iron on the under side to remain unflattened. With a machine of this kind, from two and a half to three tons of potatoes can be turned into pulp by three men in twelve hours. The other kind of machine is

shown in Fig. 547, in connection with a portion of the washing apparatus. It consists of a cylinder about twenty inches diameter, and the same in length, mounted upon an axis. The cylinder is armed with steel-saw plates, placed at the distance of little more than three-fourths of an inch apart; the teeth of these saws, which are very small and regular, and placed

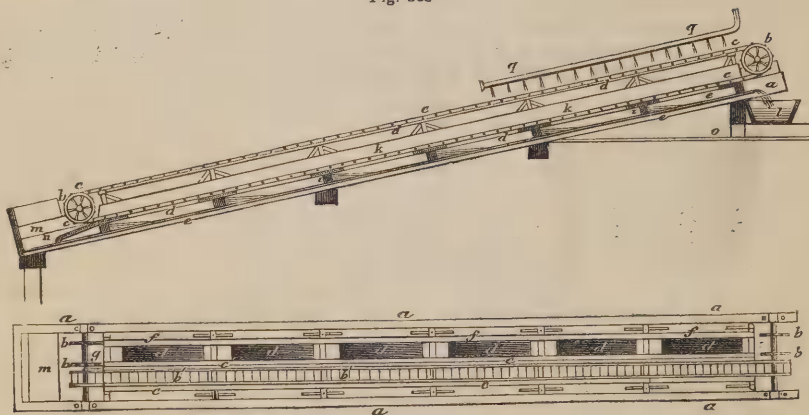
parallel to the cylinder, being held fast by iron clasps, project about four-fifths of an inch from the periphery of the drum, and the whole is turned with a speed of six to nine hundred revolutions per minute. Such a machine, making on an average eight hundred revolutions per minute, reduces to a pulp from sixteen to eighteen hectolitres of potatoes per hour, or forty-two and a half to forty-eight bushels.

In the preceding figure, the rasping drum is shown at *bb*; the inclined plane conveying the potatoes from the washing machine is indicated by *a a*, and the hopper into which the pulp falls by *c*, whence it is dropped into the washing machine by the trap-door *d*. The washing apparatus for exhausting the pulp, is that introduced by M. SAINT ETIENNE; it consists of a cylinder of wire gauze, *e*, fastened upon wooden or iron rings for support, and divided into two compartments, *j, l*, each provided with a wirecloth bottom, the lower finer than the upper one. The whole is inclosed in a sheet-iron or wooden covering, which prevents the escape of starchy waters from it when working. In the middle of the cylinder is a shaft, *g*, carrying arms furnished with brushes, *i, i*, which sweep the bottom disc of each compartment, and force out the fecula into a trough as the shaft is turned by the gearing of another one, *p*, acting upon a wheel appended to it at its base. By the very rapid

revolution of the brushes and agitators in the drum, aided by the stream of water projected from the rosed-pipe, *f*, the pulp is speedily washed, the fecula passing out at the sides and middle disc, *g g*, whilst the coarser pulp is thrown out by lateral openings, and is removed from the outer case by a door into the canal, *n*. The finer portions of the pulp, which pass through the upper part of the machine, are separated in the lower one; the granules of fecula falling through the fine meshes of the wire swept by the brushes into a trough, *m*, leading to the vats, *o, o, o*, where the starch is permitted to deposit, whilst the fibrous matter is ejected by an aperture at the side, and removed through a door in the case to the canal, *n*. In this form of machine there are several imperfections, which are obviated by a modification introduced by LAINÉ. The principal defects are, that the working is not continuous, the machine having to be stopped at intervals to remove the exhausted residue; that only comparatively small portions can be operated upon at once; and lastly, that the residue is not thoroughly divested of its fecula.

In the machine, improved by LAINÉ, and further perfected by DAILLY, the wire sieves are retained, but the washing space is considerably extended and prolonged, though the quantity of pulp exhausted in a given time is increased. This is done by

Fig. 548.

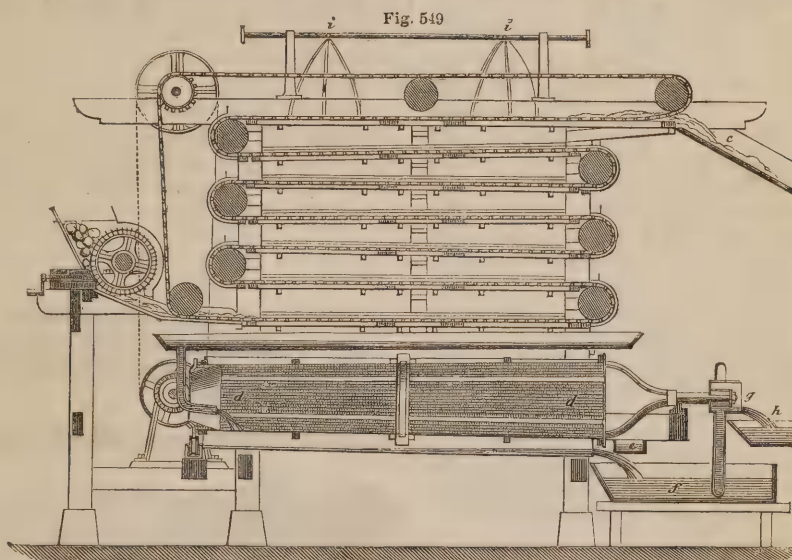


means of an inclined sieve, represented in plan and section—Fig. 548; a long inclined plane is constructed of planks, and this plane is converted into a kind of trough, by side planks, *a a*, secured in their places by cross planks, *i i*, and bolts, which fasten the latter to the base, *e e e*, of the plane. At each end are pulleys, *b b*, the crowns of which are notched in eight places, and into which the bars, *b' b'*, connecting the endless VAUCANSON chain, *c c c*, are caught and carried forward as the pulleys turn. Motion is given to these by connecting the axle of the lower one with the shaft of a steam-engine, water-wheel, or other motive power. Each of the eight divisions of the base of the inclined shallow sluice formed by the cross bars *i i i*, is covered with

a wire gauze, *d d*, increasing in fineness from the lower to the top one; and upon this finely-perforated surface the pulp to be washed is conveyed by the bars, *b' b'*, connecting both links of the chain as it travels from the lower to the upper end, in the slides at the sides and overhead, as seen at *f f f* in the figure. The chain and grooved slides on which it moves on its return overhead are supported by upright pieces of wood, bearing horizontal pieces, *g g*, on which the part *f f f* rests. From the rasping cylinder, or *cylinder devorateur*, as it is called, the pulp is conducted into the trough, *m*; and being diluted with the water employed to keep the cylinder clean, it overflows the inclined board, *n*, and so comes within reach of the cross-bars of the VAUCANSON'S chain as it travels over the lower

pulley, whence it is conveyed over the several compartments of the wire gauze in the inclined plane; but whilst in the act of passing upwards it meets with a stream of water projected from a pipe, *q*, along the upper three divisions of the plane, and which flowing downwards over the several frames, completely exhausts the pulp of all its fecula, leaving nothing but fibrous matter, epidermis, *et cetera*, when it reaches the top and is thrown out into the trough, *l*. From the three upper compartments the water projected upon the mass is conveyed to the lower ones in succession by a series of pipes, not shown in the drawing, connecting the several levels; thus from the lowest part of the highest square, a pipe issuing at the side conveys the liquor to the highest part of the third square; another from the lowest part of the second delivers the starchy liquid of this upon the fourth square, to meet the

ascending pulp; the third sends its water to the fifth, and so on to the lowest and first division, whence it issues into the canal, *r*, leading to the settlers. Two sieves and two travelling chains are generally worked upon the plane, provisions for which are shown in the drawing, the one movement working both. To avoid the inconvenience of the great length to which these planes extend on LAINÉ's plan, and also in DAILLY's, M. SAINT ETIENNE places the sieves one above another, and carries the endless chain over each, as shown in the drawing, by means of pulleys at the ends, the pulp being secured by a flange passing over the pulley and chain in each case. The pulp is delivered at once from the grater or *devorateur* to the chain carriage, and carried upwards till it is discharged at the top into the sluice exhausted of its starch. The disposition referred to is shown in Fig. 549, in which the principal



parts are similar to those last described. The water entering upon the top of the apparatus, flows from the highest of the compartments of each of the levels to the lowest, and thence upon the highest of that immediately beneath, and so on till it travels over the whole space to the base, where, loaded with the fecula, it collects in a receptacle, whence it flows by a pipe into a circular drum, *d d*, of very fine iron wire, revolving upon a central axis moved by mechanical power. Any pulp still retained is here separated and ejected into a receptacle, *e*, at the lower end, whilst the starch flows with the water through the gauze into the vat, *f*, and thence, by a *dénaiide* mounted upon the end of the axis of the cylinder, and revolving upon it, it is lifted into a sluice leading to the settlers, which are disposed as represented in Fig. 547.

By such a machine as the preceding, it is stated that the pulp from one hundred and sixty hectolitres—four hundred and forty bushels—of potatoes is exhausted in twelve working hours.

Besides the foregoing, several other inventors have constructed machines in which the advantages of uninterrupted working, combined with complete exhaustion

of the pulp within the smallest space, have been the points aimed at, and such advantages are claimed by HUCK, VERNIER, and STOLZ for their respective machines. All, with the exception of SAINT ETIENNE, have recurred to the cylindrical wire-gauze sifter, as being the one which affords the largest extent of surface in the smallest space. HUCK's machine consists of two wire-gauze cylinders, connected by a brass drum; in the cylinders are inclosed brushes and rousers, as usual, and also two drums, one for supplying pulp and water to the upper, and another in the lower for supplying water only. Both the wire-gauze cylinders and the drums move independently of one another and in opposite directions, the brushes and rousers taking the same course as the inner drums. The continued agitation in passing through both the cylinders, together with the action of the rousers, deprives the pulp of the most part of the fecula. The starchy liquid is collected in a cistern beneath, and flows into a third circular sieve in which only brushes revolve, but the wire of which is much finer, so that the last portions of pulp are separated. VERNIER employs a combination of three cylindrical sieves moving on the same axle; the

pulp arriving at the upper part of the first or smaller cylinder falls into it, and subsequently by the rotation of the entire system, as well as by the inclination at which the cylinders are fixed, it traverses each successively, being always exposed to a stream of water, till the exhausted matter finally issues partially drained from the middle one. The drainings from the sieves collect in a tank below the cylinders, and are thence conducted through another fine cylindrical sieve for depuration before they are run off to the settlers. STOLZ's machine is on the same principle as the preceding, and is said to be very effective, working off not less than four hundred and forty bushels of potatoes in a space of not more than twelve or thirteen feet. Whatever be the form of sieves employed, it is evident that the efficiency of the process depends in a great measure upon the quality of the rasping machine, and the fineness to which it reduces the tubers. On an average, only sixteen to seventeen per cent. of starch is obtained from potatoes really containing from eighteen to twenty or twenty-one per cent.; and therefore from two to four per cent. is left in the residue in consequence of the inefficacy of the *devorateur* to rupture all the cells containing the starch corpuscles. VÖLKER to obviate this, proposed to disintegrate the cells of the potato more completely than is done by the rasping machine, by submitting the pulp to a fermentative process, at a temperature between 68° and 86° in presence of sufficient water, by which the cells are in a short time destroyed, and the whole of the fecula is set free to be removed by a course of sieve washing. Though good in principle, yet the time occupied, and the difficulty of removing the greatly disintegrated cellular substance, offer almost insurmountable obstacles to the adoption of this method.

After the extraction of the starch from the fibrous matter of the pulp, the next operation is the separation of any particles of sand, clay, and other heavy impurities from the fecula. This is done by allowing the liquor as it passes off from the sieve to collect and repose for the space of a few hours, when the supernatant liquid is siphoned off, and the deposit agitated with its own bulk of water; the mixture is then passed over a fine sieve, by which stones, sand, and coarser impurities are removed. Three or four such repetitions with fresh water, using at each successive sifting a finer wire gauze than the preceding, complete the purification. To assist in this part of the work a mechanical agitator is employed in the large fecularies, similar to that shown in Fig. 553, and which may be elevated or lowered at pleasure by a lever handle. When such an arrangement is appended to the sieves the labor of purifying the starch is much diminished, as the various impurities are retained in the intermediate vessels.

PURIFICATION.—The several filtrations and depositions above alluded to being effected, the milky liquor is allowed to flow into large settlers, where it is left to repose for several hours, till the whole matter in suspension falls to the bottom; the clear water is then siphoned off, and the brownish layer on the surface, consisting of fibrous particles, pulp, and other substances lighter than the fecula, scraped off as clean as

possible by an iron scraper. This impure starch is agitated with fresh water, and then passed through a very fine brass wire or silk sieve, and allowed to rest for some time, till a further amount of white starch falls, when the same operation is repeated. The deposit left after the removal of the brownish light matter, is known in the French and Belgian works as *gras de féculé*. It is further purified by stirring it with fresh water, passing the mixture through a No. 90 brass-wire sieve, or one of silk cloth, conveying the milky liquid into a vat, allowing it to rest till the starch falls, then decanting and scraping the surface, and finally, if the mass be pure and of sufficient consistence, dividing it into lumps and placing these to dry, either unsupported or in a conical wire case; if it has not acquired this density it is customary to agitate it, and to run the thick semifluid mass into small perforated boxes lined with coarse cloth, such as flannel or calico.

Sometimes the purification of the fecula, deprived of its supernatant brownish deposit, is effected by washing it under a slight stream of water on an inclined table or sluice, twenty to twenty-four feet long by three feet in breadth, and declining one and a half to two inches in its whole length; the lighter matter is carried off by the water, leaving the pure fecula. Figs. 550 and 551

Fig. 550.

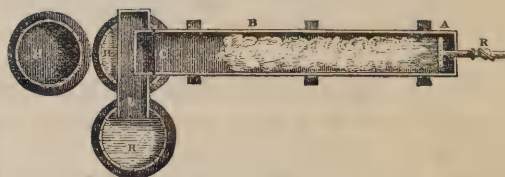
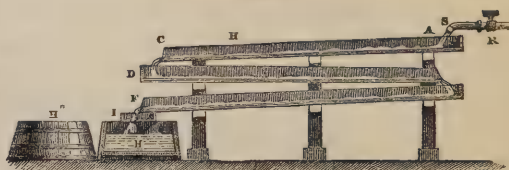


Fig. 551.

illustrate this arrangement; A, C, represent a portion of the first plane; D the next; and F the third; the three being placed on supports one above another to economize room. The starch being spread upon the first ledge, a stream of water in numerous small jets is delivered upon it by the pipe R; the workman agitates the surface of the layer with a brush, and the slight current carries the lighter particles forward, depositing a portion of the fecula in suspension as it proceeds, till it arrives at F, whence it falls into the canal, I, and thence into the settler, H. The purified starch is then brushed from the plane under a stream of water into the second vessel H'; and by siphoning the liquor from the vessel H into H'', the operation of laying a second batch may be proceeded with. As soon as the fecula has subsided in the tub or vat H', the water is decanted; the starch is then transferred into boxes of a conical form, perforated

to allow the water to drain away, and covered with cloth and set aside.

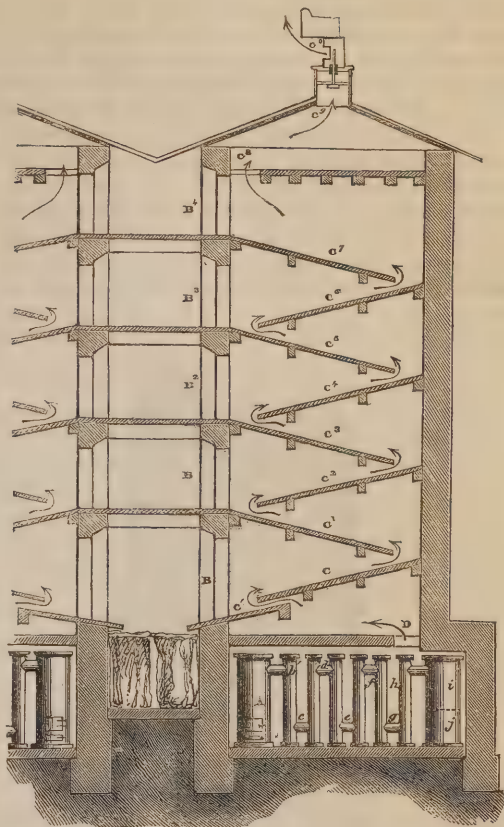
DESICCATION.—At this stage another operation, the *drying of the starch*, commences. It may be remarked here, however, that the large quantity of fecula which is converted into grape sugar and dextrin is not dried, but is at once acted upon in a manner which will be described at the end of this article.

During the time that the starch is allowed to drain in the lined boxes, it acquires sufficient hardness to enable it to retain the shape of the box; and as soon as this state is attained, the mould of starch is inverted upon a mass of plaster of Paris, which abstracts a further portion of the retained moisture, thereby rendering the loaf of fecula so solid as to endure being placed upon the stages of the drying-house for further desiccation. In this state the product is known as *green fecula*, and contains fully two-thirds water.

Desiccation in Free Air.—The free-air drying chamber is a large rectangular room, on either side of which are ranged, one above another, a number of horizontal shelves formed of bars of wood placed at a distance of three quarters of an inch to one inch apart, the whole being supported by upright posts, as shown in Fig. 552. A current of air is passed through the gallery by means of venetian ventilators at both sides, which admit of increasing the draught at will without permitting much dust to enter. The loaves of fecula are broken into three or four pieces, and laid on the longitudinal hurdle or bars already mentioned, on which they are permitted to remain during six or eight weeks; they are then taken, and, if necessary, reduced to powder under a wooden roller, and placed in the hot-air stove. In the construction of the latter, it is indispensable to have the arrangements such that the heat may be entirely under control; for if a high temperature were to act upon the starch, the corpuscles would be swelled to bursting, and a number of gummy concretions in proportion to the extent of the change would result. Such a consequence need not be feared after the chief part of the water still retained in the starch—amounting to forty per cent.—has evaporated. Several kinds of drying stoves are used for this purpose; one being a long gallery like the preceding free-air drying chamber, closed with apertures in the front for sliding shelves, on which the starch is placed to pass inwards where the warm air circulates. The heat in these cases is obtained from cast-iron pipes passing round the walls at the base, in which the draught from a fire is conducted to the chimney; and getting thereby warm they heat the air in the interior as it passes through the compartment. Fig. 552 is a sectional view of the drying stove of LACAMBRE and PERSAC, in which the starch is exposed gradually from 60° to 212°, the highest degree of heat to which the fecula is subjected. It consists of a chamber, beneath the ground floor of which a heating apparatus consisting of a stove, A, and a system of iron pipes, b, c, d, e, f, g, h, i, leading to a chimney, is erected; and the air entering this compartment by lateral apertures passing over the heated surface of these pipes gets warmed and ascends by the opening, D, in the drying chamber, where, following the direction of the arrows, it suc-

cively passes over the inclined tables, c, c¹, c², c³, c⁴, to c⁷, and thence to the outlets—c⁹ and c¹⁰—at the top. The starch passes in an opposite direction, being intro-

Fig. 552.



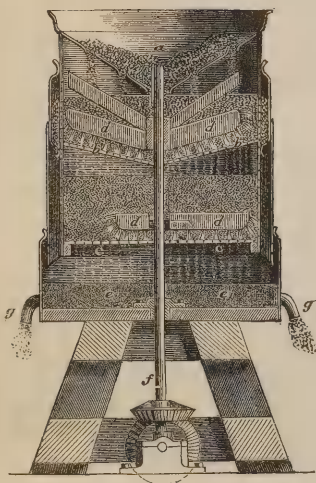
duced at the door, B⁴, at the top upon the plate, c⁷, and thence it is pushed forward over the plates, c⁶, c⁵, c⁴, c³, by the aid of the working doors, B³, B², B¹, and B, till it arrives dried at c, and falls upon the ledge, c¹, into the receiver outside the wall of the chamber.

Another drying chamber constructed upon the same principle, but self-acting, consists of a chamber and heating apparatus essentially like that last described; but instead of plates inclined one towards another, there are a number of rollers fixed two and two at the same height in the interior, upon which travels an endless band of cloth, and which are sustained in the middle by cross rods of wood. By means of gearing-wheels on the ends of these rollers, the cloth of each pair is moved in an opposite direction to that immediately above it, and the whole are set in motion by the power acting upon the highest roller, e, in the chamber. All the gearing-wheels on the axles of these rollers being of the same diameter, they move with the same velocity, so that the moist starch, introduced through the door at the top and spread upon the web, is carried forward from one end of each web to the other, till it reaches the utmost limit of the lowest one. From the disposition of the rollers the fecula falls from one

cloth to another alternately at either end, and ultimately into the chamber, the heated air ascending in an opposite direction.

The fecula during the passage through these hot-air chambers loses from eight to fifteen per cent. of moisture, according as it has been more or less dried in the free-air chamber, and is now in the ordinary state for sending into the market, except when, for laundry purposes, it is mixed with a certain amount of coloring matter, such as smalt blue and the like, or sometimes of late with incombustible matters, to secure fine light dresses from being so prone to ignition. Fig. 553 represents an apparatus employed for this purpose; *a* is a conical hopper in which the fecula is put, together with the smalt, indigo, or Prussian blue employed. The mixture passes through numerous holes in this funnel-shaped hopper, and falls upon the

Fig. 553.



first sifter, *b b*, through which it is urged by the revolving brushes, *d*; thence it descends to the second and finer sifter, *c c*, swept, like the other, by brushes, which accelerate the passage of the fecula into the bottom, *e*, of the vessel, and from this it runs by the tubes, *g g*, into sacks or boxes placed for its reception. The brushes are attached to a central shaft, *f*, which is turned by the gearing-wheels in connection with an engine, or other motive power. Sometimes the slight coloration which is given to laundry starch, as sold by grocers generally, is communicated immediately after the first desiccation in the free-air chamber; and the moisture is driven off afterwards in the drying stove.

RICE STARCH.—Within the last twenty years the extraction of starch from rice has received considerable attention in England; and is now extensively practised. It will be seen from the results stated at page 950, that this grain contains more starch in proportion to its other constituents than any other; the gluten, however, is so minutely divided in it that its separation was impossible by the old system of fermentation, and this accounts for the preference so long given to wheat and flour. By the partial use of chemical agents

this difficulty has been overcome, and rice is now extensively employed for the manufacture of starch. Among the several patent processes introduced for this purpose are those of JONES, BERGER, BIERLEY, REHE, and others, who employ either an alkali or an acid for the solution of the gluten.

JONES directs that the rice be steeped in a solution of caustic potassa or soda, containing two hundred grains of alkali to the gallon, using fifty gallons of such lie to one hundred pounds of rice; the mixture is well stirred, and then allowed to digest for twenty-four hours; after which the lie is siphoned off as much as possible, and the grain is washed with twice as much pure water as the liquor drawn over. The grain is then placed upon a drainer, after which it is crushed or ground between stones or rollers, and the coarse flour sifted in an apparatus furnished with brushes. That which refuses to pass through is returned to the mill with a fresh portion of prepared grain, and this process is repeated until the whole, with the exception of the husk, is made to pass through the sieve. The meal thus obtained is treated with a further quantity of the alkaline liquid, the proportions being one hundred gallons to a hundred pounds of the meal, and the action is quickened by frequent agitation of the mass during twenty-four hours; after which it is allowed to repose seventy hours. During this period there is first a deposit of fibrous matter with a little starch; then the starch falls, the chief portion of the gluten, with some other bodies, being retained in solution by the liquor, which is removed by a siphon without disturbing the separated matter. Double the previous quantity of pure water is now poured on the starch, the whole being well agitated, and allowed to rest for an hour, to permit the heavy substances other than starch to fall to the bottom; this done, the milky liquor containing the chief portion of the pure material is drawn over into another vessel, being passed in its course through wire or cloth sieves. A further quantity of water is used to wash the deposited matter, which, being agitated with the liquor as before, the whole is left to rest; and after the crude impurities have fallen, the starchy menstruum is again drawn off. By repeating these operations as often as may be necessary, the separation of the starch is completed; and the fine silk or brass-wire sieves detain any fragments of husk, so that the substance is well purified. All the successive liquors being added to the first, the whole is stirred and then left to settle for seventy hours; after this time if the whole of the starch has subsided, the clear supernatant liquor is drawn off, the deposit is mixed with the necessary quantity of coloring matter, and then treated in the usual way by boxing, draining, and desiccating.

BERGER's process is analogous to that just described; a hundredweight of the rice is steeped during two days, then removed from the water, and after being drained, is crushed or ground to meal, among which as much water is introduced as to give it the consistency of thick cream; in this condition it is passed through a sixty-holed sieve, returning what is too coarse to be further ground. The filtered or sifted mass is now stirred with a solution of seven pounds and a half of carbonate of soda in three and a half

gallons of water; and when the whole has been thoroughly blended, it is allowed to rest during four hours, then agitated again, and the operation repeated at equal intervals till the contact has been prolonged to about sixty hours. After this it is suffered to rest eighteen hours, and at the end of that time the lie containing the chief portion of the albumen is drawn off. A second treatment with a similar lie is succeeded by a washing with large quantities of water, and after allowing the heavy particles to fall, the milky liquor is passed through fine sieves, and the starch further purified by the inclined plane, or by repeated washings and depositions.

By another process, likewise patented, BERGER proposed to prepare the starch of rice by fermentation, the chief feature of which is the steeping of the grain in water for successive periods of four to six days, then grinding in the usual way, and repeating the steeping until the entire gluten has been so far altered by fermentation as to be taken up by the several liquors; the starch is afterwards finished by siftings, washings, *et cetera*.

COLEMAN, in 1841, patented the following method of preparing rice starch by fermentation:—The rice is steeped during five or six days, then drained from the water, and ground in the usual way; the meal reduced to a pulp is mixed in the recipient with a quantity of the refuse of wheat, or other fibrous matter, in the proportion of fifteen pounds of the latter to the hundredweight of rice, and a sufficient quantity of water is added to reduce the whole to a homogeneous mass, which is allowed to rest during ten to fifteen days. The patentee states that by this time the starch will have separated, and may be purified in the ordinary way by washing and sifting.

Another mode for preparing rice starch by the agency of acids is thus described:—The substance after being steeped for four days is drained, and then reduced to a pulp in a mill under a stream of water, which carries it off to a reservoir, where it is allowed to settle, and the water is then separated by a siphon or plug-hole in the vessel. The deposit is then agitated with an acid liquor prepared by adding three quarters or one ounce of ordinary hydrochloric acid with two pounds of rice to the gallon, stirring well the whole mass, and leaving it to stand during five days with agitation at intervals of four hours; finally, eighteen hours are allowed for the substance to deposit, after which time the clear liquor is drawn off, and the operation repeated with a second acid liquor three-fourths of the strength of that first used. When the period mentioned for the final deposition of the starchy mass has transpired, the acid liquor is drawn off as before, and the residue washed with large quantities of water, passing it through sieves as usual to separate the husk and other impurities which may still remain, and finally the mass is drained and dried in the ordinary way.

REHE took out another patent for a method for preparing rice starch, the chief feature of which is, that he submits the rice at first to a temperature of 160° to 180° before steeping; and after the matter is levigated, he employs a stronger alkaline lie—four pounds of soda to a hundredweight of rice—for washing the pulp.

In the subsequent washings, *et cetera*, the treatment prescribed by the patentee is similar to those already mentioned.

RAINSFORD employs hydraulic pressure in conjunction with alkali to extract the fibrinous matter from the rice before grinding, and finishes the product by further treatment with alkaline-water washings, siftings, and the like; he uses pressure also to expedite the operation of expelling the last portions of water from the finished starch.

MAIZE OR INDIAN CORN STARCH.—Of late years maize has been used for the manufacture of starch, and has been found to answer the purpose very well, containing as it does a large per centage of that substance. The principal makers are POLSON and BROWN of Paisley, Scotland, who employ a process patented by the former in 1854. By this method the grain is first steeped either in an alkaline water of the usual strength, or in water only, till thoroughly soaked; it is then levigated in the ordinary way either by rollers or a mill, and the pulp is passed over a sieve, through which the finer portions are forced by revolving brushes, whilst the coarse matter is returned to the mill to be further levigated, and is then sifted again. In this way most of the husk is separated from the flour or starchy portion of the grain, and is economized as cattle food. A stream of water passes in upon the sifting machine, and carries the portion passing through the sieves over an inclined plane, or *run*, the breadth and length of which are proportioned to the work to be performed. In its course the heavier starchy matters subside, and the lighter fibrous substances are carried forward by the stream till they are thrown off. The plane is divided by dams, or pieces of wood laid across it, which intercept the deposited starch, until it accumulates in quantities convenient for removal. Most of the glutinous or fibrinous matter and husk is thus separated, and a starch is obtained which, though not entirely free from nitrogenous and fibrous matter, answers well for ordinary coarse work, having high stiffening powers. It has also been introduced by that firm as an article of diet, and meets with extensive patronage. When a finer kind of starch is to be prepared, the deposit from the plane is treated with an alkaline liquid, by which the gluten is dissolved; and by sifting through a finer texture, washing on the plane, and the other usual manipulations, the starch is obtained perfectly pure.

WATT of Belfast is also patentee of a process for preparing starch from maize, and which in its chief features is similar to the foregoing, with the exception that WATT steeps the grain in repeated changes of water, or in a current, till incipient fermentation takes place, the water being in either case heated between 70° and 140°; after which the matter is drained and ground as usual, with the necessary quantity of water, likewise heated, to reduce it to a creamy consistence. This is then sifted with the aid of brushes, and the coarser portions returned, if necessary, to be again levigated, *et cetera*. The sifted matter is washed and purified either by the inclined plane or in vats, as in the preceding methods.

STARCH FROM MILLET.—A process patented by RICKETT for the extraction of starch from millet,

especially from that kind known as *Dari*, embraces the usual series of operations, namely, steeping, grinding, sifting, and treatment with alkalies, alkaline carbonates, or acids, such as hydrochloric or acetic acids, washing and finishing in the manner already detailed.

STARCH FROM HORSE-CHESTNUT.—HEDENUS and FLAUDIN have proposed to extract starch from the horse-chestnut, in which it is stated to be contained to the extent of twenty-five per cent. The chestnuts are steeped in boiling water, then skinned and grated; the pulp well mixed with soda in the proportion of one per cent. of the chestnuts operated upon; and, after a certain time, the starch is obtained by washing the mass in the ordinary way. The alkali, it is said, thoroughly removes the bitter principle of the nut.—*Richardson and Ronalds.*

ARROW-ROOT STARCH.—This starch, so named from its virtue, as formerly supposed, of curing wounds from poisoned arrows, is extracted from the roots of plants of the *Marantaceæ* of LINDLEY, more especially from those of the *Maranta arundinacea* and *M. Indica*, natives both of the East and West Indies. There are also other plants which afford a starch, designated by the same title and the name of the locality of its production. Such is the Portland arrow-root, extracted from the *Arum maculatum* of the order *Aroideæ*; the Brazilian arrow-root, from the *Jatropha manihot* of the order *Euphorbiaceæ*; East Indian arrow-root, from tubers of the *Curcuma augustifolia* of the order *Zingiberaceæ*; and Tahiti arrow-root, or tacca starch, from the roots *Tacca oceanica* of the order *Taccaceæ*, with many others. Arrow-root is a snow-white powder, and is very much prized as a dietary article, though its estimation in this respect has now considerably diminished. The starch which is contained in cells in the joints of the rhizome or underground stem, is extracted in Jamaica, as PEREIRA states, in the following manner:—The tubers, when about ten or twelve months old, are dug up, well washed in water, and then beaten to a pulp in large, deep, wooden mortars; this pulp is thrown into a large tub of clean water, well stirred, the matter strained, the residuary pulp expressed and thrown away. The milky liquid thus obtained is passed through a cloth or hair sieve, allowed to settle, and the clear supernatant liquid drained off. More clean water is poured on the white deposit, the whole stirred; and, after the deposition of the solid matter, it is drawn off as before. Finally, the deposit is drained and dried on sheets in the sun, when it is fit for commerce.

In Bermuda, and in the Island of St. Vincent, the tubers are carefully deprived of their paper-like scale, as this is said to contain a resinous matter which imparts both a color and a disagreeable flavor to the starch; they are then rasped by a machine, or ground by a mill, and the meal being well washed with pure water through various forms of sieves is ultimately dried. To insure greater purity of the product, URE states that the vessels and cylindrical sieves employed on many of the estates, are constructed of tinned copper; that the scrapers used to remove extraneous matter from the deposit, as well as the shovels with

which it is packed in bags, are made of German silver; and that whilst drying, it is protected from dust and insects by a veil of white gauze.

A method similar to that first stated is followed in the East Indies, for extracting the starch from the roots of the same plant, as well as from the *Curcuma augustifolia*, the product of which is distinguished as curcuma starch, or *tikor*, imported from Calcutta. There are two varieties of the latter, the white and the buff-colored *tikor*, or East India arrow-root, and which can be readily distinguished from the West Indian product, both by its physical properties and by its appearance under the microscope. PEREIRA states that the white *tikor* appears to the eye to resemble a finely-powdered salt, such as bicarbonate of soda; that when pinched or pressed by the fingers, it wants the firmness so characteristic of the West Indian arrow-root. The form of the granules under the microscope he states to be different, the curcuma starch being transparent flattened disks of an ovate, or oblong-ovate shape, having a very short neck, or nipple projection, at one extremity where the hilum is situated; and, owing to the flatness of the grains, they have but little lateral shading, except when viewed edgewise, the lines forming only segments of circles. Both these kinds are used for food, like the West Indian product, to which, however, they are deemed much inferior. Portland arrow-root, or Portland sago, so named from being imported from the island of that name, is prepared much in the same way as the foregoing, namely, by scraping the tubers of the *Arum maculatum*, pounding or rasping them in a mortar or machine, washing with water, straining, *et cetera*. It is a white amylaceous powder composed of exceedingly small granules of a circular, muller-shaped, or polyhedral form, having a hilum in a central depression in the grain. This article is likewise used as a dietary.

CASSAVA STARCH.—Known also as tapioca meal and Brazilian arrow-root, is obtained from the roots of the *Jatropha manihot*, a native of Brazil. The roots contain a powerful acrid poison which is readily extracted by water and destroyed by heat, so that, in the course of the preparation of the starch—a process similar to those already described—the poison is entirely separated. It is imported into England from Rio Janeiro, and appears as a white pulverulent substance resembling the genuine arrow-root. Under the microscope the difference is seen at once, this starch being somewhat similar to the Portland arrow-root in the shape of the granules, though much smaller; the hilum circular and surrounded with rings.

Tapioca.—This substance is the meal from the roots of the above-mentioned plant, scraped, washed, and rasped into flour. Whilst still moist it is dried upon hot plates, by which treatment some of the starch grains swell to bursting, and the amylaceous matter thus liberated cements the whole into small irregular masses. Hence tapioca is partially soluble in water. In boiling water it swells up and constitutes a transparent jelly-like mass.

Tahiti or Otaheite arrow-root is obtained from the tubers of the *Tacca oceanica* and *pinnatifida*, a native of Tahiti and other South Sea islands. It is imported

into London, and sold under the title of *arrow-root prepared by the native converts at the missionary stations in the South Sea islands*. The tuberous roots, which yield a highly nutritious fecula, are washed and scraped to remove the outer skin, then reduced to a pulp by rubbing on a kind of rasp made by wrapping coarse twine from the cocoa-nut fibre tightly round a board, or, as ELLIS states, on a piece of coral; the pulp is then washed with sea-water on a sieve made of the fibrous web that protects the young frond of the cocoa-nut palm. After the deposition of the fecula the liquor is drained off, the sediment made into balls and dried in the sun from twelve to twenty-four hours, then broken up, and the desiccation finished in the sun. This starch has a slight musty odor, though in color it resembles genuine arrow-root. Its particles appear smaller than cassava starch; they are circular, muller-shaped, and polyhedral, having a small circular hilum, and but few and not very distinct rings.

There are a great many other tropical plants from which starch could be extracted, such as the unripe fruit of the plantain and banana, and the tuber of the *dioscorea* or yam, the former of which is stated to afford seventeen per cent. of starch, and the latter nearly twenty-three per cent.

Tous-les-mois.—The starch or fecula bearing this name is allied to the preceding. It is extracted from the tubers of the *Canna edulis*, a native of the West Indies. The seat of its manufacture is principally St. Kitts, whence it was introduced into England in 1836. From the account of Mr. WORDSWORTH, it appears that the plant grows to the height of four feet or more, and yields a tuber three or four times as large as average-sized potatoes. The fecula is extracted to the amount of twelve and a half per cent. of the tubers by rasping and subsequent washings in the ordinary way. Its granules are much larger than any other kind of starch, not excepting that of the potato; and consequently it may be readily distinguished from the latter by the practised microscopist. In bulk it has a satiny, glistening appearance, somewhat resembling potato starch, but devoid of the dead white of the genuine arrow-root.

PEREIRA gives the following as the principal distinguishing characteristics of this and potato fecula:—

1. The particles of potato starch are smaller and more irregular in size than those of *tous-les-mois*.

2. The larger particles of potato starch are more irregular in shape than those of *tous-les-mois*: the latter are more constantly rounded-oblong, or ovate-oblong; the former more oval, often approximating to the shape of an oyster or muscle shell, or a triangle with rounded corners, and frequently gibbous or tumid at different parts of their surface.

3. The rings seen on particles of *tous-les-mois* are fine, regular, uniform, concentric, and crowded; those of potato starch are coarser, irregular, often eccentric, irregularly drawn out, distorted, or more and unequally distant from each other. In potato starch a greater number of complete rings are visible, and may be traced round the hilum even in case of many of the larger rings. With *tous-les-mois* only a few of the smaller rings can be thus distinguished.

4. The hilum is situated nearer to the end of the corpuscle in the *tous-les-mois* than that of fecula.

Lastly, When viewed with polarized light the cross is generally less regular in the potato starch grains than in those of the *tous-les-mois*.—*Pereira*.

SAGO.—This is the title of a starch extracted from several varieties of palms very common in Sumatra, Borneo, and other islands of the Indian Archipelago; the word is derived from the Malay name, *sagu*, for the palm and the farina itself. The genuine sago is imported into England from Singapore in large quantities, but a fictitious kind is made at home in many of the starch manufactories from fecula and wheat starch. The real plant which affords the sago is still undefined, for several of the species are known to yield it, those of the *Sagus* and *Sagurus* being the most important. The *Sagus rumphii*, *Sagus inermis*, *Metroxylon sagus*—the *rambija* of the Malays—*Corijota urens*, or sago palm of Assam, *Borassus gomuto*, and a few others are the most resorted to, together with several species of *Zamia*, *Corypha*, and *Mauritia*. In most of these trees the pith is so abundant as to constitute a great part of the bulk of the entire stem, which from its rapid growth often attains to a thickness of a foot or more in diameter in the course of six or seven years. From such a tree it is stated that as much as three hundred-weight of sago can be obtained.

The method adopted for extracting the medullary matter from the tree and separating the starch from it is somewhat different from that followed in preparing arrow-root starch; but the mode of preparing the sago bears so much resemblance to the European system of preparing grain starch, that it will be unnecessary to enlarge upon it in detail. In the Moluccas, the tree when sufficiently matured is cut down near the root, and then divided into portions averaging seven or eight feet in length, which are split open and the pith extracted. By various means—such as pounding in a mortar, *et cetera*—this substance is reduced to a coarse powder, which is agitated with water and submitted to the usual siftings and washings; the farina is then allowed to deposit, and on drawing off the fluid and drying the residue, the *raw sago meal* is obtained. From this the granulated and pearl sago is prepared, after submitting it to a bleaching process preparatory to granulation. To bleach it, the sago meal or flour, mixed with water to the consistence of cream, is exposed in close vessels to the agency of sulphurous acid or chlorine, or to a solution of hypochlorite of lime or soda, and afterwards well washed; a little sulphuric acid being mixed with the washing water when the hypochlorite is used.

In New Guinea the granulation is performed by making a paste of the sago meal with water, and passing this through a sieve into a very shallow iron pot placed over a fire. The particles on being heated assume a globular form. BLUME states that the same method is followed in Singapore by the Chinese, only that during the heating the particles are constantly stirred and turned; he adds, that though the material is quite white at the commencement, it gets hard and somewhat pellucid during the process. PEREIRA says that the tapioca sago of GUIBORT is submitted to the

action of heat, but so well managed is the operation, that none of the substance is in the least charred. He adds that some of the sago of the shops presents no appearance of having been heated, and in this case it is supposed that the granulation is effected by a mill. Two kinds of granulated sago are known in commerce—the common brown or red, and the white or pearl sago. The color is attributed by PLANCHE to the red matter contained in the variety of palms from which the starch is extracted, and by the application of the heat required for granulation altered to a grey, which is the usual color of unrefined sago. Formerly the imported article presented a great inequality of aggregation, varying from very small grains to that of pearl barley or peas, the substance being, however, identical in both, and evidently composed of cemented particles of sago meal. Pearl sago dates from a recent period; CRAUFORD, whose account of it was the first published, states that the method of manufacturing it was discovered by the Chinese of Malacca, a few years previous to 1820, the year in which he wrote. It is met with in pearl-like grains of an irregularly globular form, ranging from the size of a poppy to that of white mustard seed or a little larger. The surface of the larger grains is generally smooth and even, but that of the smaller kinds is uneven and somewhat tuberculated. Under the microscope, the particles of this variety present the same appearance as that of the colored product and sago meal, except that the most of them appear ruptured from the action of the heat. Sago when granulated possesses the property of considerably swelling in hot water or other liquids, without losing its adhesive power; hence the grains appear translucent and gelatinous, but not as slimy globules. The following table by PLANCHE exhibits the quantity of water which the different varieties of sago met with in commerce take up in softening, as also the chief distinctions of the farina itself:—

Source.	Color.	Water absorbed in softening, Per cent.
Maldines,....	Grains, mostly red, some white,...	150
Sumatra,....	Grains, white or dirty-white,....	134
New Guinea,	Grains, brick-red or lighter,....	121
Moluccas,....	Red variety,.....	130
Do.,	Grey,.....	109
Do.,	White,.....	164

Of late years, more especially in Germany and France, considerable quantities of artificial or fictitious sago have been manufactured from inferior starches, such as fecula. The process is simple, consisting merely of submitting the starch after air-drying to a temperature of 212° on iron plates, and thus causing the granules to swell to such a degree that some of them burst, when the gummy matter forms a cement that envelopes other granules. Care must be taken that the heat does not rise so high as to discolor the matter by partial charring, which would be highly detrimental. After the heating the mass is passed through a mill, or sifting and rolling machine, by which it is reduced to the globular form of pearl sago. When dry wheat or potato starches are operated upon, a previous moistening is necessary in order to incorporate as much water as will facilitate the swelling and fracturing of the granules at the comparatively low heat necessary to insure its cementation.

DERIVATIVE PRODUCTS FROM STARCH.—Two products are obtained from starch which are very extensively employed, not only by themselves, but also for the production of other substances of considerable importance. These are *dextrin* and *glucose*, of each of which it will be necessary to give a short account.

Dextrin.—This substance has been briefly described under the term BRITISH GUM in Vol. II., page 313; but its importance deserves that some further details should be given here. It is a substance immediately produced from, and isomeric with starch, and is so called from its property of diverting to the right a ray of polarized light transmitted through its solution. It is soluble in water and in dilute spirit of wine, but insoluble in absolute alcohol. A solution of iodine does not alter its color in solution, except when the transformation of the starch is incomplete, in which case it produces a violet, shading off to a red tint. When the colorless solution of this substance in hot or cold water is evaporated, a viscous mass is obtained, which, on being dried, yields the dextrin in a mass somewhat resembling gum-arabic; it is similar also in its properties, so much so that in many applications it is substituted for gum-arabic at a great saving; and hence the trade that has sprung up of late years in this substance under the title of British gum, *leïocomme*, *et cetera*. It does not, however, like gum-arabic, yield derivatives, such as mucic acid and the like, when treated with nitric acid and other agents, and in this respect a marked chemical distinction is established between the two substances. On the methods resorted to for its preparation, the Editor has nothing to add to the details given at the page above referred to.

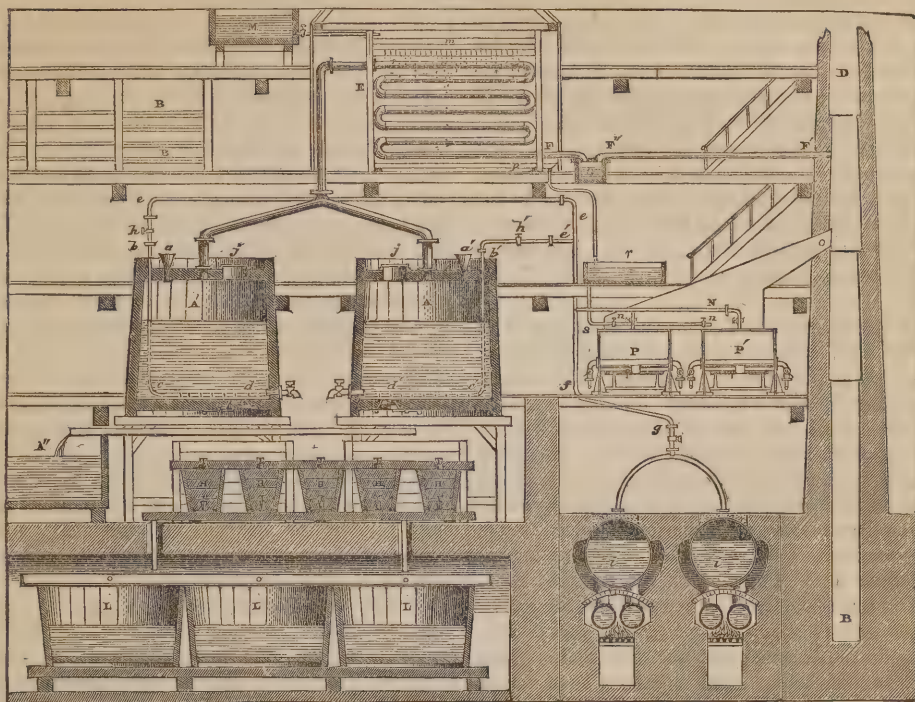
Glucose.—In starch factories, especially on the Continent, a considerable quantity of starch or potato fecula is converted into glucose—a species of sugar which is found in many kinds of fruit, especially the grape, and into which all other varieties of sugar, whether it be the product of the cane, maple, or beet, is readily resolved by the action of acids and other chemical agents. The chief use to which glucose is applied on the Continent is for the manufacture of beer, and a coarse kind of alcohol, which is said to be extensively converted into French brandy by the addition of oil of raisins, coloring matter, *et cetera*. There are two methods by which the starch; or rather dextrin, is converted into glucose; the one is well exemplified in all the breweries and distilleries of the kingdom, where thousands of tons are annually formed in the preliminary stages of malting and mashing; the other consists in the use of sulphuric acid, which is a more expeditious method, and gives a purer product than when the conversion is effected by means of diastase. The process is naturally divided into six stages, namely, the conversion of the starch into dextrin, the saccharification of the dextrin, the settling of the liquid, the evaporation, the filtration, and the concentration. PAYEN describes the apparatus and operations connected with it as follows:—

The saccharification of the starch is effected in large tubs or vats, A A'—Fig. 553—constructed of stout wood, to contain two thousand eight hundred gallons. In one of these, A', a lead pipe, *b c d*, coiled at the bottom, is placed, the circular portion being cut or

perforated for the introduction of steam to heat the acidulous water with which it is two-thirds filled; the steam from the generator, *i*, is admitted to it at plea-

sure by means of the pipe, *b f e g*, and stopcock, *h*. During the operation the vat is covered, and the disengaged vapor conducted to the chimney, *B D*; but

Fig. 553.



before escaping it may be utilized in evaporating the sirup by conveying it through serpentine pipes, *E*, *F*. By such arrangements the disagreeable odors resulting from the evaporation of the oil of the starch are considerably abated, being partly condensed in the serpentine pipe, so as to flow off with the water produced from the steam into a vessel interposed between the pipes, *F*, *G*, and partly carried away by the pipe, *F'*, *F''*; or the uncondensed vapors may be conducted into the fire where any remaining traces of essential oil are consumed, and thereby the nuisance is almost entirely prevented.

When it is proposed to convert two tons of fecula in such an apparatus, the substance is suspended in portions of two hundredweight in a trough or tub, with twenty-two gallons of water, and when thoroughly steeped, it is introduced by a funnel, *a*, in quantities of four to five gallons at a time, into the large tub or vat, which should be previously charged with about thirty-two barrels of water, and three quarters of a hundred of sulphuric acid agitated with it, the whole being raised to 212° by forcing steam into it. This temperature is maintained till all the fecula is introduced, and it is found that the transformation is accomplished in thirty or forty minutes after the last portion of the starch has been added. The point at which the change is completed is easily ascertained by simply testing a few drops of the clear liquid with a drop of a solution of iodine, when, if the saccharification be effected, no coloration takes place; in the contrary case the cha-

racteristic violet of iodide of starch manifests itself. After the conversion into glucose, the introduction of the steam is suspended, and the next operation is the saturation of the free acid by means of carbonate of lime, and the consequent precipitation of sulphate of lime. The latter being but sparingly soluble, most of it falls to the bottom. It requires from ninety to a hundred pounds of chalk to saturate the whole of the free acid; and this must be introduced gradually to guard against the evolution of too much carbonic acid at once. If an excess of lime be used, it prevents the solution from clarifying so readily as when the sulphuric acid is barely taken up; this is shown by the cessation of effervescence, and the inability of the liquid to change the blue color of litmus to more than a feeble purple tint. When the saturation is completed, the mixture is either permitted to repose in the same vessel, or if it be required to operate upon another batch at once, it is drawn off into the lower vat *A''*, where it is left at rest during twelve hours; the clear liquid is then racked through coarse bone black in the filters, *H*, *H*, the deposit of sulphate of lime being also thrown upon cloth filters, where it is drained and washed. The sirup as it flows off from the filter, having a density of 1.11 to 1.122, is retained in the reservoirs, *L*, *L*, *L*, from which it is raised by a pump or a chain of buckets to the reservoir *M*; from this it is distributed in a horizontal channel, *m*, by numerous lateral apertures upon the serpentine evaporator, *E*, *F*, and then flows by a channel, *p*, and tube, *q*, into

a receiver, *r*, whence it can be drawn at will by the tube, *s*, and stopcocks, *n, n*, into the boilers, *P, P'*, which are heated by steam, and in which the liquid is concentrated to 1.26 specific gravity. The sirup thus obtained, after reposing a sufficient time to allow the sulphate of lime precipitated by the evaporation to subside, is fit for the brewer or distiller; but if intended for the confectioner or liqueur-maker it should be allowed to rest for twenty-four hours, filtered when cold through coarse bone black, and casked immediately. When it is desired to obtain the glucose in a solid state, the evaporation is carried so far as to concentrate the sirup to 1.38 or 1.39 specific gravity—73° to 74° Twaddell; it is then poured into the cooler, where it is left till the crystallization commences, and thence transferred to the tuns in which the solidification is effected.

Of late years, instead of preparing the sugar in an amorphous solid mass, as by the preceding method, it is obtained in grains or regular crystals. The process for converting the starch into sugar is the same as that already described; but care is taken to do it more thoroughly, since any excess of dextrin in the sirup is found to prevent crystallization. After the acid has been neutralized, and the lime salt removed by deposition, *et cetera*, the saccharine liquid is decolorized, and concentrated to 1.300, or 60° Twaddell, in summer; and 1.262 or 53.5° Twaddell, in winter. At these stages it is racked off into large reservoirs where the lime salts settle down; and during this period it is necessary, in order to prevent any fermentation, that the liquid be cooled either by circulation of air or of cold water in a coil placed in the vessel. After thirty-six to forty hours, the sirup, being clarified and cooled to about 65°, is put to crystallize in ordinary tuns furnished with a false bottom placed over the lower one, which is pierced with a number of holes that are stopped with wooden pegs. These tuns are placed on stages along the walls of the room, twelve to fifteen inches above the floor. A sheet of lead, or large canal or sluice, reaches along each range of crystallizing tuns. To avoid the fermentation of the sirup, which in summer often prevents the crystallization, six or seven ounces of sulphurous acid solution are added to the content of each tun. At the end of eight or ten days the crystallization commences and goes on, the crystals depositing in succession. When the bulk of two-thirds of the liquid becomes a mass of crystals, the pegs in the lower bottom are withdrawn, and the still fluid portion is permitted to drain off, the operation being quickened towards the end by tilting two adjoining tuns against one another. The drainings are conducted to the converting tun, where any dextrin the liquor may still contain is saccharified.

The desiccation of the drained sugar was long a work of difficulty, the moisture of the air being sometimes sufficient to convert it again to sirup, which, with the heat of the factory, melted and agglomerated the remaining portion. M. FOUCHARD has obviated these inconveniences by furnishing the tuns or tubs, *R R*, with tables of plaster of Paris, which absorb the portion of the interposed sirup. This very much quickens the desiccation of the crystals, especially in

a current of air heated to 77°, taking care that the granules are not thereby soldered together. There is, however, a certain amount of the crystallized mass which has to be submitted to a second solution, namely, that which is agglomerated on the end of the loaf resting on the plaster; this must be separated, and the sugar extracted from the sulphate of lime, by grinding them between cast-iron cylinders, and dissolving in the ordinary way.—*Payen*.

Glucose crystallizes in grains formed of a number of lamellar plates radiating from a common centre, and thus forming a kind of bristling spheroid of lamellar points. It has only one-third the sweetening power of cane sugar, whilst it is once and a half less soluble; at 212° it melts in its water of crystallization, which characteristic allows of its recognition when in certain proportions in cane sugar. It may also be detected by the property which glucose possesses of forming definite compounds with alkaline and earthy bases, which compounds suffer decomposition, and become strongly colored brownish, at a temperature between 160° and 212°, which is not the case with cane sugar under like circumstances.

Glucose is composed of $C_{12}H_{12}O_{12}$, 2HO, differing from starch, $C_{12}H_{10}O_{10}$, only by an addition of two equivalents of the elements of water, and two equivalents of the water of crystallization, with which, however, it parts when carefully exsiccated, leaving the compound of the composition $C_{12}H_{12}O_{12}$.

STRONTIUM.—Although less abundantly diffused, it resembles barium both in its chemical and geological relations. Like it strontium is never found native, but only as *carbonate* and *sulphate*. It was first recognized by HOPE in 1792, in the mineral *strontianite*, so called from Strontian in Scotland.

Pure strontium was first made by BUNSEN and MATTHIESSEN in 1855; impure by DAVY in 1807. It is prepared by electrolysis from chloride of strontium. It is a golden-yellow metal, of considerable metallic lustre, harder than lead, and ductile. It melts at a red heat. Heated in air, it inflames and burns with a bright lustre in oxide. In dry air it remains untarnished; but it decomposes water, even at ordinary temperatures, with singular vehemence. Fuming nitric acid does not attack it; but dilute acids oxidize it readily. It burns in chlorine, iodine, bromine, and sulphur atmospheres, producing the corresponding compounds. Strontium has a specific gravity of 2.542, and an equivalent weight of 44. It is only in a strictly scientific light that this metal and its compounds are of any importance, excepting the chloride and nitrate, which are much used by pyrotechnists. The chemical symbol of the metal is Sr.

A few of its principal compounds are briefly described in the following:—

OXIDE OF STRONTIUM.—*Strontia*.—This base is most easily obtained by igniting the nitrate. It is greyish-white, and of specific gravity 3.932. It is neither fusible nor volatile. For water it shows powerful affinity, and forms a *hydrate*. This is soluble in fifty times its weight of cold, and 2.4 parts of boiling water. From the latter it separates in crystals belonging to the square prismatic system. Nine equivalents

of water are easily expelled by heat; but it requires a temperature approaching white heat again to render the hydrate anhydrous. Both strontia and its hydrate readily absorb carbonic acid. The symbol of strontia is SrO , and the equivalent 52; the symbol of the hydrate is $\text{SrO}, 9 \text{HO}$.

CARBONATE OF STRONTIA is found native as strontianite, both massive, and in forms belonging to the square prismatic system. It is most readily prepared pure by precipitating the nitrate or chloride with carbonate of ammonia. The artificial carbonate is beautifully white and soluble in one thousand five hundred and thirty-six parts of boiling water. It is more soluble in aqueous solution of carbonic acid, and separates in needles when evaporated. Heated to bright redness in a stream of watery vapor it loses its carbonic acid, and becomes changed into strontia. The symbol is SrO, CO_2 ; Eq. 74.00; specific gravity, 3.605.

SULPHATE OF STRONTIA is the *celestine* of mineralogists. Sometimes massive, it is often found beautifully crystallized in prisms isomorphous with sulphate of baryta. Artificially it may be prepared by precipitation from any of its soluble salts, either by sulphuric acid or a soluble sulphate. It has the form of a white tasteless powder, soluble in fifteen thousand parts of cold, and three thousand eight hundred and forty parts of boiling water. In solutions of common salt it is slowly but completely soluble. A solution of sulphate of strontia precipitates salts of baryta. The symbol is SrO, SO_3 ; Eq. 92.00; specific gravity, 3.95.

NITRATE OF STRONTIA separates from concentrated solutions in transparent colorless octohedra, soluble in five parts of cold, and half their weight of boiling water; insoluble in alcohol. It has a sharp, cooling taste, and decrepitates in the fire, leaving strontia. At low temperatures it crystallizes out from more dilute solutions with five equivalents of water. Nitrate of strontia is much used by pyrotechnists to produce a splendid crimson flame. A mixture of forty parts of the nitrate, five of chlorate of potassa, thirteen of sulphur, and four of the sesquisulphide of antimony, is found a good one in practice, but *great care* is necessary in the admixture. The symbol is SrO, NO_3 ; Eq. 106.00; specific gravity, 2.704.

On the large scale the nitrate is prepared by heating pounded celestine with one-third of its weight of bituminous coal, dissolving the resulting sulphide in water, and decomposing with dilute nitric acid.

CHLORIDE OF STRONTIUM is in long, six-sided needles, deliquescent in moist air, and soluble in three-quarter parts of cold water. It imparts an intense crimson color to flame. In alcohol it is also soluble. When heated, the chloride melts and becomes speedily anhydrous. Ignited in air, it loses chlorine and absorbs oxygen. The chloride of strontium is most easily prepared by dissolving the sulphide in water, and decomposing with hydrochloric acid. The symbol for the salt is $\text{SrCl}, 6 \text{HO}$.

General Character of the Salts of Strontia.—They are colorless; not poisonous, like most of those of barium. Before the blowpipe they communicate a crimson color to flame. Neither hydrofluosilicic acid nor

hyposulphite of soda precipitates them. The chromate of strontia is sufficiently soluble to be employed as a test for baryta; but oxalic acid produces immediate turbidity in them. On addition of sulphate of lime to a solution of a salt of strontia, there arises gradually a white precipitate of sulphate of strontia; immediately when heated.

Strontia is always determined in analysis as sulphate or carbonate; one hundred parts of the former contain 56.52 of strontia, and of the latter 70.27 parts of this base.

SUGAR.—*Sucre*, French; *Zucker*, German; *Saccharum*, Latin.—Sugar seems to come more directly from the Persian *Shukkur*, which is nearly the same as the English pronunciation. The Arabic name is similar, and the probable origin of both is said to be the Sanscrit *Sarkara*. In the old Assyrian and Phœnician languages there was no letter *k*, but both nations called the substance *suicar* or *suicra*. It is said by HUMBOLDT to have been known in very early times in China. It is probable that in early historic times it was brought as a luxury and a curiosity into Western Asia and Europe. The Hebrew word for being intoxicated is *Shacar*, and strong drink *Shecar*. These words were believed to have an intimate connection with sugar; but this could only occur in a country where sugar was so well known that its ready passage into alcohol was familiar. Such was not the case in Western Asia or Syria and the surrounding countries in known times, although it may have been so at an earlier period. In the Bible is mentioned *sweet calamus* two hundred and fifty shekels; and *calamus* and *cinnamon* in SOLOMON'S Song; *sweet cane* in ISAIAH, and in JEREMIAH and EZEKIEL. There is little difficulty in believing the scriptural writers to be the earliest who allude to sugar. Persons in frequent communication with the East were sure to obtain its products before the Greeks. HERODOTUS speaks of manufactured honey, supposed to mean sugar; and STRABO mentions that NEARCHUS, one of ALEXANDER'S admirals, speaks of a reed which yields honey without bees in India. THEOPHRASTUS mentions it as a honey obtained from a reed which grew in moist places in Egypt, and had a sweet root. This sweet root has been used as a proof that he did not allude to the cane. The mention of moist places also is an objection; but so many canes do grow in moist places that one readily forgives this error and others, seeing that the fact of sweet matter from a cane is so distinctly spoken of. THEOPHRASTUS speaks of honey from reeds, evidently cane sugar. ERATOSTHENES alludes to roots in India sweet to the taste even when boiled, as if it were the custom to boil them to remove the sugar. VARRO speaks of the juice of an Indian root so sweet that, when pressed out, no honey can contend with it. DIOSCORIDES says that there is a kind of honey called *saccharus* which is found in reeds in India and Arabia Felix, having the appearance of salt; but it was only used in medicine. If found in Arabia it might well have been known early in Syria. PLINY says that there is a kind of honey which collects in reeds, white like gum, and brittle to the teeth; the larger pieces about the size of a filbert, and only used in medicine. STATIUS speaks

of boiling canes in Ebosita; but that place is not known. ARRIAN mentions it as an article of Indian commerce; and ÆLIAN speaks of it as pressed from reeds on the Ganges. It is well to add that Dr. ADAM, the learned editor of Paulus Egineta, says that the saccharum of THEOPHRASTUS, DIOSCORIDES, GALEN, STRABO, and PLINY was a concretion formed on various reeds, but especially on the bamboo cane; also, that MOSES CHORENENSIS, fifth century, first mentions the boiling of canes. This may account for the bitterness and medicinal qualities mentioned by DIOSCORIDES and others. ALBERTUS AGNENSIS relates that the crusaders found sweet honeyed canes in great quantity in the meadows near Tripoli in Syria, which reeds were called Zucra. These the crusaders sucked, and were much pleased with the sweet taste of them, with which they could scarcely be satisfied. This plant is cultivated, the author states, with great labor of the husbandmen every year. At the time of harvest they bruise it when ripe in mortars, and set by the strained juice in vessels, till it is concreted in the form of snow or of white salt. This, when scraped, they mix with bread, or rub it in water, and take it as pottage; and it is to them more wholesome and pleasing than the honey of bees. The people who were engaged in the sieges of Albaria Marra and Archas, and suffered dreadful hunger, were much refreshed thereby. Again, JACOBUS DE VITRIACO mentions reeds full of honey in Syria, pressed out by a screw and concreted by fire. WILLERMUS TYRENSIS speaks of it as being an article of export from Tyre; it seems to have at that time spread over all the Levant, and in the time of the Emperor BARBAROSSA it was made in Sicily, and used both solid and as a sirup. Sugar is said to have been imported into Venice as early as 991. It was brought from Sicily and Egypt—cheaper from Sicily—in the twelfth century. In 1166 WILLIAM II. gave a mill for grinding sugar canes to the monastery of St. Bennet. It travelled into Valencia, thence to Granada and Murcia. About 1420 the Portuguese took it to Madeira and Spain, and to the Canaries. Thence, says Dr. MOSELEY, the cultivation of the sugar cane and the art of making sugar were extended by different nations of Europe to the West Indian islands and the Brazils.

In 1518 there were twenty-eight sugar works established by the Spaniards in Saint Domingo; and HAWKINS brought some of the sugar to England in 1563. Antwerp had exported it about the same time—1560. The English planters were realizing great wealth in Barbadoes in 1650, although the Portuguese supplied the most of Europe then with Brazil sugars.

The name sugar is used in the arts to denote certain substances in the vegetal and animal kingdoms, whose chief characteristics are a sweet taste and the power of undergoing, either directly or indirectly, vinous fermentation, that is, of splitting up under the influence of yeast almost wholly into carbonic acid and alcohol. Four principal kinds of sugar are known, namely, cane-sugar, so called from the fact that its chief source is the sugar cane, though it is found in large quantities in other plants, such as the stalks of maize or indian corn, the maple, birch, palm, the beet-root, carrot, turnip, and in a large number of

tropical fruits; fruit sugar is that to which acidulous fruits owe their sweetness, and hence its designation; it does not crystallize, and exists in large quantities in treacle. The third variety is called grape or starch sugar, owing to its being found in ripe fruit, such as dried raisins, figs, and the like, or from the fact that it may be produced in quantities from starch; and the fourth kind, called milk sugar, is exclusively found in the lacteal fluid of animals.

A remarkable feature in all these varieties of sugar is, that two of the three elements of which they are composed, namely, hydrogen and oxygen, are so proportioned as to constitute water, or, in other words, that they contain the same number of equivalents of these elements. This fact has led to sugars being designated *hydrates of carbon*; but from such terms it is not to be understood that the hydrogen and oxygen really exist as water, but rather that their combination, in the proportion in which they are found in the sugar admits of the expression. The composition of the different kinds of sugar varies only in the elements of one or more equivalents of water; to which fact may be attributed the readiness with which one species is changed into another, merely by the assimilation of that liquid. This feature in the composition of sugars extends to other substances not possessing the same properties, but readily convertible into particular kinds by certain chemical operations, such as the several starches, dextrin, inulin, gum, and several others. The following tabular view of the chemical composition of the sugars and a few of the above mentioned substances will at once exhibit the great analogy in composition between the two classes of bodies:—

Name.	Composition.
Cane sugar, or sucrose,	$C_{24} H_{22} O_{22} = C_{12} H_{11} O_{11}$
Fruit sugar, or fructose,	$C_{12} H_{12} O_{12} = C_{12} H_{12} O_{12}$
Starch sugar, or glucose,	$C_{12} H_{12} O_{12}, 2 HO = C_{12} H_{14} O_{14}$
Milk sugar, or lactose,	$C_{24} H_{19} O_{19}, 5 HO = C_{12} H_{12} O_{12} \times 2$
Manna sugar, or mellitose, ...	$C_{24} H_{24} O_{24}, 4 HO = C_{12} H_{14} O_{14} \times 2$
Starch and gum group.	
Starch,	$C_{12} H_{10} O_{10} = C_{12} H_{10} O_{10}$
Dextrin,	$C_{12} H_{10} O_{10} = C_{12} H_{10} O_{10}$
Inulin,	$C_{24} H_{21} O_{21} = C_{12} H_{10} O_{10} \times 2 + H O.$
Gum,	$C_{12} H_{11} O_{11} = C_{12} H_{11} O_{11}$
Cellulose,	$C_{12} H_{10} O_{10}$

From a comparison of the formulas in the foregoing table, it will be observed that the amount of carbon in the several varieties remains the same, but that the elements of water present slightly vary, and to these their distinct and diverse properties is to be attributed.

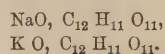
CANE-SUGAR. — *Common sugar* is manufactured chiefly from the sugar cane, but large quantities are prepared also from the sap of the maple tree and from beet-root.

Preparation.—To make pure cane-sugar the same course of operations should be followed as will be described in preparing and refining sugar, each being executed with greater care and attention; hence it will be needless to detail the process here.

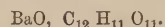
Properties.—Cane-sugar when pure, as in the finest lump, has a glistening white appearance, resulting from the multifarious reflections and refractions of light from the numerous congeries of small crystals composing it. When a very concentrated solution of this substance is left to crystallize spontaneously, it forms rhomboidal prisms with dihedral summits of considerable dimensions, especially if the nuclei be transferred repeatedly to concentrated menstrua. Thus crystallized it forms the sugar candy of the shops, and appears transparent. According to PLAYFAIR and JOULE its specific gravity is 1.594. It is soluble in about one-third of its weight of cold, and in all proportions in boiling water, forming in either case transparent colorless sirups. A solution saturated with sugar at 212° deposits a part in crystals—the candy already mentioned—on cooling. If the temperature at which the saturation is effected be raised to 230°, the whole forms a concrete granular mass when allowed to cool. This is not the case when the sirup is rapidly boiled down to the same density; for then it congeals on a cold surface in a transparent amorphous mass, which on exposure becomes opaque, owing to a fibrous crystallization radiating from the surface inwardly. In this state it is ordinarily called *barley sugar*, the change from the crystalline state being due to a dimorphism caused by the heat, analogous to that which sulphur exhibits under almost similar circumstances. Continuous boiling of a weaker sirup has a like effect. The same change, from the crystallizable to the noncrystallizable modification is effected in the cold by the prolonged contact of dilute mineral acids. Noncrystallizable cane-sugar has the composition $C_{12}H_{11}O_{11}$, HO. It is gradually converted by long-continued contact with water, especially in the presence of acids, without undergoing any chemical change, into glucose or grape-sugar— $C_{12}H_{12}O_{12}$, 2 HO—a substance which crystallizes in acicular tufts. Dilute alcohol of specific gravity 0.830 takes up about a quarter of its weight of sugar. Absolute alcohol dissolves a small quantity of it at the boiling point, but deposits it again on cooling. When the crystals of candied sugar are broken, a slight phosphorescence is discernible, and a similar phenomenon is produced on rubbing two pieces of lump sugar together. Heated to 212°, no further effect is produced on crystallized cane-sugar than the expulsion of the mechanical moisture contained in its interstices. At 320° it melts; and though not decomposed, still, as PROUT remarks, several of its characteristics are destroyed. Between 320° and 350° the liquid mass becomes transparent on cooling, though, from circumstances such as those mentioned in reference to barley sugar, the transparency is destroyed after some time. At 410° it changes to an orange-yellow, afterwards to a reddish-brown hue; and if this heat be maintained, it is converted into a new acid compound of a brownish color very soluble in water—*caramel*—with the loss of three equivalents of water. If the heat be further increased, complete decomposition takes place, with evolution of inflammable gases mixed with carbonic acid, pyrogenous oils, and acetic acid; and a carbonaceous residue, forming about

a quarter of the weight of the original substance, remains.

Cane-sugar combines directly with the oxides of the alkalies and of the alkaline earths, forming with them sugarates—improperly called sometimes saccharates; and also with certain salts, particularly with chloride of sodium. The potassa and soda compounds, which are both unstable and indefinite, are obtained as sirupy liquids on adding a strong aqueous solution of the alkali to a solution of sugar in alcohol. Their compositions are—

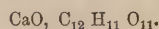


Sugarate of baryta is formed by dissolving one part of caustic baryta in three parts of hot water, and adding the solution to a sirup containing two parts of sugar and four parts of water. A mass of crystals is thus obtained resembling boracic acid, and having the composition—



Sugarate of baryta is difficultly soluble in water, and is decomposed by almost all acids into the corresponding baryta, salt and sugar. Even the carbonic acid of the air effects this change.

There appear to be three sugarates of lime, of which however the most definite and important has the composition—

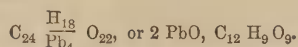


This is formed on adding milk of lime to sirup, in the proportion of two parts by weight of lime to thirteen of sugar. After filtration the sugarate of lime is precipitated by alcohol. On drying, this body appears frangible and resinous, and is very soluble in water. This compound has the rare property of being precipitated from its aqueous solution by heat, and of redissolving as it cools. The amount of lime which a sirup takes up is less according as the density of the sirup is greater. The following table constructed by PELIGOT shows this relation—

Quantity of sugar dissolved in 100 parts of water.	Density of sirup.	Density of sirup when saturated with lime.	100 parts of residuo dried at 120° contain	
			Lime.	Sugar.
40.0	1.122	1.179	21.0	79.0
37.5	1.116	1.175	20.8	79.2
35.0	1.110	1.166	20.5	79.5
32.5	1.103	1.159	20.3	79.7
30.0	1.096	1.148	20.1	79.9
27.5	1.089	1.139	19.9	80.1
25.0	1.082	1.128	19.8	80.2
22.5	1.075	1.116	19.3	80.7
20.0	1.068	1.104	18.8	81.2
17.5	1.060	1.092	18.7	81.3
15.0	1.052	1.080	18.5	81.5
12.5	1.044	1.067	18.3	81.7
10.0	1.036	1.053	18.1	81.9
7.5	1.027	1.040	16.9	83.1
5.0	1.018	1.026	15.3	84.7
2.5	1.009	1.014	13.8	86.2

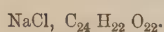
The hydrated oxide of copper is dissolved by a mixture of sugar and sugarate of lime, an amorphous double sugarate of lime and copper being formed. The sugarate of lead is not strictly an analogue of the previously described metallic compounds of sugar, which are formed by the direct union of the sugar with the metallic oxide. Sugarate of lead is sugar in

which four atoms of hydrogen are replaced by four atoms of lead—



It is produced as a gelatinous precipitate on mixing an ammoniacal solution of acetate of lead with a solution of sugar. After washing with cold it is dissolved in hot water, and allowed to stand closed from the air. The compound gradually separates out as white crystals. Massicot also gradually combines with sugar, forming the same compound, water being liberated at the same time.

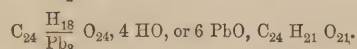
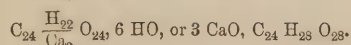
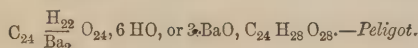
The chloride of sodium likewise combines directly with cane-sugar. If four parts by weight of sugar and one part of chloride of sodium be dissolved together in water, and allowed to evaporate spontaneously, the excess of sugar first crystallizes out; the mother-liquor, on further evaporation, deposits crystals which deliquesce in moist air, of the composition, according to GERHARDT, of—



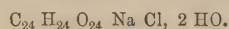
GLUCOSE, or grape-sugar, occurs in raisins, currants, and other dried ripe fruits, and in flowers. It occurs also in honey and in the urine of patients affected with diabetes, accompanying in all the above cases non-crystallizable cane-sugar. It is found also in the blood, the bile, and in eggs. Both starch and cellulose are converted into glucose by digestion with dilute sulphuric acid. The substance which appears near the germinating point at the time of germination of the cereals, called diastase, or in its crude and impure form, yeast or barm, has also the power of transforming starch into grape-sugar, for there is no evidence to show that the substance which changes starch to glucose, is other than that which changes glucose into alcohol and carbonic acid.

Aqueous alcohol dissolves all these kinds of sugar, cane-sugar, grape-sugar, and noncrystallizable sugar, in proportions greater according to the degree of dilution of the alcohol. Absolute alcohol dissolves the non-crystallizable sugar alone. This behavior is made the basis of a method of assaying sugars, as will be shown further on.

For further particulars concerning the properties and composition of this substance, see article STARCH—sub-heading *Glucose*—page 962. Glucose, like *sucrose* or cane sugar, combines with the metallic oxides to form the following glucosates—



It also combines with chloride of sodium forming—



Glucose forms with sulphuric acid a copulated acid whose salts are both unstable and incompletely examined. With nitric acid a detonating compound is produced. Mannite forms with nitric acid a similar detonating body.

MANNITE— $C_{12} H_{14} O_{12}$ —called also the sugar of mushrooms, is chiefly extracted from manna, an exudation from the *Fraxinus rotundifolia*; it is also found in celery, dog's tooth, fennel, *et cetera*, and in algæ. Mannite is one of the products of the fermentation of starch and glucose; it is produced in the transformation of starch into glucose by dilute sulphuric acid. It is readily obtained from manna by boiling it with strong alcohol; on filtering and allowing the filtrate to cool, it crystallizes out, and is purified by recrystallization from alcohol. Mannite does not readily ferment. Owing to this, it may be freed from the other sugars by submitting the liquid which contains them all to fermentation, and extracting the mannite from the unfermented residue. It is supposed that the gradual loss of sweetness effected by time on wine is chiefly due to the slow transformation which the mannite they retained after the first fermentation undergoes. Direct experiments have shown that mannite does suffer such a fermentation.

Sugar of Milk— $C_{24} H_{20} O_{20}$, 2 HO—otherwise called lactine or lactose, occurs in the milk of the mammiferæ, from which it is extracted by precipitating the caseum by a dilute acid, filtering, and evaporating to dryness.

Sorbine— $C_{24} H_{24} O_{24}$ —is found in a few plants.

Mosite— $C_{24} H_{24} O_{24}$, 4 HO—occurs in the juice of flesh, it is very soluble in water; insoluble in alcohol and ether; at 212° it loses four atoms of water.

Cane-sugar, both crystallizable and noncrystallizable, and glucose, are all capable of alcoholic fermentation. But the action of the ferment is, in the first place, to transform both the former kinds of sugar into glucose or grape-sugar.—See ALCOHOL.

Testing or Estimation of Sugar.—If a watery solution contains only one of the three kinds of sugar—namely, cane-sugar, crystallizable; cane-sugar, non-crystallizable; or grape sugar, glucose; the amount of sugar may be determined from the specific gravity of the sirup. In all cases the density of the sirup is increased by an increased quantity of saccharine matter.

The following table from Dr. URE's Dictionary shows the specific gravity at 60° of solutions of crystallizable cane-sugar containing various amounts of sugar in one hundred parts by weight of the sirup:—

Sugar in one hundred parts by weight.	Specific gravity at 60°
66·666	1·3260
50·000	1·2310
40·000	1·1777
33·333	1·4400
31·250	1·1340
29·412	1·1250
26·316	1·1110
25·000	1·1045
21·740	1·0905
20·000	1·0820
16·666	1·0685
12·500	1·0500
10·000	1·0395

The subjoined more extended table has been constructed by PAYEN for a similar purpose. It shows the density at 59° of sirups formed by dissolving one hundred parts by weight of sugar in different quantities of water. The values differ somewhat widely from those given by Dr. URE:—

Parts of sugar.	Parts of water.	Specific gravity.
100 dissolved in	50 give a sirup of	1.345
100 "	60 "	1.322
100 "	70 "	1.297
100 "	80 "	1.281
100 "	90 "	1.266
100 "	100 "	1.257
100 "	120 "	1.222
100 "	140 "	1.200
100 "	160 "	1.187
100 "	180 "	1.176
100 "	200 "	1.170
100 "	250 "	1.147
100 "	350 "	1.111
100 "	450 "	1.089
100 "	550 "	1.074
100 "	650 "	1.063
100 "	750 "	1.055
100 "	945 "	1.045
100 "	1145 "	1.030
100 "	1945 "	1.022
100 "	2445 "	1.018
100 "	2945 "	1.015

The annexed table, constructed by NEIMANN at the normal temperature of 63°, with the same object, is also submitted:—

Sugar.	Water.	Specific gravity.	Sugar.	Water.	Specific gravity.
0 ..	100 ..	1.0000	36 ..	64 ..	1.1582
1 ..	99 ..	1.0035	37 ..	63 ..	1.1631
2 ..	98 ..	1.0070	38 ..	62 ..	1.1681
3 ..	97 ..	1.0106	39 ..	61 ..	1.1731
4 ..	96 ..	1.0143	40 ..	60 ..	1.1781
5 ..	95 ..	1.0179	41 ..	59 ..	1.1832
6 ..	94 ..	1.0215	42 ..	58 ..	1.1883
7 ..	93 ..	1.0254	43 ..	57 ..	1.1935
8 ..	92 ..	1.0291	44 ..	56 ..	1.1989
9 ..	91 ..	1.0328	45 ..	55 ..	1.2043
10 ..	90 ..	1.0367	46 ..	54 ..	1.2098
11 ..	89 ..	1.0410	47 ..	53 ..	1.2153
12 ..	88 ..	1.0456	48 ..	52 ..	1.2209
13 ..	87 ..	1.0504	49 ..	51 ..	1.2265
14 ..	86 ..	1.0552	50 ..	50 ..	1.2322
15 ..	85 ..	1.0600	51 ..	49 ..	1.2378
16 ..	84 ..	1.0647	52 ..	48 ..	1.2434
17 ..	83 ..	1.0698	53 ..	47 ..	1.2490
18 ..	82 ..	1.0734	54 ..	46 ..	1.2546
19 ..	81 ..	1.0784	55 ..	45 ..	1.2602
20 ..	80 ..	1.0830	56 ..	44 ..	1.2658
21 ..	79 ..	1.0875	57 ..	43 ..	1.2714
22 ..	78 ..	1.0920	58 ..	42 ..	1.2770
23 ..	77 ..	1.0965	59 ..	41 ..	1.2826
24 ..	76 ..	1.1010	60 ..	40 ..	1.2882
25 ..	75 ..	1.1056	61 ..	39 ..	1.2933
26 ..	74 ..	1.1103	62 ..	38 ..	1.2994
27 ..	73 ..	1.1150	63 ..	37 ..	1.3050
28 ..	72 ..	1.1197	64 ..	36 ..	1.3105
29 ..	71 ..	1.1245	65 ..	35 ..	1.3160
30 ..	70 ..	1.1293	66 ..	34 ..	1.3215
31 ..	69 ..	1.1340	67 ..	33 ..	1.3270
32 ..	68 ..	1.1388	68 ..	32 ..	1.3324
33 ..	67 ..	1.1436	69 ..	31 ..	1.3377
34 ..	66 ..	1.1484	70 ..	30 ..	1.3430
35 ..	65 ..	1.1538			

The following is most used:—

TABLE OF THE DENSITY OF SOLUTIONS OF SUGAR, ACCORDING TO BEAUMÉ.

Degrees.	Sugar per cent.	Degrees.	Sugar per cent.	Degrees.	Sugar per cent.
1	1.8	13	23.7	25	46.2
2	3.5	14	25.6	26	48.1
3	5.2	15	27.6	27	50.0
4	7.0	16	29.4	28	52.1
5	8.7	17	31.5	29	54.1
6	10.4	18	33.4	30	56.0
7	12.4	19	35.2	31	58.0
8	14.4	20	37.0	32	60.1
9	16.3	21	38.8	33	62.2
10	18.2	22	40.6	34	64.4
11	20.0	23	42.4	35	66.6
12	21.8	24	44.3		

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PAYEN gives the subjoined empirical formula for the estimation of the amount of sugar in a sirup from the indications of its gravity with BEAUMÉ's areometer, namely—multiply the indicated density by two and deduct a tenth of the product, the remainder will represent the per centage of sugar in the liquor. Thus, if the indication observed be 20, the result will be—

$$20 \times 2 \text{ minus } \frac{20 \times 2}{10} = 36.0 \text{ per cent.}$$

If the sirup be of pure crystallized sugar the product of the density multiplied by two is reduced by one-twelfth; thus—

$$20 \times 2 \text{ minus } \frac{20 \times 2}{12} = 36.67 \text{ per cent.}$$

If, however, a sirup contains other solid bodies besides sugar, it is clear that the specific gravity of the solution alone can give only an imperfect criterion of the quantity of sugar present. Recourse is then had to the power which a solution of cane-sugar has of turning to the right the plane of polarized light. When therefore a liquid contains cane-sugar without any other substance possessing the same optical property, the quantity of sugar may be determined with great exactness by measuring the deviation which the liquid produces in the plane of polarization. To apply this method, the deviation must be known which is produced by a solution of sugar of known strength. For this purpose a given weight, ϵ , of sugar is dissolved in such a quantity of distilled water that the solution occupies a given volume, V . Sufficient of this solution is taken to fill a tube of a certain length, and the deviation suffered by the plane of polarization of the luminous ray passing through this tube is measured. Let this deviation be α . Let then other quantities of sugar be dissolved in sufficient water to give the same volume of solution, V ; and let the deviations produced by these solutions in the same tube be α' , α'' , α''' , *et cetera*; then the quantities of sugar contained in the volume, V , of these liquids will be represented by

the products $\epsilon \frac{\alpha'}{\alpha}$, $\epsilon \frac{\alpha''}{\alpha}$, $\epsilon \frac{\alpha'''}{\alpha}$, *et cetera*, respec-

tively. If the sugar examined, instead of being pure, is mixed with other but inactive substances, it is evident that these same products express the absolute weights of pure sugar contained in the weights of substances employed in the formation of the liquids of the given volume, V . It is possible to employ proof tubes of different lengths; but it is then necessary to reduce by calculation the observed deflections to those which would have been produced in the same tube.

It often happens that solutions of sugar which have to be examined are turbid or strongly colored. When this interferes with the examination, they must be clarified and rendered either quite colorless, or when this is not possible the color must be at least reduced. This may generally be effected by precipitating the coloring matter of the sirups with subacetate of lead; but at a sugar-work the most convenient and complete method is a filter of animal charcoal. The filtrates are then examined optically. When sirups

contain, besides cane-sugar, other constituents which exert an action upon the plane of polarization, the amount of cane-sugar present may be often determined by inverting, by means of hydrochloric acid, the rotary power of the cane-sugar. No other saccharine substance is, in fact, known which suffers a similar change under the same circumstances.

If, for instance, the liquid under examination contains besides cane sugar, glucose, whose rotary action on the plane of polarization is in the same direction as that of cane sugar; if α' be the deviation observed to be produced by the liquid, then α' is evidently the sum of the separate deflections of the cane-sugar, x , and of the glucose, y . About one-tenth of its volume of hydrochloric acid is added to the sirup, and it is kept for ten minutes at a temperature of 140° – 154° . The cane-sugar is thereby completely transformed into noncrystallizable sugar, which turns the plane of polarization to the left, while the rotary power of the glucose undergoes no alteration. When this change has been effected, the new deviation, α'' , of the liquid is observed. It is now the difference between the deviation, y , of the glucose and that of the noncrystallizable sugar derived from the cane sugars. But the degree of dilution of the liquid having been changed by the addition of the hydrochloric acid, the deviation observed, α'' , must be replaced by the deviation, $\frac{10}{9}\alpha''$, which would have

been observed if the inversion could have been produced without the addition of hydrochloric acid. Admitting therefore that a quantity of cane-sugar which effects a deviation, x , gives rise to a quantity of noncrystallizable sugar which effects a deviation, rx , there is—

Before the inversion, $x + y = \alpha'$.

After the inversion, $y + rx = \frac{10}{9}\alpha''$.

From these two equations the quantities x and y may be determined. The coefficient of inversion, r , is determined once for all by a special experiment performed upon pure cane-sugar at the temperature at which the experiments have afterwards to be made. According to BIOT, this coefficient is 0.038 for hydrochloric acid at a temperature of 71.6° .

The process is the same when the cane sugar is mixed with noncrystallizable sugar, turning the plane of polarization to the left. In this case the initial deviation, α' , of the liquid is the difference between the deviation to the right, x , of the cane-sugar, and the deviation, z , to the left of the noncrystallizable sugar. After treating with hydrochloric acid, the deviation, α'' , is composed of the deviations of the original noncrystallizable sugar, and of that produced by the action of the hydrochloric acid. One then has—

Before inversion, $x - z = \alpha'$.

After inversion, $z + rx = \frac{10}{9}\alpha''$.

It is important in examining optically noncrystallizable sugar always to employ the same temperature,

because a change of temperature materially affects the rotary power of this kind of sugar.

E. MAUMENÉ proposes chloride of tin— $\text{SnCl}_2 \cdot 5 \text{HO}$ —as a reagent for sugar. By boiling he obtains a constant result. One part of sugar evaporated with fifteen to thirty parts of chloride of tin, and heated up to 220° or 226° , produces a brown body, insoluble in acids and alkalies. This he calls caramelin. It consists of $\text{C}_{12} \text{H}_{14} \text{O}_4$. Grape-sugar, cellulose, dextrin, and such bodies, give the same compound.

According to HORSLEY, alkaline chromate of potassa produces a green color in solutions of sugar, easily detected in a few drops.

FEHLING analyses sugar metrically in a beautiful way; but it is better suited to minute quantities than to the work of a sugar-house. He has a normal solution, made of—

40 grammes of sulphate of copper,
160 grammes of neutral tartrate of potassa, or 200 grammes of tartrate of soda,
700–800 grammes of caustic soda, specific gravity 1.12.
This is diluted with water to 1154.5 cub. c.

Of this solution 1 cub. c. = 0.0050 grape-sugar, or 0.00475 cane-sugar.

Grains may be used instead of grammes, and then 1 grain = 0.0050 grape-sugar, without change of calculation.

100 parts of grape-sugar, ... }
95 “ cane-sugar, ... } = 220.5 CuO, or 198 Cu₂O.
90 “ starch, }

This mode is peculiarly valuable for urines, as it measures the smallest quantities. The urine should be diluted from ten to twenty times with water. It should be boiled a few seconds after adding each portion of copper solution. The sugar of urine is grape-sugar.

On the Manufacture of Cane-sugar.—The manufacture of sugar from the sugar-cane may be divided into five parts. 1. *The cultivation of the cane.* 2. *The extraction of the juice.* 3. *The purification of the juice.* 4. *Its concentration; and* 5. *its crystallization.*

1. *Cultivation of the Cane.*—The sugar-cane—*Arundo saccharifera*—is an indigenous plant of the gramineous family. Cultivators distinguish three great varieties—the Creole, the Batavian, and the Otaheite cane. The first is indigenous to India; but it has been transplanted to other soils, such as those of Sicily, the Canaries, the Antilles, South America, and the West Indies. It is known by its thin, very knotty stem, and green leaves. The Batavian cane is a native of Java, but is met with at present in some of the sugar plantations of the New World and the West Indies; it is covered with purple stripes, and has a heavy foliage. The Otaheite variety is spread over the West Indies and South America, and is esteemed by far the richer and more productive of the several species. There are besides, the purple-banded and the purple Otaheitian and the ribbon cane. The Bourbon is said to be the same as the Otaheite cane of Singapore.

The sugar cane in a state of maturity is usually from six to fifteen feet in length, and from one and a half to two inches in diameter. It is jointed, and the distance of the joints from one another is from three to seven inches. These joints correspond to the extremities of hexagonal cells of which the intermediate

portions of the stem are composed, and which are in the living state of the plant filled with a solution of sugar. The exterior of the cane is smooth, hard, and cylindrical, and is covered with a coating containing a large quantity of silica. Germination occurs at the joints, and takes place at the opposite sides of alternate joints.

The sugar cane grows from pieces or slips of itself containing germs, and these develop rootlets at the joints, which draw sustenance to the young shoot as it increases. In the course of time the buds in the radicle, or root joints, of the first cane throw out roots, and form a radicle for a second stem; and in this way it happens, under favorable circumstances, that several canes are produced from the parent stock for a period of about six years, sometimes even for twenty years. From the first and second year, however, the canes diminish in the length of joint and circumference, and so the quantity of juice decreases; but it is alleged that the juice is much richer than when younger, and also produces a finer sugar. A common mode of obtaining successive crops is as follows:—When an old cane has been cut for its sugar, the incision is made some inches below the ground and the stump covered with mould. In about twelve months' time the offshoots from the original cane are ready for transplanting. In planting these slips or *ratoons* the system of wide planting is gradually superseding the old close planting. In addition to the advantage which the former kind offers in allowing the use of the horse-hoe for weeding, the great length of the root of the sugar-cane, which often extends laterally to a distance of six, and vertically to a depth of two feet, makes wide planting imperative, when rapidity of growth, as determined by quick absorption, is required. The cane holes are advantageously formed five feet from one another, in rows which are also five feet apart.

Of late years the system of cultivation of the sugar-cane has attracted considerable attention, as well in regard to the preparation of the soil as to the manner of planting. Formerly the custom of preparing the land by manual labor was followed; it is sometimes so still, and the consequence of not having the soil sufficiently disintegrated to the proper depth required by the plant, made itself apparent in the defective harvests of the plantations which followed; besides, by the practice of utilizing for fuel the *magass* or expressed cane, called *cane straw* and *cane trash*, instead of returning it to the land, the latter was rendered deficient in humus, and, therefore, not suited to retain the proper quantity of moisture, which, in the warm climates of its growth the cane absolutely requires for its proper development. And, although the ashes of the refuse might be consigned to the soil, yet this, instead of improving, rather defeated the objects which the cultivators had in view, as by the use of too much mineral matters as a manure, the sugar secreted by the plant was rendered uncrystallizable, and so, in a comparative sense, lost to the planter. An excess of soluble salts should always be guarded against in the cultivation of the sugar plant; but the fertilizer should be rich in humus and nitrogenous constituents, as the consumption of both these classes of bodies by the plant is greater in a much larger proportion than of mineral

fertilizing matters. The knowledge of these facts has led to the desire of employing such matters as blood, decomposed flesh, rotten fish, wool refuse, and the like, for manure in the sugar plantations. Charred peat would, in the opinion of the Editor, be a valuable adjunct to such matters, as it would materially prevent evaporation of the natural moisture of the soil, and supply carbon to the growing plant. Another feature in the modern innovations on the old system of culture is, that the *ratoons* or *stocks* are planted much wider apart. Various parties differ in their views in this respect—some recommending the plants to be set four feet apart in rows six feet asunder; others recommend a greater distance between the rows, such as eight feet; while some state that this should be increased to ten, or that each *stock* ought to have a space allotted to it of six and eight feet either way from the next one. It is to be hoped that from considerations like these, of the necessity of pursuing a more rational course of tillage, the planter may, and he doubtless will, be led, in the course of a few years' practice, to adopt the mode which enlightened observation and study will show to be most advantageous.

The frequent droughts which occur in the countries adapted to the cultivation of the sugar plant, render the artificial prevention of the too rapid evaporation of the water, which would be very injurious to the freshly-planted ratoons, of the highest importance. The great bulk and solidity, and the richness in mineral constituents of the stem of the sugar-cane, would cause a rapid impoverishment of the soil, were not some adequate return made to it. Both purposes are effected by surrounding the stems of the newly-planted ratoons with the *megass* or cane from which the sugar has been extracted.

Canes require a well drained but still a rich and moist soil. Land with much saline matter is frequently found to prevent the canes ripening; they remain green and watery.

One variety greatly in cultivation in Jamaica came from Otaheite. When this cane is well cultivated, and in favorable soil, it rises in the first year to twelve or fourteen feet in height, being six inches in circumference, and having joints six inches apart. No field, however, will give an average so high as this. Plants such as these will produce two and a half to three tons of dry sugar per acre, but the average is considered good at two tons per acre. It sometimes attains maturity in ten months. Its foliage is of a pale green; leaves broad and much drooping, and flowering or arrowing in a manner graceful and ornamental. It requires a rich soil. The *yellow violet* may be put in poorer soil. It gives a fine sugar, but not so much as the Tahiti cane. It has a dark-green foliage. The juices of the two are frequently mixed. The *purple violet* is from Java, and is eight to ten feet high, and six inches in circumference. On the joints of the cane there is a large amount of a resinous film, which sometimes completely shades the purple beneath. This resin is very hard and troublesome to grind. The sugar of this cane is excellent. The cane itself is hardy, and is sometimes used in Jamaica as a border to other canes, defending them against the trespassing of cattle.

The large red cane of Assam is said to flower in eight months, and to give similar sugar to the Tahiti cane. In Bengal a large red cane is cultivated which gives excellent sugar. The China cane is said to be extremely hardy, standing both cold and drought, and, with abundant rain, giving out as many as thirty shoots. It resists the inroads of the white ants, which cannot penetrate its hard crust, whilst it is also safe against the teeth of the jackals. It requires, however, a stronger mill for grinding than the other varieties mentioned. Mr. WRAY asserts that the Salangore cane is the finest in the Straits of Singapore, and perhaps in the world. He says that he has cut five from one stool, which were of a weight of from seventeen to twenty-five pounds. They have been known to produce seven thousand two hundred pounds of undrained sugar per acre, equal to five thousand eight hundred of dry sugar for shipping.

Dr. LIVINGSTONE says that sugar is cultivated in the Shire valley, as well as many parts of Africa near the Zambesi, and may be had for as little as one half-penny per pound. There is field enough for great enterprise in that direction. The amount obtainable has not been investigated.

The time of harvesting the cane varies with the mildness of the season, the locality, the nature of the soil, and the variety of the cane cultivated. Generally a dry, smooth, brittle skin, a heavy cane, a grey pith,

approaching to brown, and a sweet glutinous juice, indicate the maturity of the cane. A dry season is the time in which the canes should be cut, if possible, so that, by the absorption of too much moisture, the juice may not be diluted, and thus occasion increased trouble and expense in preparing the sugar from it. The canes are cut as close to the *stole* or root as possible, as well because the lower joints are found richer in sugar, as to give vigor to the ratoons, which are to spring from the old stock; the tops, with one or two joints, if they be not sufficiently ripe, are cut off, and the canes tied in bundles, and conveyed to the crushing mill. It is absolutely necessary that the cane be cut just before expressed in the mills; for, if allowed to remain any length of time at the high temperature of the climate, the sugar ferments, and a considerable loss is consequently occasioned.

Dr. EVANS gives the products of an acre of canes in Barbadoes as—

Weight of canes.	Weight of juice.	Extract.	Extract per 100 pounds of juice.	Extract per 100 pounds of canes.
30 tons. . .	60,480 lbs. . .	10,886 lbs. . .	18·0	16·20
30 tons. . .	47,040 lbs. . .	8467 lbs. . .	18·0	12·6
30 tons. . .	33,600 lbs. . .	3500 lbs. . .	10·0	5·0
30 tons. . .	33,600 lbs. . .	7280 lbs. . .	21·6	10·8

An acre may be said to yield thirty tons of canes. The following table gives the produce in juice and sugar:—

Juice obtained per cent.	Juice in pounds.	Pounds of Sugar.			Subtract for Molasses and Skimmings, at 12 per cent.			Pounds of dry Sugar yielded by one Acre,		
		At 18 per cent.	At 20 per cent.	At 22 per cent.	At 18 per cent.	At 20 per cent.	At 22 per cent.	At 18 per cent.	At 20 per cent.	At 22 per cent.
70	47,040	8,468	9,408	10,348	705	792	862	7,763	8,616	9,486
75	50,400	9,092	10,080	11,088	757	840	924	8,335	9,240	10,164
80	53,760	9,676	10,752	11,827	806	896	994	8,871	9,856	11,173

This supposes the juice to stand at 10° Beaumé; at the same time all the numbers given are above the amount actually obtained in practice, which does not appear to be above five thousand pounds per acre.

But it is difficult to tell the real amount of sugar obtained on the estates. The books on the subject are frequently very one-sided, or very confused, or they are not possessed of the information except for certain estates. Perhaps four thousand pounds of sugar and one hundred and seventy gallons of rum, twenty per cent. over proof, is a very fair specimen of the yield.

The following table by M. DUPREZ is given by Dr. EVANS. The average amount of juice from one hundred pounds of canes was—

1. By mills having horizontal rollers—motive power not stated—probably steam	61·2
2. By mills, motive power steam	60·9
3. By mills, motive power wind and steam	59·3
4. By mills having vertical rollers	59·2
5. By mills, motive power cattle	58·5
6. By mills, motive power wind	56·4

but 70 can now be obtained by greater power, and some speak of 80.

Of the eighteen to twenty-two per cent. of sugar in the cane, it is generally believed that no more than eight is obtained crystallized.

If only fifty per cent. of the juice is taken from the plant, and thirty still remain in it, three-eighths of the sugar are taken away in the megass and burnt

as fuel. Sugar must be to the planter at least worth twenty pounds per ton, whereas he could get coals from England at one pound. But this would not be an important loss, it is said, if the ashes of the megass were only taken and thrown on the soil, as was shown by Dr. STENHOUSE. The climates which grow sugar grow ligneous fibre rapidly, and it is well to use it for fuel when it can be obtained. The ground, however, must not be deprived of its inorganic constituents. It is also important to use the megass early, as the sugary matters unavoidably left in it oxidize, and, of course, give less heat in burning. It is well, however, to burn as little sugar as possible, at the same time to avoid an excess of soluble salts.

The following tables are from PAYEN:—

OTAHEITE CANE AT MATURITY.

	Centesimally.
Water,	71·04
Sugar,	18·00
Cellulose, ligneous matter, pectin, and pectic acid,	9·56
Albumen and three other nitrogenous matters,	0·55
Cerosin, green matter, yellow coloring substance, substance capable of being dyed brown, and carmine, fatty matter, resins, essential oil, aromatic matter, and a deliquescent substance,	0·37
Insoluble salts 0·12; soluble 0·16; consisting of phosphates of lime and magnesia, alumina, sulphate and oxalate of lime, acetates, malate of lime, potassa, and soda, alkaline chlorides, and sulphates,	0·28
Silica,	0·20

100·00

CANE ONLY AT A THIRD OF ITS DEVELOPMENT.

	Centesimally.
Water.....	79.70
Sugar.....	9.06
Cellulose and incrustated ligneous matter,	7.03
Albumen and three other nitrogenous substances, ...	1.17
Starch, cerosin, green matter, yellow coloring substance, and bodies colorable to brown and carmine, }	1.09
Fatty, aromatic, and hygroscopic substances, essential oil, soluble and insoluble salts, alumina, and silica,	1.95
	100.00

The fresh cane has been estimated to contain—

	Tahiti. Per cent.	Cuba. Per cent.
Water	72.1	65.9
Ligneous fibre.....	9.9	16.4
Sugar and other substances	18.0	17.7
	100.0	100.0

The juice of Martinique cane has been found to contain—

Sugar	20.9
Water	77.2
Organic substances not sugar	0.2
Inorganic salts	1.7
	100.0

The megass or residue, after passing the rollers—

Sugar	7.9	7.3
Molasses	3.0	2.7
Ligneous matter and earthy salts	38.6	39.5
Water	50.5	50.5
	100.0	100.0

CASASECA has analyzed the Havana cane—the *creole*—and found—

	Cane entire.	Cane peeled.	The rind.
Water	77.0	77.8	69.5
Sugar and soluble substances	12.0	16.2	11.5
Ligneous matter.....	11.0	6.0	19.0

He says that 23 of dry cane contain 12 of sugar, and 23 of the dry rind only 8.6.

	Cane sugar.	Grape sugar.	Water.	Ashes.	Water of the insoluble part.	Remainder—caramel, gum, and acids.
Ten sorts of Java	98.6 — 83.1	5.5 — 0.3	6.1 — 0.3	1.9 — 0.2	0.2 — 0.0	3.5 — 0.5
Six sorts of Havana	97.0 — 87.3	3.7 — 0.9	3.5 — 0.9	1.1 — 0.0	0.3 — 0.0	4.5 — 0.4
Four sorts of Surinam	92.3 — 85.4	4.4 — 1.6	6.3 — 3.6	1.4 — 0.8	0.6 — 0.4	2.1 — 1.1
Pure candy	99.6	0.1	0.2	0.1	—	—
White sugar	99.7	0.2	0.1	—	—	—

Twelve kilogrammes of molasses of cane sugar contain according to PAYEN—

Sugar	7.561.00
Acetate of potassa	0.209.30
Chloride of potassium	0.114.60
Sulphate of potassa	0.085.50
Mucilaginous matter	0.076.30
Phosphate of lime	0.052.00
Nitrogenous substances.....	0.050.00
Silica	0.023.90
Acetate of lime	0.016.20
Phosphate of copper	0.000.20
Water	1.800.00
Glucose and uncrystallizable sugar	1.561.00

RICHARDSON found sugar and the molasses from it to contain—

	Sugar.	Molasses.
Potassa	19.42	36.23
Lime	14.67	12.72
Magnesia	10.72	11.14
Oxide of iron	6.55	2.62
Oxide of copper	0.71	trace of
Protoxide of manganese	trace	both

The amount of water in the sugar-cane increases according to CASASECA, towards the top; the greatest amount of sugar is found in the lower third of the cane, but much less in the upper part; the centre third contains about an average of the whole. The water even of the joints increases on rising.

The pure or nearly pure juice, when the green matter is removed, contains—

	Per cent.
Water	81.00
Sugar	18.20
Organic matter, precipitated by lead salts	0.45
Saline matter	0.35
	100.00

Cane juice has a specific gravity of 1070 to 1090—10° to 13° Beaumé. It has been obtained as low as 1046, and as high as 1110, at 80° Fahr. It is opaque, frothy, and of a yellowish green. The green part may be filtered out, leaving a pale yellow fluid, which is almost pure sirup. The green scum consists of chlorophyll, cellulose, ligneous fibre, and albumen. Its analysis given by AVEQUIN is—

	Per cent.
Cerosie—a peculiar wax.....	50.0
Green matter	10.0
Albumen and ligneous fibre	22.7
Phosphate of lime	3.3
Silica	14.0
	100.0

A gallon of juice, weighing about ten and three-quarter pounds, contains about twenty-seven grains of this greenish scum.

MULDER believes that the light-colored sugars contain most cane-sugar generally. He also says that the many varieties into which sugars are divided in Holland are not well based.

MULDER gives the following analyses of several raw sugars:—

	Water.	Ashes.	Water of the insoluble part.	Remainder—caramel, gum, and acids.
Ten sorts of Java	6.1 — 0.3	1.9 — 0.2	0.2 — 0.0	3.5 — 0.5
Six sorts of Havana	3.5 — 0.9	1.1 — 0.0	0.3 — 0.0	4.5 — 0.4
Four sorts of Surinam	6.3 — 3.6	1.4 — 0.8	0.6 — 0.4	2.1 — 1.1
Pure candy	0.2	0.1	—	—
White sugar	0.1	—	—	—

A few, out of many analyses made by Dr. STENHOUSE of the ashes of the cane, may be given—

	Sugar.	Molasses.
Chloride of potassium	8.03	1.58
Chloride of sodium	15.46	25.87
Sulphuric acid	10.85	7.91
Silica	13.59	1.93
Ashes	1.33	3.60

100.00 100.00 100.00 100.00

Refuse of sugar has been analyzed by—

	Prof Johnston.	Dr Anderson.
Water	60.26	48.44
Organic matter—refuse blood and sugar	20.77*	39.10*
Phosphates of lime and magnesia	8.67	3.97
Lime	3.55	3.41
Magnesia	—	0.19
Common salt sulphates of potassa and soda	0.77	1.64
Insoluble silicious matter and sand	5.98	3.23
	100.00	100.00
* Containing ammonia	1.06	2.23

Blood is now less used, and a refuse like the above would not now be easily obtained.

The feculencies of the sugar obtained by defecation, without the addition of lime, or indeed of anything but

	Water given off at 212°	
Five kinds of candy sugar	0.011	—0.475
Four kinds of white sugar	0.071	—0.100
Four kinds of common sugar	0.121	—0.225

It is found that sugar which is brought over in iron vessels, frequently oozes out and attacks the iron, doing injury to the vessel. Iron is rapidly dissolved by sugar. The sugar may become a little acid and then attack the iron, but it soon throws it down again as an oxide, as Dr. GLADSTONE has observed, and thus a small amount of sugar destroys a large amount of iron. Dr. GLADSTONE obtained the following compound:—

	Found.	Calculated.
Protoxide of iron	17.20	17.39
Sugar	82.80	82.61

Sugar readily decomposes a sesquioxide of iron in solution into a protoxide. Dr. GLADSTONE did not find that zinc prevented the oxidation of the iron. Zinc itself is not easily separated from sugar. Copper is scarcely acted on by sugar, but the oxide is dissolved, and lead is dissolved in no small quantities. This corroding power is not known to belong to pure crystallizable sugar, and the experiments of the above chemist must be taken as referring to the molasses, *et cetera*, united with it.

From the analyses on page 972 may be learned the absolute necessity of permitting the cane to attain its full growth and maturity before being cut for the extraction of its secreted sugar; and further, that in the system of manufacture in some cases adopted, the exhaustion of the cane is so imperfect as to leave fully one-half or three-eighths of its juice in the straw; thus, at the very first outset, causing a loss to the planter or sugar-maker of about one-half the quantity which the cane contains. When the other defects of the manufacture are considered as tending to convert the crystallizable into uncrystallizable sugar, producing fermentation and

water, were found by Mr. THORNTON J. HERAPATH to contain 13.574 parts of ashes, composed of—

	Per cent.
Water	48.940
Organic matter	37.486
Carbonate of potassa	0.146
Sulphate of soda	0.155
Chlorides of sodium and potassium	0.237
Carbonate of lime and some carbonate of magnesia	3.964
Sulphate of lime	1.231
Phosphate of lime and some phosphate of magnesia	2.679
Phosphate of iron and alumina	1.320
Silicious residue insoluble in acids	3.842
	100.000

The dry substance contained 5.42 per cent. of nitrogen.
Undried

The prepared sugar is very pure. MULDER found in one hundred parts of dry sugars—

	Ashes.	Grape-sugar.
....	0.0 —0.104	0.132 —0.192
....	0.03 —0.735	0.134 —0.239
....	0.052 —0.152	0.230 —0.365

oxidation, the clue to the enormous waste in the manufacture of sugar is at once obtained. These losses may be grossly set down as being due—

To imperfect extraction of the juice 45 to 50 per cent.
To transformation to uncrystallizable sugar, *et cetera* } 12.5 to 15 "

Loss of crystallized sugar 57.5 to 65 "
Balance, or quantity of sugar obtained 42.5 to 35 "

2. *Extraction of the Juice.*—The sugar exists in the cells of the cane in the state of solution, which constitutes the juice or sap of the plant. Analyses have shown that the quantity of juice and its richness in sucrose, are variable to some extent; but on an average the per-centage of sugar amounts to seventeen or eighteen parts in good cane. The following additional analyses indicate an average composition—

	Centesimally.		
	From Martinique, by Peligot.	From Guadeloupe, by Dupuy.	From Cuba, by Casaseca.
Water	72.1	72.0	65.9
Sugar	18.0	17.8	17.7
Ligneous matter	9.9	9.8	16.4
Salts	—	0.4	—
	100.0	100.0	100.0

Such also is the average composition of the cane of the third, fourth, and succeeding years' growth from the parent stock, as shown by PELIGOT's researches on this subject. HERVEY examined two specimens of sugar-cane of Guadeloupe, and the megass which they yielded. The samples were grown on two different soils—No. 1 being produced by a dry, calcareous, and elevated one; and No. 2, by a low soil in the neighborhood of volcanic eruptions. The following are his results calculated without water:—

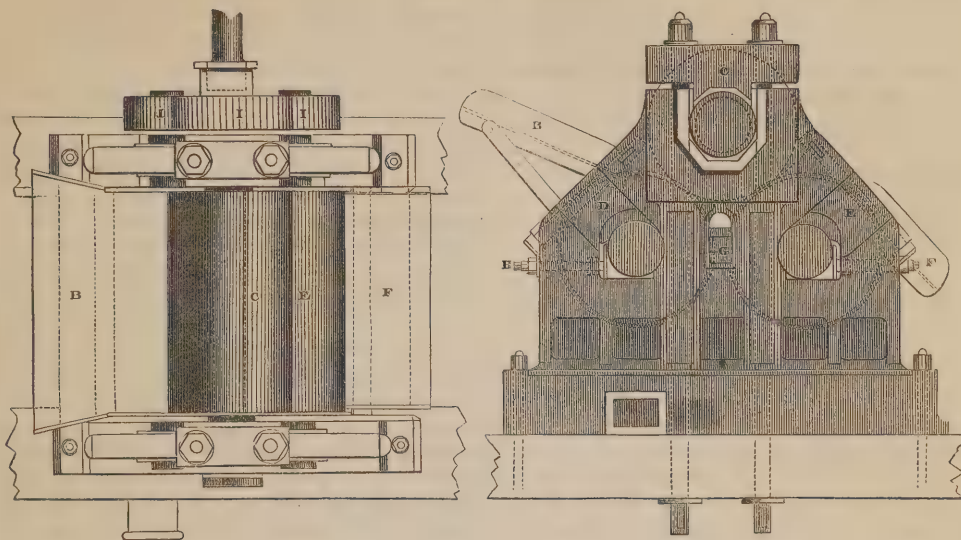
	No. 1.		No. 2.		
	Sugar-cane.	Megass or Straw.	Cane Sugar,	Megass or Straw.	The same brown and decomposed.
Sugar	64.6	22.5	67.0	29.2	42.4
Extractive matters	0.3	—	0.3	—	—
Wax	0.9	1.8	1.2	1.6	1.6
Soluble salts	0.3	1.8	1.2	2.4	3.3
Insoluble salts	1.0	—	1.3	—	—
Ligneous matter	32.6	73.9	28.9	66.8	52.7
Loss	0.3	—	0.1	—	—
	100.0	100.0	100.0	100.0	100.0

The saccharine liquid is extracted from the cane by pressure. The sugar-mills employed for this purpose are chiefly three, namely, the horizontal and the vertical roller mill, and the hydraulic press. The latter,

however, has not received general adoption. The accompanying woodcut—Fig. 554—shows the construction of horizontal sugar mill.

The vertical mill, in which the crushing cylinders

Fig. 554.



are placed vertically, has the advantage of being more easily cleaned; but it is less easily fed, and is more costly in its construction. A great deal depends upon the right adjustment of the distances of the three rollers, a too near approximation causes, on the one hand, an increased expenditure of force in the working of the mill, and on the other, a too great distance allows a portion of the juice to escape extraction, and to be carried off in the megass. The distance between the feeding roller and the upper one is about half an inch; the delivering roller is still closer to the upper one. In feeding a horizontal mill, the canes are cut into lengths of about three feet, and so spread upon the feeding board that these may overlap one another as little as possible. Mills have also been constructed with five and with four rollers. When five rollers are employed three are placed below and two above. A five-roller mill is said to extract ten per cent. more juice from the cane than a three-roller one; but the megass is thereby much broken, and a much greater expenditure of mechanical power is required to work the mill. In the four-roller mill, where two rollers are placed below and two above, while a greatly superior amount of juice is obtained, the expenditure of force is said to be not much greater than in the ordinary three-roller mill; hence it is probable that the four-roller mill will gradually supersede those now generally in use.

Some years ago a method was patented by Mr. MICHIEL for extracting the sugar from cane without the use of the mill; it was proposed to cut the canes into thin slices and treat them with lime water. The object of this was to render the nitrogenous constituents of the

cane insoluble. On treating the so-prepared canes with water, a sirup is obtained of a purity much greater than that obtained directly by mechanical means. Probably the mechanical difficulty experienced in slicing the canes has prevented the adoption of this method. The following are the experiences of Dr. EVANS—given in the *Sugar Planter's Manual*, published in 1857—in regard to the advantageous working of a sugar mill:—1. The rollers should be approximated as closely as the work which they have to perform will admit of. In mills in which the rollers observe a vertical direction, the space between the first and second should scarcely, if at all, exceed a quarter of an inch, whilst a distance of one-sixth of an inch is the most that should be allowed between the second and third. When they are placed horizontally, the upper one should be distant a space of one-fifth to a quarter of an inch from the two lower. 2. The velocity of the rollers should be rendered as uniform as possible, not by diminishing the amount of the motive power, but by a carefully regulated supply of canes. 3, 4. The megass should be invariably repassed between the rollers so as to extract as much as possible the juice which still remains in it. When canes are rich, and their juice of considerable density, the megass should be sprinkled with a little water, or, where it is practicable, exposed to the action of steam before it is submitted to the pressure; but when the canes are large, green, and watery, this may be dispensed with.

The amount of juice obtained from the cane is not always a criterion of the comparative yield in sugar. The drought or humidity of the season preceding the cutting of the canes determines the presence of a less

or greater amount of water in the cane, while the quantity of sugar remains for a time unaffected. Between moist and dry seasons, and thorough and imperfect crushing, the yield of juice may vary from fifty to seventy-five per cent. of the weight of the canes employed.

The following table shows the proportions of the solid constituents—other than sugar—in cane juice. The relation of these amongst one another is probably pretty constant, although the quantity of sugar and of water may vary much with the age of the plant and the season at which the juice is extracted.—

Ure.

One hundred parts of solid constituents contain—

Sulphate of potassa,	11.3
Phosphate of soda,	10.2
Chloride of potassium,	5.3
Acetate of potassa,	40.6
Acetate of lime,	22.9
Silicic acid,	9.7

100.0

The methods employed in Hindostan and Ceylon for the extraction of the sirup or *goor* from the cad-goollee and other species of indigenous cane are so imperfect as to require no special description.

Captain MARGETSON, R.N., has proposed to cut the cane in pieces, and dry it as beet-root is dried, sending the substance home for the extraction of the sugar. This is a very promising field of inquiry.

3. *The Purification of the Sirup.*—The removal of impurities from the juice, as it is delivered from the mill, may be divided into two processes, defecation and clarification.

The crude cane juice contains, besides sugar and water, the impurities—earthy insoluble particles, fragments of the crushed cane or megass, albumen, caseine, wax, soluble coloring matter, and soluble salts. The coarser of the insoluble particles are sometimes removed mechanically previous to the process of defecation. But certain of the nitrogenous impurities of the crude juice if left in contact with the sirup speedily determine its fermentation, thereby occasioning loss in sugar, and owing to the subsequent conversion of the alcohol generated by fermentation into acetic acid, causing the corrosion of the metallic portions of the machinery, and the introduction of metallic acetates into the sugar. It is of the greatest importance that the process of defecation, whereby the nitrogenized compounds are removed, should follow with as little delay as possible upon the extraction of the juice. For this reason the storing of the sirup in tanks until a sufficient quantity is obtained for purification, is to be reprehended. The first filtration also should, for the same reason, be performed as rapidly as possible. This filtration is effected through a double sieve, the metallic meshes of the first sieve being about one-twelfth, those of the lower about one-thirtieth of an inch asunder. The sirup is run from these sieves, or directly from the crushing mill, through a wooden gutter lined with lead to the clarifiers. These are a series of copper cauldrons capable of holding from three thousand to four thousand gallons each. The bottoms of the clarifiers are usually concave, being bulged inwards from below.

Each cauldron is provided with a separate fire, the flues from which run into a common chimney, and each fire is provided with a separate damper for regulating or stopping the draught.

Defecation.—When this is performed in the Colonies, the sugar is boiled down from the strength of 10° Beaumé only to about 27° or 28°, which is the strength suited for hot filtration. When it is performed in England, the sugar is dissolved in water, so as to be of the strength of 27° Beaumé.

Lime is the agent most frequently employed in defecating the sirup; but considerable differences of opinion exist concerning the best method of its application. The lime should be thoroughly burned and quickly slaked with hot water, enough water being added to give the consistence of a cream. This should be then filtered through a fine wire sieve in order to remove silicious particles and fragments of unslaked lime or unburned limestone. Some sugar manufacturers adopt the following process:—When the sirup in the clarifiers has attained the temperature of 130° Fahr. successive portions of the cream of lime are added, until the acids in the sirup—acetic and lactic—have been completely and exactly neutralized, which is shown by its neutrality to blue and red litmus paper. The mixture of sirup and lime is thoroughly incorporated with an oar, and the whole left to digest for about a minute. The portions of cream of lime successively added to effect neutrality should not contain more than about four ounces of solid lime per gallon. The product so obtained is run off through a stop-cock in the clarifier, either through bag filters or through charcoal filters, subsequently to be described. In the more common process of defecation, however, after neutralization by cream of lime, as above described, the heat is urged until a temperature just below the boiling point of the sirup is reached. A thick scum is then formed upon the surface of the sirup, and the clarification is judged complete when this scum breaks and a white froth appears in its interstices. In all cases an excess of lime is to be avoided, partly because nitrogenous matter, upon the removal of which, from an acid solution by heat and lime, the clarification in a great measure depends, is redissolved by an excess of this agent, but mainly because of the destructive action of caustic earths on sugar. If, however, an excess of lime has been added, it may be remedied by the addition of small quantities of a solution of alum. When this salt is added to any alkaline solution with excess of lime, its alumina is precipitated and rises with the same, fixing a portion of the coloring matter of the sirup at the same time, and thus assisting in the clarification. Of the simultaneous products found in this reaction, *videlicet*, sulphate of lime and sulphate of potassa, the first is in a great measure insoluble and rises with the scum; the second, however, is soluble in the sirup, and cannot be subsequently separated from it; and this is the only drawback in the employment of alum to neutralize overlimed sirup. Sulphate of alumina, however, is not subject to this disadvantage, and may, therefore, advantageously replace alum in the neutralization of overlimed sirup.

Other substances have been employed for the defe-

cation of cane juice, of which the principal are bullock's blood, nut-galls, sulphate of zinc, alum, sulphate of alumina, sulphuric acid and lime, and subacetate of lead. As bullock's blood is almost exclusively employed in the defecation of beet-root sugar, its application will be described under that head.

Nut-galls.—After the clarification by means of cream of lime of four hundred gallons of sirup has been effected, the temperature is raised to 150° or 160°, and a decoction of nut-galls is added, formed by digesting two ounces of the bruised galls in half a gallon of boiling water. The mixture is stirred for two or three minutes with an oar, boiled and strained through bag filters.

Sulphate of Zinc.—Twelve ounces of sulphate of zinc are added to a clarifier of three hundred gallons. The sirup is then neutralized with cream of lime, boiled and filtered.

This process has not been used, as it is difficult to remove the taste of the zinc.

Alum.—Four pounds of alum in solution are added to a clarifier of three hundred and fifty gallons; as it begins to get warm the heat is rapidly raised to 140°, and the sirup neutralized with cream of lime.

Alum should never be used, as it introduces salts of the alkalies, which cannot be removed.

Sulphate of Alumina.—A pound of sulphate of alumina is added to every hundred gallons of juice, and the whole quickly neutralized with lime and filtered as before; still not of much value.

Ammonia has been proposed as an addition to sugar, especially to beet-root juice; but its value has not been shown.

Alumina and Sulphate of Lime.—The alumina obtained from two pounds of alum by precipitation along with sulphate of lime, by means of carbonate of lime in suspension, is washed by decantation and added to one hundred gallons of cane juice. When the temperature of the sirup has reached 150°, lime is added to neutralization and the juice is then filtered.

Sulphuric acid diluted with thirty times its volume of water is added to the sirup—for three hundred gallons of the latter, two fluid ounces of sulphuric acid are employed—at a temperature of 120°; four ounces of lime are then added, and when the temperature reaches 170°, the sirup is neutralized with more lime and filtered.

The value of this method is extremely small.

Subacetate of Lead.—It has been proposed to effect the defecation of the sirup by the successive employment of subacetate of lead and phosphate of lime. Subacetate of lead has the power of throwing down the whole of the coloring matter and other organic foreign substances present in the sirup. But the subsequent separation of the lead which is in solution by phosphate of lime, is either not perfect in the presence of sugar, or requires more delicate manipulation and greater care than can be usually looked for in sugar manufactories. The deleterious action of repeated though very minute doses of lead on the system has prevented its employment as a defecating agent.

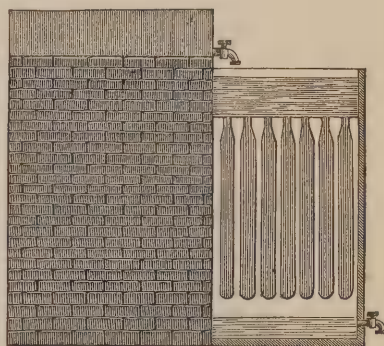
Dr. SCOFFERN precipitates the lead by sulphurous acid, and by this means it is found that he can remove

it all; but the dangers attending the use of lead are so great, that his process, although beautiful when done well, and perfectly capable of being done well, has been discouraged if not prohibited, and the plan will therefore probably be abandoned. Man's constant accuracy cannot be trusted. *Tin* has been tried, but is not practically found useful.

When the scum has risen to the surface, and the clear sirup is seen through its cracks, the approach of which point is usually judged of empirically by the thickness of a portion of the sirup removed from the clarifier, and by the equalization in size of the bubbles formed in the liquid, the defecation is complete. The defecated sirup is then removed from the scum by tapping, or the latter is removed from the sirup by skimming, in both cases sufficient time being allowed for the heavier portions of the scum to subside. As the scum always contains a considerable portion of sirup in its pores, it is generally submitted to pressure in a simple lever press, and the extract added to the liquid which has been tapped off. Fig. 555 shows the usual form of the clarifier.

In those countries where fuel is cheap, and especially in those manufactories where steam is employed, either as a motive power for the mill, or the vacuum pan—afterwards to be described—or for other purposes,

Fig. 555.



the heating of the clarifier is sometimes effected by means of steam. It is clear that as the temperature requisite for boiling in the open air is above that of boiling water, the steam by which it is effected must be either overheated or high pressure steam. And as in most sugar growing lands fuel is scarce, and as a great use of fuel attends the application of overheated steam, high-pressure steam is employed. This is usually conveyed by a copper worm through the clarifier, the steam passes downwards round the spirals of the worm, and the condensed water is discharged under pressure.

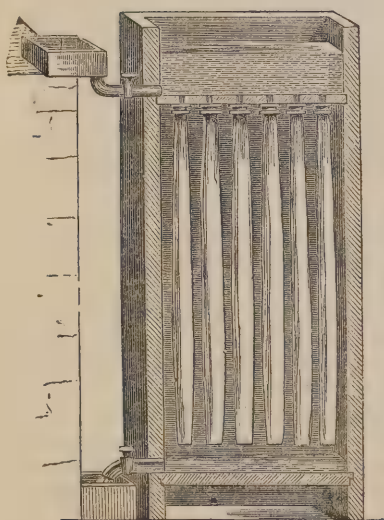
Simple Filtration.—The process of defecation always leaves impurities in the sugar, either in the form of suspended scum, or when filtration is not performed previous to the defecation of the mechanical impurities formerly mentioned. In all cases it has now to undergo another filtration.

It is usual to run off the sirup at once from the clarifiers upon the filters, and the preceding diagram shows the simplest arrangement for this purpose. The matter of the filter is always cotton. Woollen textures are rapidly destroyed by the alkaline nature of the scum. The forms given to the filters are chiefly two—the leaf-filter of *LOVERING* and the bag-filter of *TAYLOR*.

The leaf-filter is composed of a series of cotton bags stretched over thin quadrangular frames, which keep the sides of the bags apart, and cause them to present a smooth even surface instead of folds, thus greatly facilitating the operation of cleaning, when it has to be performed. These frames are arranged side by side in a box, and the juice which filters from without inwards, escapes by a hole in the bottom of the frame. The juice is poured into the box outside of the frames, and the filter, therefore, is not clogged by impurities as readily as *TAYLOR*'s filter, in consequence of which it works more rapidly and does not require to be cleaned so often.—*M^cCulloch*.

TAYLOR's bag-filter—Fig. 556—consists of a number of cotton bags about two feet in length and a foot in diameter when fully extended. Into their narrow mouths the nozzles of the tubes pass which deliver the sirup. The bags are fastened on the nozzles by means of a sliding ring. Each bag is inclosed in a cylindrical one of canvass about four inches in diameter, the object of which is to prevent the swelling out of the interior cotton filter. In such a filter of course the interior bag is much folded; nor can it in this state present the same amount of filtering surface as it would were it fully inflated. It may indeed be questioned whether

Fig. 556.



with tolerably clean sirup such a folded filter offers much advantage above a filter of the size and shape of the exterior canvass bag.

When the leaf or bag filter has become choked it

must be washed; this is sometimes done by machinery. The use of very dilute hydrochloric acid or of acetic acid facilitates the washing, by dissolving the lime in the scum. But the first acid at least, however dilute, weakens the cotton fabric when often applied, and the presence of every acid should, when possible, be avoided in every process of sugar manufacture; because the vinous fermentation to which all saccharine liquids are liable is found to be facilitated by the presence of any acid.

Charcoal Filtration.—The previously described processes of filtration and defecation effect the removal of the mechanical impurities in the sirup, as well as those albuminous and nitrogenous substances which are solidified by the heat of the clarifiers, and removed in the scum which is formed in them. But besides such impurities, the juice of the sugar cane contains various coloring matters whose chemical nature has not been examined, and which are not removed either by filtration or defecation—except where, in the latter process, subacetate of lead is employed. As these coloring matters do not separate by the further evaporation of the sirup, but obstinately remain with it, a further process of decolorization is necessary before the final evaporation is effected. Animal charcoal is the agent employed for this purpose. When the bones of animals are subjected to dry destructive distillation, without access of air, the residue consists chiefly of carbon, and the phosphates and carbonates of lime, with a little of the same salts of magnesia. Such charcoal possesses pre-eminently the power of removing many organic substances from solution when brought into prolonged contact with the liquids which contain them. Thus strychnine when in solution is removed by agitation with animal charcoal. The decolorization of sugar depends upon the same power of animal charcoal. Animal charcoal or bone-black, in removing coloring matter from sirup, undergoes no profound change. It appears to act by a species of superficial affinity; that is, as far as the process can be followed, an affinity that pervades the surface of every one of the minute pores of the charcoal, rendering the actual superficies enormous. But although the charcoal thus remains unchanged, its decolorizing power is so far limited, as when its surface becomes too thickly covered by the coloring matter it withdraws, a charcoal surface is no longer presented to the liquid.

The bone-black preferred by sugar manufacturers for the decolorization of sirup is that obtained from the larger bones of animals—as the thigh and shoulder bones of oxen. This variety is generally not only more compact than that obtained from the smaller bones, or from the bones of smaller animals, but appears to possess a specifically greater decolorizing power. Such bones after burning are reduced to a coarse powder. The grains of which are about the size of small peas. In some manufactories, however, where the process of defecation and decolorization are united, and where powdered bone-black is added to the sirup in the clarifier, the bone-black is employed in a finer state of division, the grains being then of the size of those of the finest gunpowder. But as in this method the bone-black

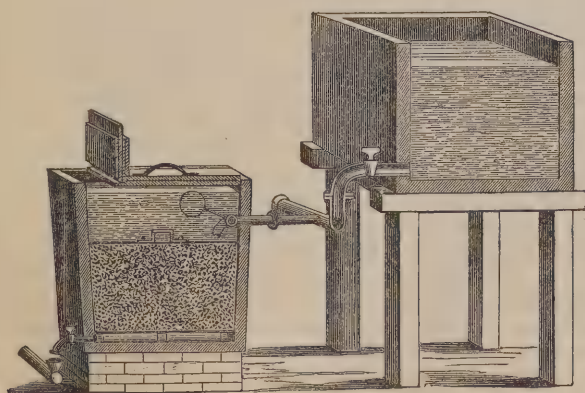
employed is thrown up with the scum in the clarifier, mixed with the salts of lime and other feculences from which it cannot be separated, it is lost, and consequently the application of bone-black in the clarifier is seldom adopted. The decolorization by filtration through bone-black is generally effected immediately after the filtration through the cotton filters above described. The following description of the two kinds of bone-black filters most frequently employed abroad, but now scarcely used here, is from R. S. M'CULLOCH's report.

Dumont's filter consists of a wooden box of the form of a four-sided truncated pyramid with a double bottom. The inner bottom is a metallic plate pierced with numerous holes; upon it a cotton cloth is laid, and coarse-grained animal charcoal moistened with water is then spread layer by layer; each layer being rendered of uniform thickness, and packed or pressed closely together by means of a sort of trowel. When the bone-black has been thus formed into a compact bed or stratum of about fifteen or eighteen inches in thickness, and within five to ten inches from the top of the box, it is covered with another cotton cloth, and with another metallic plate pierced with holes. The object of the second cloth and metallic cover is to collect any substances which would otherwise obstruct the interstices of the superior stratum of the bone-black—an inconvenient accident which is easily prevented by the use of such a cover, and this cover is readily exchanged for another, should it become itself obstructed. The superior cover is only of use when the previously described filtration through the cotton bag or leaf filter is omitted.

It is important, in order to avoid false passages, that the juice should be constantly at the same level of about three or four inches above the cover of the bone-black. This is accomplished by means of a self-regulating cock.

To facilitate the action of DUMONT's filter—Fig. 557

Fig. 557.



—the bone-black must be perfectly free from fine powder, which would obstruct the passage of the sirup, and thus retard its flow. To render it so it should be carefully sifted each time after revivification.

PEYRON's filter is another form of metallic filter

to be used like that of DUMONT's with coarse bone-black. It is intended, however, to act continuously and without renewal of the bone-black. This filter is cylindrical, in height eight feet, and in diameter thirty-nine inches. The top is closed with a perfectly air-tight cover, and the vacant space of the double bottom communicates by a tube and cock with the top of a second and smaller filter, so that the sirup which has filtered through the first passes through the second, from which, in like manner, it proceeds through a third. The closed top permits the use of hydrostatic pressure to increase the rapidity of filtration, and the juice enters the first filter for that purpose by a tube from a reservoir above. The double bottom of each filter of the series is also provided with another outlet and stop-cock to permit the fluid contents to be drawn off at any time, if desired.

The filters of PEYRON, like those of DUMONT, are charged with coarse bone-black, carefully compressed in layers; after which the fine powder is washed out thoroughly with water, and when this flows perfectly clear the sirup is allowed to pass into the filter, and to remove the water by *displacement*. As soon as the water which escapes from the double bottom is sweet to the taste, it is collected in the reservoir to be evaporated. After the sirup ceases to flow freely, hot water is used to displace that portion absorbed by the bone-black; and as soon as the density of the escaping liquid becomes feeble it is no longer collected. The hot water is then allowed to flow through the filters until they are washed perfectly. Fermentation soon commences in the filter by reason of the dilute sirup and nitrogenous impurities absorbed by the bone-black; and after twenty-four hours, when the fermentation is considered complete, and the impurities taken up by the bone-black are thereby destroyed, the filter is cleaned to prepare it for work a second time, by first passing through it for half an hour a jet of high-pressure steam, and subsequently washing it thoroughly with hot water.

Another form of filter somewhat similar to PEYRON's is as follows:—A series of four cylindrical boxes, provided with perforated false metallic bottoms are connected together as before with stop-cocks in such a manner that each may be removed without disturbance of the rest. If they are all charged with fresh bone-black, and the sirup is run through until it begins to become colored, it follows that the charcoal in the upper boxes must have lost its decolorizing power to a greater extent than that in the lower ones. The highest box is therefore removed; the next highest becomes now the highest, the third becomes the second, and so on—a box of fresh charcoal being introduced below. In this manner the filtration may be carried on with but little interruption for any length of time. To insure the uniform distribution of the sirup upon the upper layer of the box, a mechanical contrivance is sometimes employed. This is of the form of a horizontal tube, perforated with holes throughout its length, but closed

at its ends, and capable of revolving with facility about its centre. The passage of the sirup through the tube and through its orifices determines the revolution of the tube about its axis, and the consequent distribution of the sirup upon its surface.

The filters on the Continent are still frequently of this kind, but such are seldom used in England, where it has been found economical to use them of enormous size, being about thirty feet in height, and four to eight feet in diameter. A filter like this contains about twelve tons of animal charcoal. Charcoal is expected to purify, on an average, an equal weight of fine, or twice its weight of *seconds* sugar.

The same bone-black may be employed any number of times, provided the substances which it has withdrawn from the sirup be removed. This is sometimes done by allowing them to ferment, as in PEYRON's filter; but more frequently by simple rekilning. The kiln made by G. F. CHANTRELL of Liverpool for the revivification of the bone-black is seen in Fig. 558. Those of PONTIFEX and WOOD and others are under the article *Charcoal*.

Perhaps no part of a sugar refinery is more important than the burning of the charcoal or bone-black. This is generally used in small pieces, the largest about the size of a half pea, and slightly elongated in the direction of the length of the bone from which they are formed. It was at one time usual to grind the charcoal to dust, but this habit is now almost entirely given up. When fine the sugar does not run so rapidly through the filter, and it is not mixed with so much facility or so much convenience; besides, it is not so easily burnt or revivified. In general, too, refiners object to the very fine charcoal, and either drive it off by blowers when the charcoal is dry, or remove it by lixiviation. It is sold to the manufacturers of superphosphate of lime at about five to six pounds per ton.

By means of flues a series of brick walls about eight feet in height are heated red hot. The walls are in pairs, each two of which are about eight inches apart. The space between each pair of walls is completely filled with the spent bone-black, the pile of which rests upon the ground. The upper end of each vertical layer forms a part of the heap of spent bone-black, which therefore covers the top of all the walls. When the walls have reached a red heat, and remained for a quarter of an hour at that temperature, enough bone-black is raked from the lower ends of the columns to cause each pile to sink about six inches. The heap of charcoal at the top supplies each column as it sinks. The same process is repeated, so that every portion of the bone-black gradually falls between the red-hot walls, and is raked out from below. The column of bone-black is sufficiently compact to prevent the ingress of much air, and the consequent burning of the carbon which would thence result. The red-hot charcoal as it is raked from below is thrown into metal boxes to cool; it is then sifted to remove the powder which has been formed, and is fit for use again.

The animal charcoal effects not only the separation of the coloring matters, but also that of the excess of

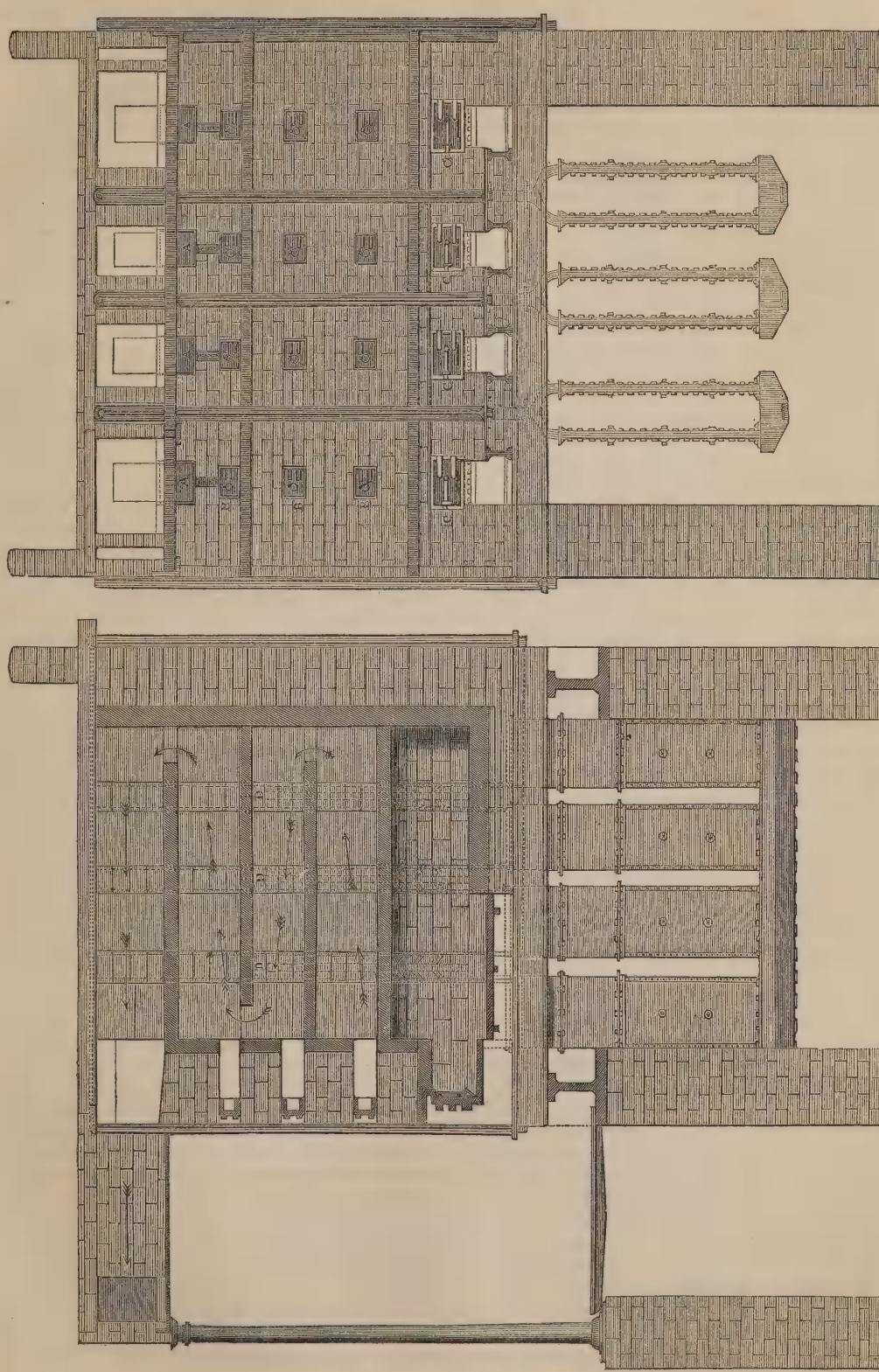
lime present in the sirup, and in the vivification of the spent bone-black this lime of course remains behind. It is proved, however, that the lime does in nowise impair the decolorizing power of the charcoal. It has been supposed that such lime forms phosphate of lime with the phosphoric acid contained in the coloring matters of the juice, and thus on their carbonization gives rise to a charcoal having the same decolorizing power as the original bone-black derived from animal organization. But the gain from this must be trifling.

The kiln made by Mr. CHANTRELL of Liverpool is now becoming more and more extensively used. It is of firebrick. Fig. 558 shows the kiln in elevation. Above is a hot floor, on which the charcoal is dried before it is strongly heated. The hot floor is seen also in the longitudinal section, where it is shown to be heated by the flux which comes from the furnace on its way to the chimney. The kiln represented here contains twelve chambers for the charcoal, each two feet long and three inches broad. In front there are three, and in the side view four behind each furnace door. These chambers or slits receive the charcoal at the top after drying, and, being filled up with it and heated to redness, all the organic matter in the charcoal is destroyed. When this is done, or in about forty minutes, the slide at the bottom is removed, and the charcoal falls into coolers or iron vessels somewhat narrower than the red-hot chambers. Each chamber divides into two coolers, which are exposed externally to the air, and allow the charcoal to become black, removing all fear of burning or uniting with oxygen, when it arrives at the measuring box at the bottom.

The elevation shows the furnace doors, and above them three doors to open into the flues which circulate among the chambers, as seen by the arrows in the longitudinal section. Each door has a spy-hole, which is usually kept covered. It is used to inspect the condition of the flue as to heat and cleanliness. Three perforations between the furnaces at D are holes for conveying away the gases which are generated. On the elevation the iron braces are seen at the side and between the kiln doors. This kiln is said to require much less coal than the iron pipes, saving, according to some, seventy per cent. Certainly we know the greater conducting power of heat possessed by iron. For this reason it is used for cooling, whilst bricks are used for containing the heat. Some persons expose the charcoal to the air some days before using it, believing that it is improved thereby. Many people carefully avoid using it warm. There may be a true foundation in these customs, but some careful observers have looked in vain. It is common in London for the sugar refiners to have no charcoal of their own, but to obtain it from the charcoal burners ready for use, returning it again when it is used. For the use of a ton they pay thirty-five shillings. This may suit the London method of filtering, which is slow; but it will not suit the Lancashire method of rapid filtration. The first may last a week or more; the second only two or three days.

The burning of charcoal may become a great nuisance to a neighborhood, if not watched. The sugar sometimes left in it is decomposed, and a very

Fig. 558.



pungent vapor is sent off, whilst salts of ammonia also are found in it. To avoid these evils, it is needful to wash the charcoal with great care as soon as it has done its work. Charcoal usually contains seven or eight per cent. of carbon, and when this is removed the charcoal is of little value. It is easily removed if heated in contact with air. Its value is about thirteen pounds per ton, or perfectly dry about fourteen pounds. There is a large amount of soft charcoal, which readily goes into dust; hard charcoal is more valuable.

Charcoal is sometimes allowed to ferment, in order to free it of its acquired impurities. This fermentation generally means merely the action of a weak acid—dilute muriatic. It is useful in beet-root establishments, on account of the large amount of lime needed to throw down the substances in the juice. In the sugar, or in the juice of the sugar-cane, no such excess of extraneous matter exists, and no large excess of lime ought to be used. Such at least is the opinion of the writer, and his experience has not been small. Charcoal itself is like a cavern of mysteries, the more it is studied the more wonderful are its secrets. Science has not yet approached the difficulties as seen in practice, and partly overcome.

A mode of renewing the charcoal, by passing heated steam through it, is in actual use in France. The charcoal need not be taken from the filter, but constantly renewed *in situ*. The process may be conducted for a long time, but as far as inquiries have extended, the plan is actually more expensive than burning in kilns.

No substitute for animal charcoal has been found to approach it in value. It must be hard enough to retain its form after years of use and frequent movement. It must also be porous, and must contain fully seven per cent. of carbon.

The sirup after passing through the bone-black filter is in the state of maximum purity. The subsequent processes of the sugar-maker consist in the removal of the water. This is effected by evaporation.

4.—*Evaporation*.—The modifications of the method employed in evaporating are four:—

1. Evaporation assisted by artificial currents of air.
2. Evaporation by fire in open or closed vessels.
3. Evaporation by steam-heat in open or closed vessels.

4. Evaporation by steam-heat *in vacuo*.

The sirup after treatment with bone-black is run into the evaporating or concentrating pan; the shape of this is various according to the method of concentration to be employed. In a patent taken by G. KNELLER the heated sirup in the pan was submitted to the action of currents of cold air, which was blown through it from a perforated copper pipe immersed in the sirup. The currents of air performed the double purpose of subduing the heat of the sirup and of removing the vapor of water which was formed. The apparatus employed by M. HALLÈTE was based upon a similar principle. It consisted of two concentric copper cylinders, so closed at top and bottom with circular discs as to form a cylindrical jacket. This jacket turned upon an axis in an inclined direction, and was heated by a current of steam. The sirup was allowed

to fall upon the surface of the internal cylinder at its upper end. The heated column of air and aqueous vapor in the internal cylinder determined an upward draught, which carried off the vapor; while by the rotation of the jacket the sirup was spread by centrifugal force into a uniform film upon the internal cylinder, thus exposing a great surface to the drying current. M. CHEVALIER devised an apparatus which combines the principles of those of KNELLER and HALLÈTE. The sirup in the evaporating pan is heated by the action of a coil of steam-pipe immersed in it. The pan is provided with a false perforated bottom. Air which has been heated by passing through pipes heated in a separate vessel, is blown by machinery into the pan below the false bottom. It ascends and escapes as bubbles through the perforation of the bottom, carrying with it the aqueous vapor in its passage through the sirup. This apparatus is said to be very effective and rapid in its action, but the fuel required for its working is great. A simpler and equally effective plan is that proposed by Mr. GADDESSEN, which is thus described by Dr. EVANS:—

This gentleman's apparatus consists of an iron or copper pan, having nearly the form of the half of a hollow cylinder, in which is placed a drum or wheel adapted to the shape of the vessel, and formed of a number of metal rods so arranged that the evaporating surface given to the sirup is increased as much as possible. The wheel, half its circumference being immersed in the liquid, is kept constantly revolving, so that by exposing fresh portions of the heated sirup to the action of the atmosphere at each succeeding revolution, the evaporation of the aqueous particles is rendered more rapid than it otherwise would be, while the temperature is, at the same time, in a corresponding degree reduced. The time required to take off a skip in a pan containing one ton of sugar varies from two and a half to four hours, and the temperature of the sirup ranges from 150° to 180°. From the principles upon which this method of concentration is based, it is evident that its successful working will depend upon the degree of dryness of the atmosphere, and upon the rapidity with which the air passes over the surface of the sirup. The apparatus should therefore always, when it is practicable, be placed at the windward side of the boiling-house; at all events it should be beyond the influence of the vapors which arise from the evaporating vessels.

Some manufacturers assert that the revolution of the drum is apt to occasion frothing in the sirup, however pure the latter may be—especially, as is sometimes the case, if the rods on the drum are of wood instead of iron. The advocates of GADDESSEN's pan, on the other hand, maintain that the frothing, when it occurs, arises from albuminous and other impurities in the sirup, and that it may be entirely prevented by the addition of one or two drachms of washed butter or a few drops of fresh olive oil—an addition which, in all sugar boiling, hinders the formation of permanent bubbles, and, in GADDESSEN's process, allows the drum to be worked at a greater velocity, and the evaporation to be thereby accelerated without inconvenience.

When the water is expelled from the sirup by the simple application of heat to the evaporating pan, and without the aid of mechanical means to increase the evaporating surface of the sirup, the heat applied must be greater than when such helps are had recourse to, in order that the sirup may be concentrated in a reasonable time. For this reason, the evaporating pans must be so constructed and filled with the sugar as not to allow the parts of the pan above the liquid to become unduly heated, and to cause thus the caramelizing and blackening of the sirup. Great care must on this account be employed in the firing of such pans. Where open pans are employed, that is, where the sirup is boiled at the ordinary atmospheric pressure, the approach to sufficient concentration for removing to the crystallizing pans may be judged of either by the physical appearance which a portion of the sirup presents when removed from the evaporating pan, or by the temperature which the sirup assumes; for a sirup consisting wholly of crystallizable cane sugar and water, boils at temperatures which are higher, according as the quantity of water it contains is less. The examination of the physical appearances of the sirup for this purpose is called proof by touch. When the sirup is approaching concentration, it presents the following appearances in succession:—

1. A copper ladle dipped into it, inverted and withdrawn in such a manner that the edge of the ladle is horizontal, is covered with a layer of sirup of uniform thickness, which drains off, not in isolated streams, but, for some distance, in a continuous sheet.
2. On taking a pinch of the sirup between the fore-finger and thumb, and depressing the latter, the sirup separates, and the drop on the finger is nearly equal in size to that on the thumb.
3. By the separation of half an inch, a thread is drawn out, which finally breaks below, the end of the thread becomes hooked, and it rises slowly towards the finger.
4. The same thing occurs at a greater distance, the end of the thread is folded back, and gives to the thread the shape of a long ribbon or stick, which rises more rapidly than before.
5. After a greater separation of the fingers, the thread breaks, being very fine at the end, which turns aside and twists up like a corkscrew. It does not fold itself upon the rest of the thread as before, and the thread does not increase in volume, except by the cohesion, which draws the particle towards the finger, which is the only adhering point. A little more concentration prevents the thread from shrinking at all.

The proof by blowing is performed by dipping a perforated copper ladle—the holes in which are about one-eighth inch in diameter—into the sirup, and then, inclining its edge at an angle of about 45°, the workman blows strongly into the cavity of the ladle, whereon, if the sirup be well concentrated, bubbles are formed of half an inch in diameter on the other side of the ladle.

The following table shows the connection between the temperature of the sirup and the amount of water it contains for one hundred parts by weight of sugar. It shows, also, the degrees of concentration at which some of the above-mentioned terms are applied. The table is from DUMAS:—

Temperature. Fahrenheit.	Composition.		Name.
	Sugar.	Water.	
213·8	100	124·66	—
215·1	100	106·81	—
215·6	100	88·96	—
217·4	100	91·11(?)	—
219·6	100	53·26	—
220·1	100	47·26	—
221	100	41·63	—
223	100	36·00	Weak hook.
226	100	28·52	Thin thread.
231	100	25·05	Common hook.
233·6	100	18·84	Strong hook.
246·2	100	—	Ordinary bubble.
248	100	—	Perfect bubble.
234·5	100	—	—
239	100	16·29	—
251	100	—	Small fracture.
263·3	100	10·92	Large fracture.
270·5	100	—	Fracture on the finger.
271·4	100	—	—

It appears from this table that when the sirup has reached 248°, although water continues to be given off, yet the temperature sinks to 234·5°, after which it again rises. If there be no error in the observation, this is probably due to the formation of a definite hydrate of sugar, which requires a higher temperature for its decomposition; but that decomposition being once determined, the water expelled takes up the caloric as latent heat in its conversion into steam, thus depressing the temperature of the sirup.

The danger of caramelizing portions of the sugar, and thus impairing not only the beauty of the product, but, by the formation of noncrystallizable sugar, diminishing the quantity obtained, has caused sugar manufacturers to seek for means by which this evil may be avoided. The vacuum pan of HOWARD answers this purpose completely. It is universally employed in Europe, and to a large extent in the Colonies.

All liquids boil at lower temperatures when the pressure upon them is lessened. The pressure exerted by the atmosphere upon liquids in open vessels varies from fifteen to ten pounds per square inch. In a vacuum no such pressure exists, and, therefore, liquids boil at lower temperatures than in open vessels. HOWARD'S process for concentrating sirups consists in heating them in vessels from which the air has been wholly or partially withdrawn, that is, in more or less perfect vacua. The heat is applied to the sirup in the evaporating pan by means of a pipe containing high-pressure steam.

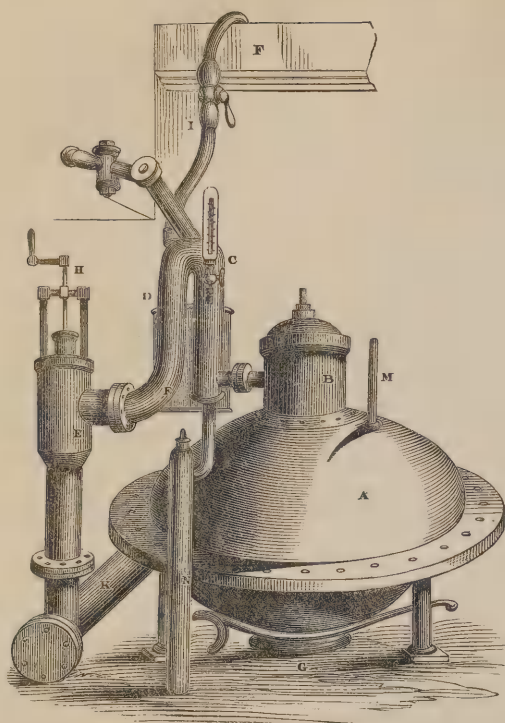
The following table gives the boiling point of the sugar in a vacuum pan, at different pressures of the air:—

Height of barometer in inches.	Boiling point.		
	Fahrenheit.	Centigrade.	Reaumur.
0·74	115	46·11	36·89
0·86	120	48·89	39·11
1·01	125	51·67	41·35
1·17	130	54·44	43·56
1·36	135	57·22	45·78
1·57	140	60·00	48·00
1·80	145	62·78	50·22
2·05	150	65·55	52·44
2·36	155	68·33	54·67
2·72	160	71·11	56·88
3·10	165	73·89	59·11
3·52	170	76·67	61·33
4·00	175	79·44	63·56

The drawing on next page—Fig. 559—shows the various parts of HOWARD'S pan.

The principles employed in evaporating by HOWARD'S method, namely, the use of steam as heating

Fig. 559.



agent, and the employment of a vacuum, have received several modifications. These are principally those of ROTH, DEROSNE and DEGRANDE, and RILLIEUX.

The modification of ROTH consists in the absence of the air-pump to produce the vacuum. The vacuum is formed by condensation alone, and this condensation is effected in a separate vessel. It has not been found possible to work so entirely free from air. This process cannot be used without some aid from a pump.

The evaporating pans of M. DEROSNE differ from those of ROTH in the shape of the condensing vessel, which in the former's consists of a tube bent like a cracker, the folds of which lie in a vertical plane. Instead of effecting the condensation by water, DEROSNE employs sirup, which, being allowed to flow upon the upper fold of the tubes, trickles down from one fold to another. In condensing the steam in the inside of the tube, the sirup which flows down the outside of the tubes becomes itself heated, and parts with a portion of its water; while the heat of the tube and its vertical position determine an ascending current of air, which removes the vapor of water as it is formed.

DEROSNE's plan has been modified by M. DEGRANDE by the introduction of an air-pump to complete the vacuum, and employing the vapor given off from the sirup in one pan to heat the steam-pipes in a second

one. It should be mentioned that in DEROSNE's apparatus the sirup is allowed to flow from the pan into a closed vessel, so as not to impair the vacuum. The disadvantages of the plans of DEROSNE and DEGRANDE consist in the complexity of the apparatus they require; in other respects an excellent sugar is obtained with great rapidity.

The system employed by RILLIEUX is the same in principle as that of DEGRANDE. The vacuum is formed by an air-pump worked by a steam engine, and a succession of evaporating pans are employed, the sirup of each pan being heated by the vapor from the sirup of the preceding pan, and furnishing itself the vapor for heating the succeeding sirup. Each pan, however, may be connected directly with the boiler. The steam-pipes in each pan do not form, as is usual, one single layer, but they are piled upon one another like the boiler pipes of a locomotive.

5.—*Crystallization*.—Each mould stands over a separate earthenware basin, or over a leaden trough, which conducts to a cistern. When the moulds are filled with the concentrated sirup—the bung being in its place—the sirup after six or eight hours shows signs of crystallization. It should then be repeatedly stirred, so as to equalize the temperature throughout, and to distribute the crystals already formed, from which the subsequent crystallization is carried on. Several patents have been taken out for the purpose of using atmospheric pressure. The small ends of the sugar loaves may be united together, or, in other words, all may meet in a tube which runs along and connects itself with the pump. In

this way they are all readily drained. The loaves are then removed to a warm room of uniform temperature. After twenty-four hours' standing the loaf is set, that is, it has attained a sufficient consistence to admit of draining. It is with concentrated saccharine liquids as with all other saturated saline solutions, namely, that such a solution, during the process of crystallization, deposits crystals which are larger according as the crystallization takes place more slowly. Hence, if the sugar be required in large grains, the sirup should be kept still; if a fine-grained sugar be required, repeated agitation must be employed during the process of solidification. When the loaves are judged to be sufficiently set the bungs are withdrawn from below, and the mother liquid, which is of course a saturated sirup at the temperature employed in crystallization, is allowed to drain off for two or three days. It is a well-known fact that when a solid body separates in the crystalline form from a solution which contains foreign soluble impurities, the crystals are more free from such impurities than the liquid from which they separate. Hence, in the above-formed loaves, the crystals of the loaf are purer than the sirup which runs from them; they would indeed be of the maximum degree of purity were it not for the sirup with which they are still moistened. The next process consists in the removal of this adhering sirup. Formerly this was effected by the method of *claying*.

This consisted in scooping a shallow hollow in the thick and upper end of the loaf by means of an instrument called a bottoming trowel, and filling the hollow with a paste made of fine white clay and water. The water gradually leaves the clay and percolates downwards through the loaf, carrying with it the colored sirup, and dissolving also from the first strata a portion of the crystallized sugar. In its descent, as it becomes saturated with sugar, it acts simply by displacement, forcing out the colored mother-liquor or molasses from below. The fact that in this process a portion of the solid and whiter sugar is dissolved renders this method a wasteful one; it is now but little employed. In the process of *liquoring* the principle of displacement is alone employed. In this method the top of the loaf is levelled, and upon it is poured a saturated or strong solution of colorless sirup; as this sinks down it displaces the colored molasses. When the sirup commences to flow nearly colorless from the hole below, the loaf is allowed to drain, then inverted to distribute the sirup uniformly, and transferred to the drying oven. M. PAYEN mentions the following points in connection with the process of liquoring:—

1. The liquor must be sufficiently charged with crystallizable sugar to dissolve little or nothing in filtering.

2. The density of the liquor must be nearly the same or very little less than that of the displaced sirup; for if too dense it would flow badly: if too dilute it would escape without removing the sirup or molasses adhering to the crystals. To attain this condition the sugars used for preparing the liquor must be more impure in proportion as those to be liquored are so; for saturated sirups are more dense and viscid when they contain non-crystallizable sugar.

3. The crystallization in the moulds must be regular and not too compact; and for this end it must commence and terminate in the same vessel.

4. The temperature of the room in which the liquoring is performed should not vary much, and should be at least 70°. The operation of liquoring is performed as follows:—The crystallization is complete in twenty hours. The superficial crystalline crust is then removed from the base of each loaf with a trowel, and the surface is levelled. These surface scrapings—or rather those of a previous day's work—are added to sirup until the density becomes 67° Twaddell at 60°.

About five pounds of this liquor is poured at one time into each drained mould, containing about sixty pounds of crystallized sugar, which corresponds to ninety-three or one hundred pounds of concentrated sirup, put into the mould. This operation is repeated three times at intervals of twelve hours, and the sugar is then allowed to drain for three or four days. At the end of this time it may be put into casks, and it will be much drier and less alterable than ordinary brown sugar.

Instead of allowing the mother-sirup to drain out by the force of gravity alone, recourse is sometimes had to the pressure of the atmosphere. This is applied in the following manner:—The moulds are rectangular boxes, about six feet long, four feet broad, and two deep; they are called *tigers*. They are provided with false

bottoms formed of wire gauze or perforated plate. When the sugar is set the space between the real and false bottom is exhausted, and the pressure of the atmosphere forces the sirup from among the crystals of sugar into the hollow space. The mass of sugar which has been thus rapidly drained is either dried at once or previously stamped, to give it compactness, into brass moulds. It has been supposed in the above account, that loaf sugar is to be made; if so the filtered part is reboiled and again crystallized, by which means a sugar of an inferior color is obtained. The filtered portion of this second crystallization is also boiled down and crystallized, producing a third quality of sugar. The liquor from this last is the *treacle* of this country, or if clarified, it is the *golden sirup*. By this means the sugar is divided into *fine*, *seconds*, *bastards*, and *treacle*. Lump sugar is not necessarily white, nor is moist sugar necessarily brown. In making any of these sugars, the crystals are not allowed to stand and harden, unless lump sugar be wanted. If lump sugar be not wanted, the rotary machine is used instead of drainage to separate the sirup. At the same time, in the rough management of the colonies, one boiling down is common, the molasses coming from it being used for rum, or perhaps entirely thrown away, as frequently happens in Cuba, far from the coast.

The sugar with the adhering sirup is then introduced into the centrifugal drying machine, which is shown in Fig. 560 succeeding page.

The crude sugar is placed in the cavity as far as the rim extends. On bringing the drum into gear the box is turned round with a velocity of about 1000 to 1700 revolutions per minute. It follows that the contents of the box are forcibly pressed outwards. The crystalline grains are retained by the copper casing, while the molasses is forced through its interstices and thrown off into the outer reservoir. A rotation of a few minutes is sufficient for the drying of a charge of sugar. The machine is then stopped and the sugar is scraped out with a trowel. The sugar so obtained has seldom the brilliant whiteness of loaf sugar, nor does it possess the same compact form; but the immense saving of time effected by the use of the centrifugal drying machine is bringing it more and more into use.

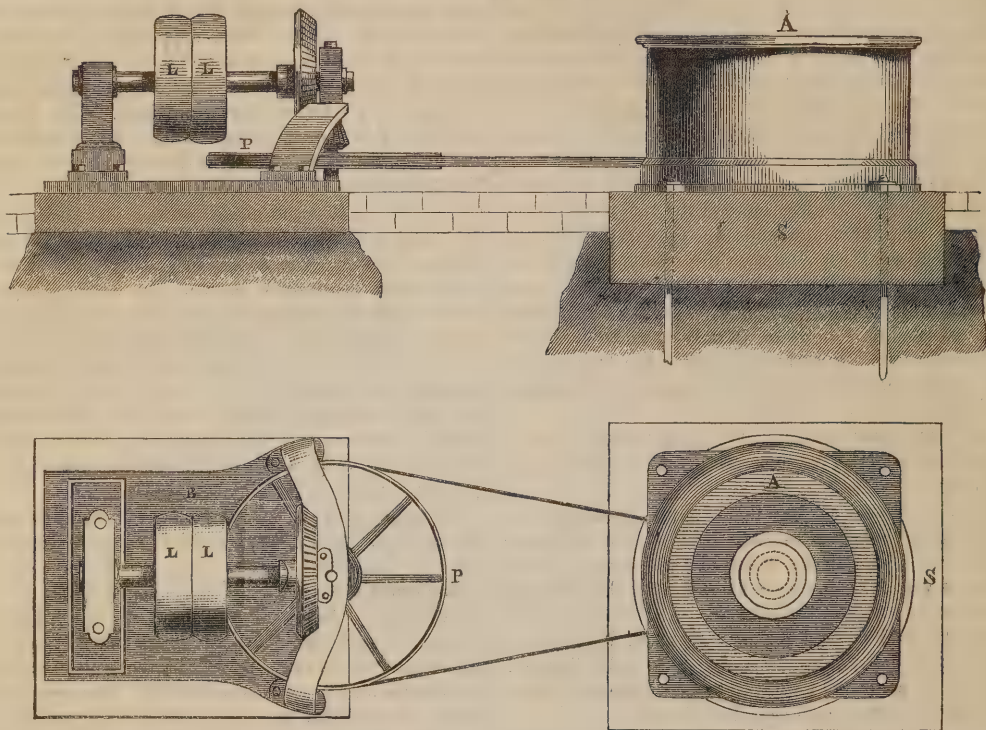
The very large crystals, remarkably distinct and difficult to dissolve, which have of late been manufactured, are made by boiling to partial crystallization in the vacuum pan; drawing off half and adding fresh sirup, this may be repeated to any size of crystals. In countries where the cane is grown, it is usual, to employ the molasses or treacle for the manufacture of rum, or to export it to Europe to the sugar refiners. The coarser kinds of sugar, moreover, which are made from unclarified or imperfectly clarified juice, and which are known as moist or brown sugar, are also bought by the European refiners, who separate the white sugar from the molasses which they contain. A great loss is experienced by the transportation of sugars from the Americas to Europe. This is in part occasioned by the gradual and more complete separation of the molasses which drains off and escapes into the hold of the vessel, such draining being greatly facilitated by the motions of the vessel; but partly and perhaps

chiefly by the escape of the sugar which such motions produce. The whole bulk of a sugar vessel becomes impregnated with sugar, and metallic bodies in the ship which are far removed from the sugar in cargo, become speedily tarnished and corroded, owing

to the deposition upon them of particles of sugar, and the subsequent fermentation and acidification of such sugar.

Sugar Refining.—The great difference in price between coarse and white sugar, the cheapness of fuel

Fig. 560.



and the facilities of making and repairing machinery in Europe, have given birth to its sugar refineries. In the sketch of the preparation of sugar from the cane—Fig. 560—it is supposed that the whole process is carried through at once. But where the crude products from the colonies are bought by the European refiner for purification, his process differs only from the above-described one, inasmuch as he has at starting solid brown sugar or molasses to deal with, instead of the juice of the cane at its natural degree of dilution. The refiner, therefore, at starting has to dissolve his sugar or dilute his molasses to the necessary degree in order to submit it to filtration. The processes which the refiner has to perform depend, of course, entirely upon the nature of the raw sugar with which he has to deal. In most cases the material which comes into his hands has undergone the process of defecation, but not that of filtration, or the filtration where performed has been very incomplete. To dissolve the raw sugar warm dilute sirup is employed. The sugar is agitated with the sirup by means of a flanged wheel worked by machinery, and the product is then pumped up to the top of the refinery. It then undergoes the various processes of filtration through cotton bags and charcoal and evaporation, which have been already described. In refineries the evaporation is always effected in

vacuum pans, and the drying is generally performed by the centrifugal machine.

Abridged description of the Process of Refining.—As conducted in sugar works here, the process of refining consists simply of the following operations:—The bags are cut up and thrown aside to have the sugar washed out of them. They may be thrown away, or they may be sold for paper, according to their value. The sugar is thrown into a pan which will contain from two to three tons of it in solution. Sometimes it is broken up by a spade, sometimes by machinery cutting it with revolving knives. It is heated more or less; some bring it to boiling. Frequently, if not generally, it is treated with a little lime water; this is called defecation, or blowing up. It is then sent through the bag filters, from which it passes into great iron tanks, where it waits till a charcoal filter is ready. It then passes on to the charcoal filter, and from thence to the vacuum pan to be boiled down. It is then set to crystallize. When this is done, it is freed from its liquid sirup or molasses by the centrifugal machine. Instead of being put into this machine, it may be poured into sugar loaf moulds and washed with sirup. This is sometimes called claying, and is made to sound mysterious. Both processes are one in principle, as sugars when put into the centrifugal machine are in reality washed with sirup.

	Beauvé	Fahr.
Defecation takes place at	27	and about 180°
Syrup runs from the charcoal at	27	" 80°
Syrup from first crystals,	40	" 100°
Reduced to 25° Beauvé for boiling to obtain second crystals—		
Drainage from second grain	40	" 100°
Drainage from third grain	34	" 80°
Drainage or treacle at the last	41-43	

Sugar is soluble in one-fifth of its weight of boiling water, and one half its weight of cold water. Six pounds of sirup, containing five of sugar and one of water, deposit on cooling three pounds of sugar, leaving three pounds of sirup containing two of sugar. Sirup containing one of water to five of sugar boils at 238° Fahr., but it is evaporated till the boiling point is as high as 240° or 242°. If evaporation takes place in the open air, this temperature is actually attained; if HOWARD'S pan is used, no matter what variety of shape be chosen for the pan, the vacuum brings down the boiling point as low as to 145°, but on an average we may say that the sugar is boiled down in the vacuum pan at 160° Fahr. In the open air the appearance indicates the condition of the sirups. In this country the vacuum being of necessity used, a specimen of the sugar is removed by the proof stick. This is simply a brass rod, which is driven from the upper part of the side of the vacuum pan down an aperture made of the same size as the rod. When it reaches the bottom, the rod is twisted half round by the cross handle, and opens a communication with the end of the rod and the sirup. In the end of the rod is a groove into which the sugar enters; the rod is half turned again and drawn out, and the entrance is closed as at first. A portion of sugar is taken between the finger and thumb, and the indications are obtained which have been already described. When the sugar is ready, the vacuum pan is opened, and the sugar falls out into a large copper. There are various ways of disposing of it at this period; but in every case it is put into a series of small vessels. If loaf sugar is to be made, it is here heated up to nearly boiling. In some places it is put into pans of earthenware not unlike, or it may be exactly like the sugar loaves, even although there is no intention of making loaf sugar. Sometimes these vessels are made of zinc, and painted; iron has been tried. Sometimes the vessels are very large, containing from one to ten hundredweight of sugar. These vessels are allowed to cool slowly. For fine sugar 90° Fahr. is used, for common 115° Fahr., during which time the crystallization takes place. Every vessel must, of course, have an aperture at the bottom, which is opened for drainage as soon as crystallization has commenced. Each vessel has a drain under it communicating with a general receiver; when the drainage ceases the sugar—in houses on the newest system—is taken to the centrifugal machine, unless, of course, loaf sugar be made. The time of standing is from two to six days. The sugar when crystallized is surrounded with colored sirup, not so pure as the sirup which comes from the charcoal; time and workmanship have produced a dark hue again. It has become exceedingly hard, the crystals being strongly held together, some very dark-colored sirup still remaining. It is removed from the moulds or forms by a pickaxe and spade, or

more frequently by a cutter, which is of the same curve as the inside of the crystallizing vessel, and which, being driven by considerable force, scoops out the sugar readily. In order to remove the liquid about three minutes are required. It is often the case that the sirup has hardened too much, and it is then needful to soften it with a jet of steam, which enters the side of the *hydro*, as the hydro-extractor is technically called. The liquid, with all the impurities, flows off by an underground pipe, and is used again. The first crystallization produces fine sugar; the next, seconds; and the third, bastards. The uncrystallizable treacle is the fourth product. When loaf sugar is to be made, the moulds are of the well-known size, containing about thirty pounds.

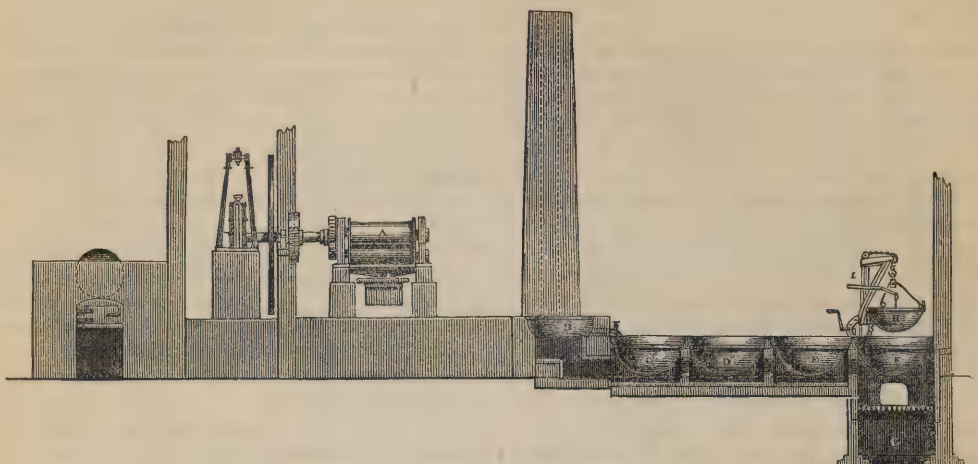
Special description of the more complex machines, with some additional details.—In order not to load the account of the processes used in sugar refining with the description of too many machines and minute details, the special parts of the apparatus will be more minutely described in this part of the article, and additional particulars given for those who desire to enter more fully into the subject.

Sugar Mill.—Fig. 561 represents the arrangement of mill and boiling-house as used in the colonies. The size of a sugar plantation in the West Indies varies from one hundred and fifty to two thousand acres, producing from one hundred to five thousand hogsheads of sugar per annum. The boiling-house should be situated in a central position on the plantation, to avoid loss of time in carriage of the canes from the fields to the mill. The mill A—Fig. 561 and drawn to a larger scale in Fig. 554—consists of three heavy cast-iron rollers, about two feet four inches diameter and four feet long, fixed in strong cast-iron frames. The canes are fed from the feeding table, B—Fig. 554—and are squeezed twice between the top roller, C, and each of the two lower rollers, D and E. The megass, or solid part of the cane, after being squeezed passes from the mill by the shoot, F. A trash-turner, G, is placed between the two lower rollers, and under the top one, to guide the canes between the upper and second lower roller. The spaces between the upper and lower rollers are adjusted by the screws, H H; the space between the top and first lower roller should be a quarter of an inch, the second lower roller being set close to the top one. The juice drops into a trough below, from which it runs to the clarifiers, directly if possible; but if the mill cannot be placed sufficiently high to command the clarifiers, a pump is used, worked from the top roller spindle and fixed in a cistern under the trough. The speed found most advantageous for expressing the juice from the canes is at the rate of twenty feet per minute at the periphery of the rollers. The two lower rollers are driven from the upper one by spur pinions, I I I, keyed on the ends of the spindles. The mills are driven by steam—as shown in the drawing—but sometimes water or wind power is used according to the physical character of the country in which it is used. Cattle are also employed to work them in some places, especially on small estates where fuel is difficult to be obtained. In cattle mills the rollers are usually vertical instead of horizontal, being simply driven by yoke arms fixed to the spindle of the

centre roller; the cattle working from the ends of the arms. The rollers, three in number, are fixed in a line with each other, the two outside ones being driven from the centre roller by spur pinions keyed on the tops of

the spindles. The weight of the rollers is carried on hardened steel plates fixed in the framework of the mill; a steel toe being fitted to the bottom of the spindle to bear on the steel plates. The canes are fed

Fig. 561



between the first and centre rollers, the megass coming out on the same side between the centre and third roller, a piece of plate-iron bent to a sweep corresponding to the diameter of the centre roller, guiding the canes round to be squeezed the second time between the centre and third rollers. The juice falls into a trough placed under the three rollers. A cane carrier is often used to supply the canes to the horizontal mill. It consists of two endless pitch chains working over barrels, the upper one being driven from the spindle of the top roller by spur-wheels or another endless pitch chain. On the outer side of the chains are attached boards sliding over a wood framing, with a ledge on each side to keep the canes on the carrier. The top of the carrier is level with the top of the feeding table and extends some thirty feet from the mill. The canes are delivered on the carrier instead of on the feeding table of the mill, which facilitates the work, besides causing the mill to be more regularly supplied with canes than when they are delivered on the feeding table of the mill.

Clarifiers.—The juice, as it is expressed from the canes, runs into the clarifiers, one of which is shown at B—Fig. 561. Two are generally used, one filling while the juice in the other is clarifying. They are generally cylindrical copper-pans with crown or arched bottoms to resist the action of the fire. They are fitted with a large cock at the bottom for running the juice into the first copper. They are set in brickwork at the end of the battery, the flame passing under them previous to going into the chimney, a damper being provided to each to direct the flame under the one that is full. Milk of lime is added sufficient to neutralize the acid in the juice.

The battery is a range of pans, C D E F, with the fur-

nace, G, at one end. The fire passes under the range, and under either of the clarifiers to the chimney. The pans are hemispherical in shape, diminishing in size from the first copper, C, under the clarifiers, to the striking teach, F, in which the evaporation is completed. As the juice becomes concentrated in the pans nearer the furnace, they are filled up from those behind them, until the striking teach is sufficiently full, and the sugar in it concentrated to the granulating point. It is then ladled into shallow wooden vessels, where it is allowed to cool, and from thence it is conveyed into the hogsheads in the curing-house. An improvement in the old system of lading from the striking teach to the coolers is now much used. It consists of a copper pan, H, fitting the inside of the striking teach as accurately as possible. At the bottom of this pan or dipper is a large valve opening towards the inside of the dipper, the valve being worked by a lever, I, over the side, and a chain from the ground. The dipper is attached to a crane, J, which commands the striking teach and a gutter to the coolers. The advantage of the dipper is that the striking teach can be emptied and refilled in much less time than by the ladle, and consequently there is not so much risk of burning the copper and the sugar. A gutter is made in the brickwork at the side of the battery into which the impurities that rise to the surface of the liquor are skimmed. The skimmings—from which are distilled the best rum—are conveyed from the gutter to a tank previous to fermentation. The floor of the curing-house, in which the molasses is drained from the sugar, is composed of a series of gutters which incline to the centre of the building and deliver their contents to a main gutter which communicates with a tank for the molasses. The hogsheads are placed on end over the gutters,

small holes being bored in their ends for the passage of the molasses. The sugar, after remaining in the curing-house about fourteen days, is ready for shipment, and is known in the market as raw or muscovado sugar.

The megass, after passing through the rollers of the mill, is dried and used as fuel for the battery; being better suited for that purpose than any other convenient fuel, as far as heat goes, a very quick fire being required. A saving of fuel is effected by placing the boiler of the cane-mill engine at the end of the battery, so that the products of combustion may pass from the battery through the boiler flues, previous to going into the chimney. A furnace is fitted to the boiler for use before the battery is at work in the morning, and which can be shut off when not required, the waste heat from the battery being almost sufficient to work the boiler for the cane-mill engine.

In the striking teach of the ordinary battery there is a liability of the upper part of the teach becoming overheated, and so making the sugar of a darker color when it splashes up against it, depreciating its value. A pan made so that the heating surface is entirely covered with liquor is used in some places, called a *bascule* or tiltpan. It is a shallow, cylindrical, copper pan, about five feet diameter and two feet deep. It is furnished with a lip to run off the sugar, and works on a hinge under the lip. The pan is set over a fire, and when the sugar is boiled to the granulating point, it is tilted up by a lever and chain fixed to it. The sugar being turned out at once into the cooler, there is not the same risk of burning as in the ordinary fixed pans.

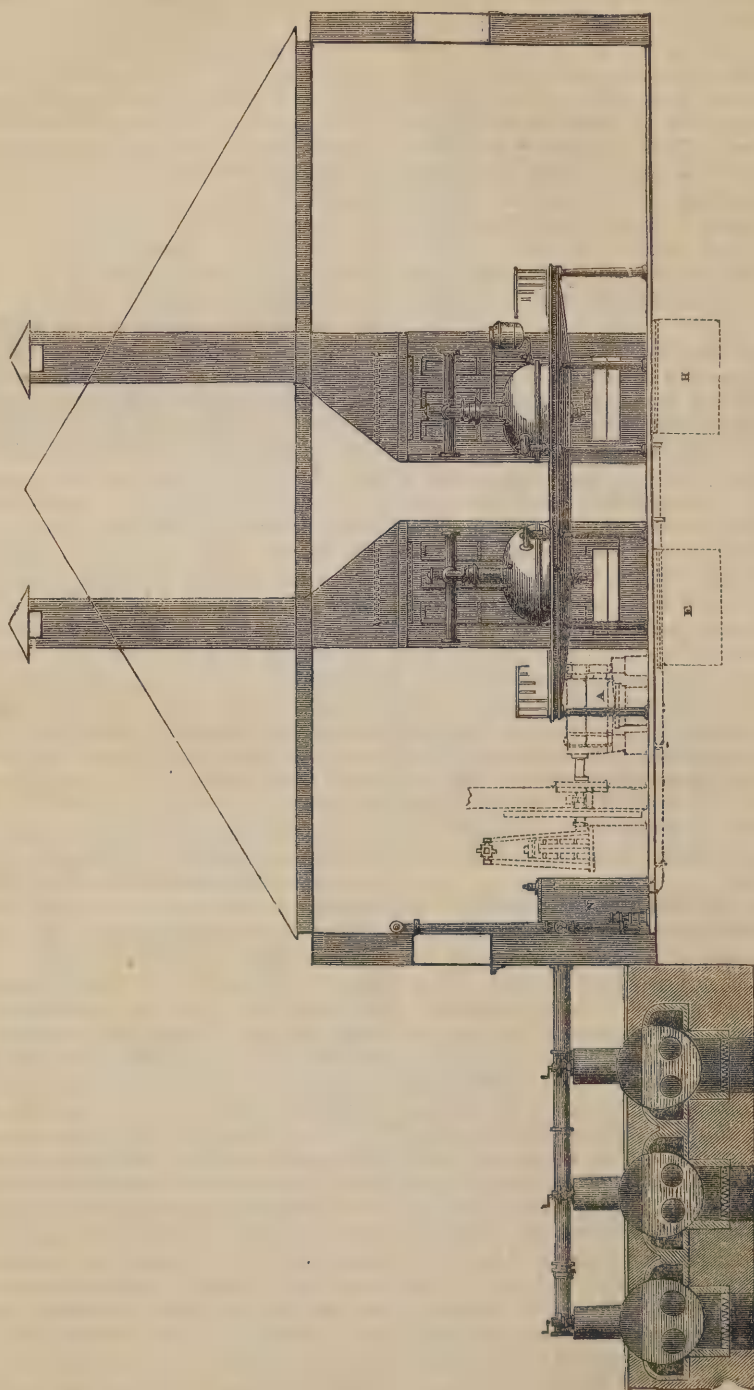
Rectangular copper pans with crowned bottoms have also been substituted for the hemispherical pans with cocks or valves, to empty them from the bottom. They are ranged side by side over the furnace, so that the flame runs under them from end to end; and there being no side flues, the metal of the pans does not become heated, and consequently the quality of the sugar is not injured.

Figs. 562, 563, 564 show a boiling house fitted up with the latest improvements in the machinery connected with the manufacture, for facilitating the process and improving the color and quality of the grain. It is worked wholly by steam heat, as being more economical in the working, and admitting of more perfect regulation of temperature. The juice from the mill, A—as described before—is forced up to the top of the building to the clarifiers by a *monte-jus* or juice elevator, B, consisting of a wrought-iron vessel into which the juice flows from the mill by a pipe and cock. Another pipe is fixed to the top of the monte-jus and rises to the required height, dipping down to near the bottom of the monte-jus; the steam being admitted at the top forces the juice up the pipe. This is more convenient than a pump, is cleaner, and not so liable to acidify the juice. The clarifiers, C C C, used here are hemispherical copper pans, hammered out of one piece of copper fixed by a flange laid off to an outer cast-iron pan, allowing a space between the pans for steam. A copper light course is fixed to the top, the heating surface not being required up to the top of the pan. A valve is attached at the side to regulate the supply of steam, and a two-way cock at the bottom;

the smaller branch being for the clarified juice, and the larger for the scum. The juice in the clarifier is raised to a temperature of 176°. Milk of lime is added sufficient to neutralize the acid in the juice. The heat is then continued till a scum, consisting of impurities present in the juice, has risen to the surface and appears about to crack. The time occupied in this should be about ten to twelve minutes from the commencement of the operation. The steam is then shut off and the liquor allowed to subside for fifteen or twenty minutes, when the scum will be found to remain at the top; some heavy matter, such as dirt, *et cetera*, will have fallen to the bottom, and between them will be the clarified cane juice, clear, and of a pale straw color. The clear liquor is separated from the impurities in the following manner:—At the bottom of each clarifier is a plug, ground into the top of the cock, with a rod and handle above the top of the clarifier. At the side of the plug are holes about three or four inches above the bottom of the clarifier, adjustable by a copper clip, below which all the heavy matter will have accumulated. The clarification then being complete, the cock is first turned on to the smaller aperture until the scum accumulated at the top begins to appear. The cock is then turned to the large way and the plug taken out. The heavy matter at the bottom and the scum formed during the process are conveyed to a cistern, from whence it is placed in bags, and any juice remaining in it is squeezed out, leaving only a small portion of solid matter behind. The clarified juice or liquor, after coming from the clarifiers, is passed through mechanical filters. The kind commonly used are rectangular cases of cast or wrought iron with an internal flanch at the top to support a copper box, about twenty inches deep, to receive the liquor to be filtered. At the bottom of the box a number of holes are drilled and screwed to receive the bells or connections, to which filter bags are attached. These bags are made of twilled cotton cloth, about six feet in circumference and six long, wove without a seam. They are inclosed in a strong open webbing, about eighteen inches in circumference, thus giving a large surface of filtering medium in a small space. The filters are shown at D D D. The liquor is drawn off at the bottom into a receiving cistern, E, to supply the evaporating pan. Steam cocks are attached to the side of the cases for cleansing them after use; and doors are fixed to them for changing the bags. The evaporation is here effected in vacuo, as being most advantageous, the liquor boiling at so low a temperature as not at all to discolor the liquor or alter the saccharine matter in it. The first cost, however, of the apparatus is increased, and alone prevents its universal adoption.

The vacuum pan, F, used for the evaporation of the liquor, consists of a copper pan fitted in a cast-iron steam case, allowing a space between for the steam, and on the top is a copper dome; the copper and iron pans and dome being accurately fitted and bolted together, so as to be perfectly steam and air tight. In order still further to increase the heating surface, a large brazed copper worm is fixed inside the pan. A manhole, with a ground brass cover, is attached to the top of the dome, from the side of which a pipe leads to the receiver or safety vessel, furnished with a glass

Fig 562.

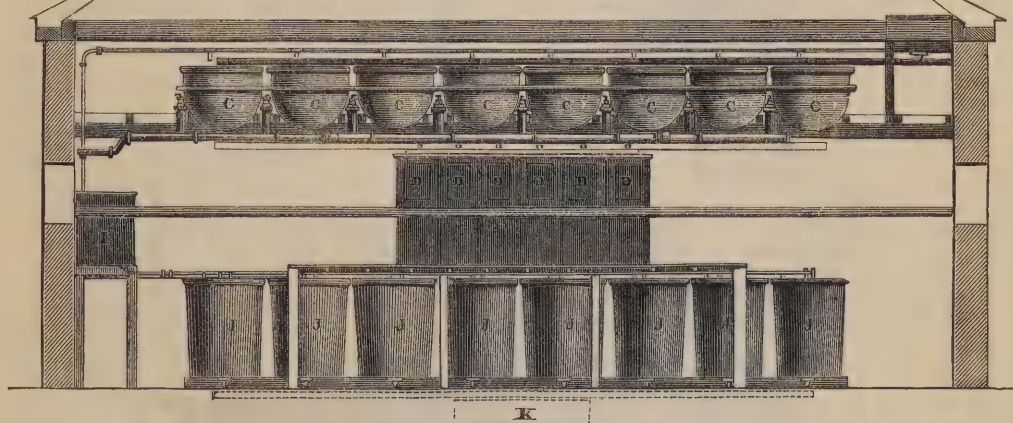


guage and draw-off cock, the use of which is that the attendant may see if the pan primes or boils over ; if it does, the sugar must fall into the receiver, and be indicated by the guage. A pipe from the top of the receiver, with a valve to shut off the communication, connects the pan with the condensers. The pan is fitted with a cock at the bottom for running off the liquor when sufficiently concentrated, namely, at about 36° Twaddell. On the dome of the pan are fixed a barometer ; a thermometer, with bulb dipping down into the liquor ; light and sight glasses for looking into the pan ; an apparatus for testing the concentration of the liquor without destroying the vacuum in the pan ; air-cock for letting in the air when the liquor is required to be drawn off ; and a steaming valve for cleaning the pan after work. Surface condensation is employed to maintain a vacuum in these pans, in

situations where there is not sufficient water to admit of condensation by injection being used.

The surface condensers are here shown, G & G. This process of condensation was introduced and patented by Messrs. PONTIFEX and WOOD of London, who have recently patented a simple and efficient method of connecting the pipes—admirably adapted for the colonies, and all places where skilled labor is difficult to be obtained. The condensers consist of one or more series of copper pipes, fixed to boxes at each end, with partitions to direct the current of the vapor. Above each series of pipes is fixed a trough always kept full of water, and so constructed that the water trickles in a gentle shower, uniformly spread over the pipes, so as to keep them well covered with a thin film of water; the lowest pipe is connected with a small pump, worked by the engine, which draws the condensed

Fig. 563.

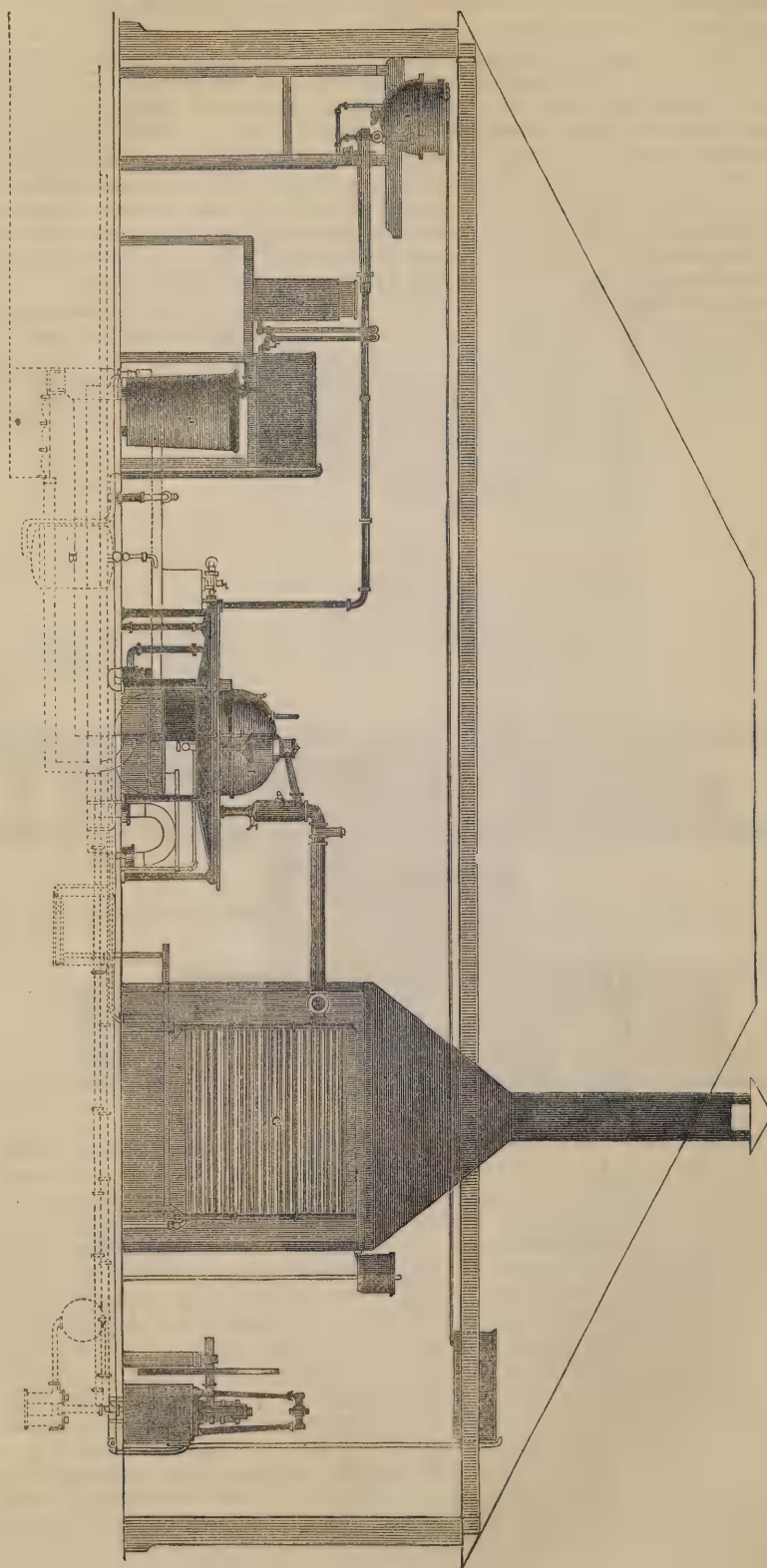


vapor from the pan, and any air that may have collected there. The improvement referred to consists in doing away with solder joints at the junction of the pipes with the case, the solder being liable to crack from the unequal expansion of the pipes, owing to the lower pipes being cooler than the upper ones, and the substitution of an elastic joint, which allows for the irregularity of the expansions, without injuring the vacuum; they are also easily replaced, not requiring any mechanical skill, and take up less space for shipment; these pipes and cases being packed separately. The superior economy of water in these condensers, is owing to the condensing water being evaporated and carrying away not merely sensible but latent heat. The ordinary method of condensation is similar to that employed in the condensers of steam engines, when the steam is led into a vessel, where it is brought into con-

tact with a stream of cold water. In this case, as the condensing water must not be allowed to become vaporized, all the heat it absorbs must be in the form of sensible heat, and it is said practically to require about thirty times the quantity of condensing water; but in these surface condensers the vapor which passes off from the surface of the pipes, not only carries off the sensible heat, but it also renders latent a great amount of heat in its conversion into vapor, the quantity of water passing off from the surface being equal or nearly so to the quantity condensed inside the pipes. The water which falls into the trough under the condenser is used over again, the heat of it not materially affecting the action of the condensers.

When sufficiently concentrated, the sugar-liquor is let down into a receiving cistern, H, placed below the pan, from whence it is forced up by the monte-ijs to

Fig. 564.



a cistern, I, above the level of the top of the charcoal filters. The charcoal filters, J J J J, are large, slightly conical vessels, generally of wrought-iron, with a perforated false bottom about an inch and a half from the bottom. A blanket is spread over the false bottom to prevent the charcoal from being carried through with the liquor; some, however, always accompanies the liquor at first, which runs into a separate receiver to be filtered over again. In filling these vessels, the first few inches of charcoal should be pressed compactly down, after which it is packed lightly but evenly, nearly to the top, where space is left to receive the liquor. The object to be attained in these filters, is to remove all the vegetal coloring matter from the liquor, and any excess of lime that may have been added during the clarification, as well as some of the mineral salts, such as sulphate of lime, originally existing in the cane juice. The liquor from the charcoal filters runs into a cistern, K, preparatory to being drawn into the granulating pan.

The granulating is also performed in vacuo, and the pan, L, is similar in its construction to the one before described for evaporation, and a similar surface condenser is applied when there is a deficiency of water. To the granulating vacuum pan a measure is usually attached, so that the attendant may know exactly how much liquor he lets into the pan. There is also a proof stick or instrument for taking a sample of the sugar out of the pan during the concentration, without destroying the vacuum. A slide is fitted to the bottom, instead of a cock, for letting out the sugar when the granulation is completed. The pan is also fitted with light and sight glasses, barometer, thermometer, *et cetera*.

The sugar, on being let out of the pan, drops into a heater, M, a hemispherical pan of a similar description to the clarifiers described before, in order to raise the temperature of the sugar above what it was in the pan, to harden the grain previous to being conveyed to the curing-house. The water arising from the condensation of the steam in the various vessels, passes from the bottom through a condense water box attached to each vessel, in the interior of which box a float and valve are so arranged that the water passes through without letting the steam escape. The outlet pipes from the condense water boxes are carried to a cistern, into which the suction pipe of the feed pump to the steam boilers dips, to be used over again to supply them, a very small quantity of cold water requiring to be added to make up for loss by waste. In some parts of the manufacture, high pressure steam being required, such as for clarification, for the steam engine, and the montejus, it is found better to keep the steam up in the boilers to a uniform pressure, lowering the pressure to the vacuum pans and heaters when the temperature of high pressure steam would injure the quality of the sugar. N represents an expansion vessel for effecting this purpose, and is fitted with one of Messrs. PONTIFEX and WOOD's patent improved valves, by which the steam in the expansion vessel is sustained uniformly at any required pressure. However high or fluctuating the pressure may be in the boilers, the excess of pressure shutting the supply valve to the expansion vessel,

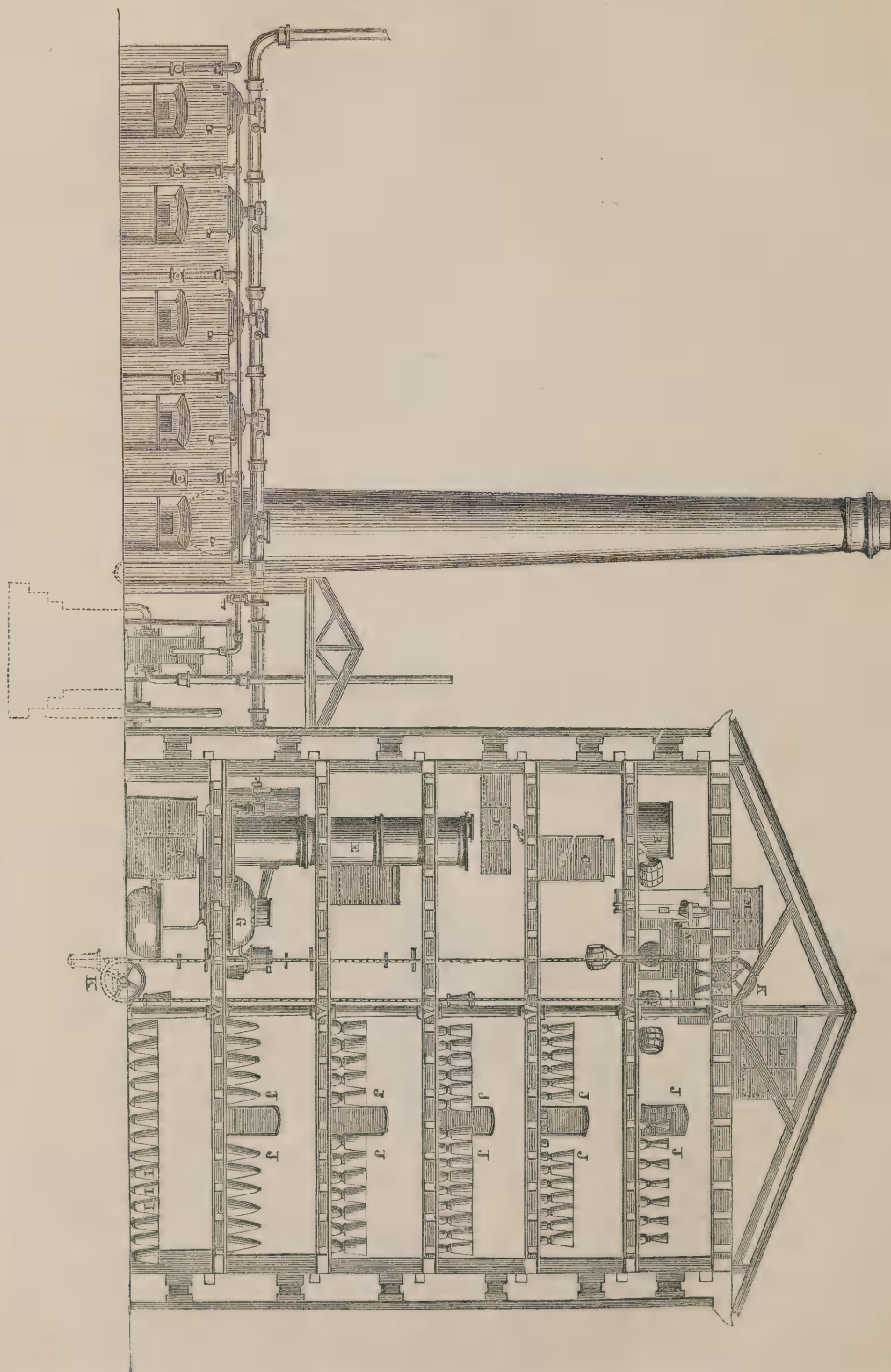
safety and whistle valves are attached to the top, and a gauge on the side to indicate the pressure of steam.

The evaporation of the juice, up to 48° Twaddell, may be carried on in the ordinary battery of hemispherical pans or the improved rectangular ones, as previously described, without being seriously detrimental to the liquor, although the plan last described of evaporating, as well as granulating in vacuo, is most approved. A better method of evaporating than by direct fire heat is by using steam evaporators—the best form of which having the largest heating surface, combined with facility for cleaning, is a rectangular vessel, generally of wrought-iron, at the bottom of which is placed a range of copper pipes as close to each other as convenient. The pipes are connected together by copper bends brazed to the pipes. The entrance of the steam and exit of the condensed water are at the same end of the evaporator, and pass through stuffing boxes, to admit of the pipes being turned up, so as to be able readily to approach all parts of the evaporator to clean them—a point of great importance in the manufacture.

Machinery and apparatus, such as those described in the preceding, and fitted with all the modern improvements are, it is true, costly in erection, but they very soon pay for themselves in the superior quality of the article produced, and the greater return from the same quantity of canes. By employing the strong mills and powerful engines as now manufactured, the canes yield a much larger per centage of juice than previously; and the megass leaving the mill being much dryer is in a better condition to be used as fuel. By applying steam heat, and boiling in vacuo at low temperatures, the color is improved, and less of the sugar is converted into molasses, so that estates which were worked at a loss before may, by the introduction of improved machinery and utensils, be made to yield a profitable return. In colonies where field labor is difficult to be procured, it is especially important to the planter to obtain the most approved machinery, so as to cause as little waste as possible of the raw material.

The machinery of a sugar refinery as worked in Europe is shown in Fig. 565, which represents the elevation of a refinery of the most modern construction, for the conversion of the raw sugar, as imported, to the white loaf sugar of the consumer. The raw sugar, in hogsheads, boxes, or bags, is lifted from the waggon to the upper story of the house by a crane worked by a steam hoist machine, A. The first operation is to melt the sugar, which is usually done in cylindrical or rectangular open pans, one of which is shown at B. At the bottom of the melting, or *blow-up* pans, as they are termed, is a perforated copper worm, and over the worm is a perforated false bottom to keep back any large substance that might be mixed with the sugar. After adding to the sugar a sufficient quantity of water to bring the density of the liquor, when dissolved, to about 44·5° to 46·5° Twaddell, the steam is then turned on, mixing directly with the sugar; whilst being dissolved, bullock's blood—still in some places—and lime water are added to clarify it and neutralize the acid. Mr. FINZELL

Fig. 565.



of Bristol, one of the largest sugar refiners in the world, has patented a modification of the vacuum pan in place of the ordinary melting pans, which he thinks expedites the operation of melting; the sudden expansion of the air confined among the sugar assisting the steam and water in the breaking up and melting of the mass. A movable false bottom is placed over the worm to allow a space for the water between the sugar and the heating surface, and to keep back any extraneous matter. Messrs. FINZELL and ASPINALL have also recently patented a new form of pan for melting sugar, in which the sugar is suspended near the surface of the water in such a way that, as it becomes dissolved, it falls by reason of the greater density of the solution to the bottom of the pan, leaving the next stratum to be acted on by water not so saturated with sugar; whereas, if the sugar lies at the bottom of the pan, the water in immediate contact becomes thoroughly saturated, and, remaining at the bottom by reason of its density, retards the dissolution. This is, however, compensated for by a large stirrer, universally used in blow-ups. On emptying the hogsheads, *et cetera*, a portion of sugar is left behind sticking in the crevices of the staves; this is removed by placing the hogshead in a *steamer*—when, the steam being turned on for a short time, all the sugar is washed out of the hogshead, and drops mixed with the condensed steam to the bottom, from whence it is conveyed to the melting pan.

From the melting pan, B, the liquor is drawn off to the bag filter, C, similar to those described before for the cane juice. The liquor then runs into the receiving cistern, D, with a coil of copper steam-pipe at the bottom to increase the temperature previous to entering the charcoal filters. The charcoal filters, one of which is shown at E, as generally used in refineries, are cylindrical vessels of cast-iron or copper, about five feet diameter, and twenty to thirty feet high; the greater the depth of charcoal the liquor has to pass through, the less coloring matter is left in the liquor. The filters are furnished with a perforated false bottom, a blanket being spread over it to prevent the charcoal from passing through with the liquor. The tops are generally closed, to admit of a head of liquor above the charcoal to accelerate its passage through the filter, a manhole being cast in the cover to let in the charcoal, and another at the bottom to get it out when required to be changed. From the filters the liquor runs into a cistern, F, placed on the basement or *fill-house* floor, from which it is drawn up into the granulating pan, G. A vacuum pan is used for this purpose similar to the one before described for granulating the sugar from cane juice; only in this drawing the condensation is shown, effected by the injection of cold water into a vessel when it meets the vapor from the pan: this method is adopted when water is abundant, the outlay not being so great. The sugar, when granulated, is let down into the heater, H, by a slide in the bottom of the granulating pan, the sugar requiring the temperature to be increased in order to harden the grain; it must also be well stirred, to mix the grain thoroughly previous to being ladled out into the moulds. This operation of lading is usually performed in copper

filling-out basins, into which the sugar is ladled from the heater. When practicable, labor may be saved by raising the pan and heater up to a floor above, so as to draw the sugar off from the bottom of the heater by a slide.

CENTRIFUGAL MACHINES.—If the sugar is intended to be in the form of crystallized, from the heater it is put into the centrifugal machine, which consists of an outer cylindrical case, in which revolves at a very high speed an inner vessel perforated round the circumference, into which the sugar to be dried is placed; the centrifugal action from the velocity causes the sirup to pass through the perforated circumference into the outer case, from whence it is drawn off, leaving the crystallized sugar behind. By this means much time is saved in the draining of the sugar. The same effect is sometimes attained by connecting the bottoms of the moulds to a pipe communicating with an air-pump, when the pressure of the atmosphere acts in the same manner as the centrifugal force; or the sugar is placed in a large box fitted with a perforated false bottom, from which the air is exhausted. This latter plan is often adopted with much success in the West Indian Colonies.

The moulds, I, I, I—Fig. 565—into which the sugar passes from the heaters, are of a conical shape, and usually made of sheet-iron; the lower part or apex of the cone being of cast-iron, with a small hole for the sirup to drain through. They are either painted or galvanized inside and out, to preserve them from rust; they are made of different dimensions, according to the size of the loaves required and the quality of the sugar, and are named respectively—loaves, titlers, lumps, and bastards. From the fill-house the moulds are conveyed to the various floors, which are heated by steam-pipes to a temperature of 75° to 80° Fahr., to facilitate the drainage. The moulds are ranged all over the floors, with the points of the moulds resting on iron or earthenware pots, to receive the sirup drained from them. After standing some time till their own sirup drains from them, fine liquor, consisting of a saturated solution of pure sugar, is poured on the top of the moulds, thus, as it percolates down the loaves, washing away with it the impurities remaining on the sugar, which would otherwise adhere to the surface of the crystals. After this the loaves are taken out of the moulds, the lower end is cut to a point in a nosing machine, as it is called, and the top trimmed off by a machine with revolving knives. The ends so cut off are not of equal quality to the centre of the loaf, and are melted over again. The loaves are then papered up and further dried in a stove, J, which is heated by steam pipes at the bottom, and fitted with shelves on which the loaves are placed. After drying they are ready for the market. The moulds are lifted from one floor to another by a machine called a mould-hoist, which is driven by the engine. The mould-hoist, as made by Messrs. PONTIFEX and WOOD, is shown at K, K, and consists of two endless pitch-chains working over pulleys fixed under the fill-house floor, and at the top of the house; between these chains are slung cradles, with rings adapted to the various sizes of moulds used in the house. Holes are cut in the various floors

sufficient for the passage of the moulds, which are readily placed in and taken out of the cradles as they pass up or down. The cradles are slung upon axes, so that the moulds turning over the drains remain in the same position, thus preventing the risk of accident in case the attendant should omit to take them out as they pass him, in which case they only make the circuit with the chain, and are taken out the next time they come round to the floor on which they are required.

The charcoal, after it is removed from the filters saturated with coloring matter, is dried, and then reburnt. The retorts of cast-iron or kilns of clay are so constructed that the charcoal, when at a red heat, does not come in contact with the atmosphere, which would destroy it. The charcoal reburners, as arranged by Messrs. PONTIFEX and WOOD, are shown in Vol. I. of this work, page 340, under the article BONE-BLACK. L is a cistern for water, and M a cistern for fine liquor, a pipe from which runs down the house, with a cock at each floor. This is used for washing the impurities off the sugar crystals in the moulds, as before described.

M. ALFRED FRYER of Manchester has been for some time at work with apparatus which, if successful, will greatly alter the sugar manufacture. He believes it is a wasteful mode of procedure to attempt to purify sugar in the colonies, even to the smallest extent, the facilities for doing so here being much greater. His method is designed to dry the cane-juice rapidly down into a hard concrete, and so to import it into Europe. In the concrete form, and almost free from molasses, it will not decompose, and the enormous waste of more than half the sugar will not take place, the loss in the European refineries being considered large at six or seven per cent.

BEET-ROOT SUGAR.—In Germany and France cane sugar is extracted in large quantities from the beet-root. The beet-root is a biennial plant, native to the South and South-west of Europe. It appears to have been introduced into the Netherlands during the possession of that country by the Spaniards, and to have thence passed into France, Schleswig-Holstein, Germany, Sweden, England, *et cetera*. There are many varieties of the beet, but that specially prized by the beet-root sugar manufacturer, and therefore chiefly cultivated in those countries where this branch of industry is pursued, is the Schleswig beet, or white beet—*Beta alba*—called also from its qualities the sugar beet. When the leaf-buds appear above the ground, the leaves thrown off sometimes rise very high before spreading; sometimes they spread almost immediately above the surface of the ground. This variation, which is partly hereditary, partly conditioned by soil and other circumstances, gives rise to a considerable difference in the quality of the sugar which is extracted. For as the thick and upper end of the tapering root is, during the growth of the plant, projected a little above the surface of the ground, the exposed portions are acted upon by the light, and the otherwise white root is thereby turned green owing to the formation of chlorophyll. But where the leaves spread out on emerging from the ground, the root is

shaded and preserved from such colorization. The Quedlinburg beet has a shade of red on its outer coating, and a species of a yellow variety has been recommended on account of the greater quantity of sugar that exists in its juice. The root of the beet contains water, cane sugar, vegetal fibrin, and fat, gum, coloring matter, pectin, together with the carbonates, chlorides, sulphates, nitrates, phosphates, oxalates, malates, *et cetera*, of potassium, sodium, iron, lime, and magnesia. The water varies from eighty to eighty-eight per cent. of the whole root. The solid matter—twelve to twenty per cent.—contains from four to six per cent. of vegetal fibrin; the remainder is cane sugar, with the other constituents. The length and straightness of the healthy beet points to a deep soil as the one appropriate to its cultivation, while the large quantity of water limits its growth to tolerably moist localities. An over-rich soil, however, is harmful, on account of the introduction into the plant of too much of the mineral constituents. Two or three of the seeds of the beet-root are set by means of a hand hoe, about a quarter of an inch below the surface, at regular intervals of between thirteen to sixteen inches, and covered with earth. If, in consequence of a short heavy rain succeeded by dry weather, the surface of the earth becomes so hardened that the young plants are suppressed, and the prospect of a sufficient crop is lost, the land should be reploughed, and a fresh sowing performed. The amount of sugar contained in the beet varies with its size, the smaller plants containing more sugar in proportion than the larger ones.

It has been found that—

Beets weighing $\frac{1}{2}$ pound contain	13	per cent. sugar.
" " $\frac{3}{4}$ " "	11-12	" "
" " 2 " "	8-10	" "
" " 3 " "	6-7	" "

Nevertheless, on account of the greater mechanical trouble of working the smaller beets, the larger are esteemed most. The tapering point of the root and the thick and higher end also contain less sugar than the central portions; this is especially the case with the thick end when it has grown above the ground and become colored by exposure to the light. During the growth of the plant, which lasts about four or five months, the soil must be turned by the hoe four or five times, the first hoeing being performed soon after the appearance of the young plant. The following rotation of crops is said to be favorable for the cultivation of the beet—1. Barley or wheat—with manure. 2. Beet. 3. Oats—three fields being kept under crop. If four fields be employed, clover may be advantageously introduced after the beets.

The beet, as before stated, is a biennial plant. During the first year of its life the root is developed to its full size, and secretes the whole amount of sugar which, in the natural life of the plant, furnishes the material for the growth and maturity of its upper part. It follows that when the plant is cultivated for its sugar, it is for this purpose ripe when its first year's stage of development is complete. The time required for this depends upon that of the sowing, and upon the seasons. Its criterion is the commence-

ment of death in the leaves. When ripe the beet-roots are dug out, the mould gently shaken off, and the heads cut off, together with as much of the root as shows the presence of leaf buds. As the action of light is detrimental even to the exhumed roots, the latter must be covered quickly. If the quantity be small they may be covered with the leaves which have been cut off. It is more usual, however, to pile them in heaps on the ground, to hinder the evaporation of their water, and to protect them from light and frost by covering the heaps with a thin layer of earth. These mounds are sometimes sprinkled with water, which is taken up by the roots, restoring to them their plumpness and crispness which they have lost in a dry season.

The amount of beet root obtained on a given space is, according to BOUSSINGAULT, in—

	On a hectare; kilogrammes.	On an acre; lbs.
Pas de Calais	31,400	27,664
Aisne	25,500	22,770
Nord	35,000	31,226
Somme	24,500	21,859
Eure et Loire.....	8,500	7,570
Seine et Oise	27,250	24,312
Cher	38,000	32,904
Seine et Marne	30,000	26,766
Meurthe—Roville	17,500	15,613
Mean.....	26,405	23,508

Some roots were examined by RAGSKY and COREN-WINDER for their specific gravity—

By RAGSKY.

	I. From Venice.	II. Olmütz.	III. Hungary.	IV.	V.	VI.
Specific gravity	—	—	—	1.050	1.042	1.056
Sugar	10.70	—	—	9.4	9.8	8.73
Salts	0.92	0.87	0.85	1.76	0.94	—

By CORENWINDER.

	VII.	VIII. From North of France.	IX.	X.	XI.	XII.
Specific gravity	1.048	1.044	1.045	1.038	1.045	1.037
Sugar	10.00	9.40	8.76	7.90	9.45	8.01

PAYEN gives the following as the chemical constitution of beet root:—

	Per cent.
Water	83.5
Sugar	10.5
Cellulose	0.8
Albumen, casein, and nitrogenous matters	1.5
Salts, &c.....	3.7
	100.0

Under salts, *et cetera*, are included malic acid and gum, nitrogenous substances, fatty matters, aromatic substances, coloring matters, essential oil, chlorophylle, malamide, oxalate and phosphate of lime, phosphate of magnesia, chloride of ammonium, silicate, nitrate, sulphate, and oxalate of potassa; oxalate of soda, chlorides of sodium and potassium, pectates and pectinates of

lime, potassa and soda, sulphur, silica, oxide of iron, *et cetera*. The sugar is entirely in the state of cane sugar.

It has been shown, however, that ammoniacal salts do not exist ready formed in beet juice, but are the product of decomposition eliminated, especially when lime is added.—*Michaelis*.

Lactic acid is readily formed by the decomposition of beet root sugar in its juice, and some persons find mannite, although others are not able to do so. A gummy substance is also produced, probably similar to that found in cane sugar refineries, when the sugar has been too long boiled and worked with.

The beet is grown in temperate climates, and it requires a good deal of moisture.

BOUSSINGAULT gave the following analyses of French beets:—

Where grown.	Time of taking from ground, <i>et cetera</i> .	Per cent. of dry matter.	Water.	Sugar.	Ligneous fibre and albumen.	Pectin?
Botanic school,	Aug. 2.—Roots small,	9.5	90.5	5.0	4.5	added to the lig. matter
	Sept. 1.—A root of 1100 grammes = about $\frac{1}{2}$ lbs.,	7.4	92.6	4.2	2.5	1.0
	Sept. 1.—A root of 460 grammes = about 1 lb. $2\frac{1}{2}$ oz.,	9.4	90.6	5.0	2.8	1.6
	Sept. 7.—Root, 700 to 800 grammes,	10.0	90.0	7.3	1.9	0.8
	Young root of 0.3 grammes = 4.6 grains,	13.7	86.3	5.9	4.4	3.4
Garden of M. Brongniart,	Sept. 26.—Root from 80 to 100 grammes = $5\frac{1}{2}$ oz.,	16.1	84.9	10.0	3.3	1.8
	Oct. 9.—Root, 150 grammes = about 5 oz., ..	14.1	85.9	—	—	—
Vigneux,	Sept. 23.—Root, 500 grammes = 1 1-10th lb.,	16.9	83.1	11.9	3.2	1.8
	Sept. 23.—Root, 700 grammes = $1\frac{1}{2}$ lb.,	13.0	87.0	8.6	2.7	1.7
Grenelle,	Aug. 7.—Root, 300 grammes = 6-10ths lb., ..	15.5	84.5	8.9	6.6	to preceding.
	Aug. 11.—Root, 600 grammes = $1\frac{1}{2}$ lb.,	12.6	87.4	8.2	2.8	1.6
	Aug. 30.—Root, 1 kilogramme = 2 1-5th lbs.,	13.1	86.9	8.6	3.1	1.4
	Beet in flower, 200 grammes = about 4-10ths lb.,	16.5	83.5	9.8	3.3	3.4
	Beet of two years in seed,	5.5	94.5	0.0	2.5	1.1*
Roville, Meurthe,	White beet of Silesia,	15.8	84.2	10.6	3.1	2.1
Analysed by M. Braconnot.	Leaves of the beet,	6.4	93.6	1.3	3.6	—†

* Add 0.9 of nitre.

† Add 1.5 nitre; the albumen added to the sugar.

The following analyses of ashes of beet are by WAX and OGSTON :—

	Yellow globe.		Long red.	
	Bulb.	Leaf.	Bulb.	Leaf.
Potassa.....	23.54	8.34	29.05	27.53
Soda	19.08	12.21	19.05	5.83
Lime	1.78	8.72	2.17	9.06
Magnesia.....	1.75	9.84	2.79	9.10
Oxide of iron....	0.74	1.46	0.56	4.48
Carbonic acid....	18.14	6.92	21.61	6.11
Phosphoric acid...	4.49	5.89	3.11	4.39
Sulphuric acid....	3.68	6.54	3.33	6.26
Chloride of sodium	25.54	37.66	14.18	29.85
Silica	2.22	2.35	4.11	1.35
	99.96	99.93	99.94	99.96
Per cent. of ash ...	1.02	1.40	1.00	1.91

One ton of beets they calculate, removes from the soil :—

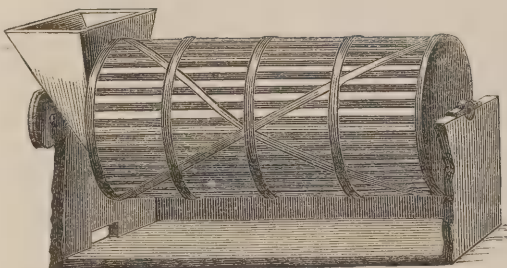
	Mean of three specimens of bulb.	Mean of three specimens of leaf.
	Pounds.	Pounds.
Potassa.....	4.99	7.86
Soda	3.02	2.52
Lime.....	0.41	3.31
Magnesia.....	0.43	3.27
Oxide of iron....	0.12	0.52
Phosphoric acid....	0.66	1.94
Sulphuric acid....	0.65	2.20
Chloride of sodium	5.29	12.82
Silica.....	0.54	0.76
	16.11	35.20

It has been found that beet with a large amount of juice containing many salts, gives little sugar; either the sugar is not formed, or it is combined with the salts and rendered useless. Manures with a large amount of soluble salts must therefore be avoided; farmyard manure, for example, must not be used in large quantities. Neither a very wet soil nor a very dry one suits the beet root. The Silesian beet is most admired; its juice has a specific gravity of 10° to 15° Twaddell—105° to 107°—and is very pure. It is not a large root.

The amount of juice obtained is from seventy to eighty per cent. of the beet.

The roots, after their extraction from the earth, have to be cleaned and the bruised or diseased portions extracted. For the first purpose they are brought into

Fig. 566.



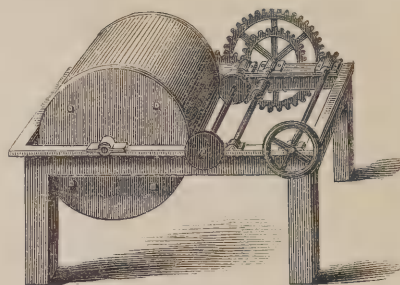
a horizontal cylindrical cage, which rotates round a horizontal axis, and is turned by machinery.

After washing, the roots are examined by women and the unhealthy parts cut out, the smaller side-roots cut off, *et cetera*.

In order that the greatest quantity of juice may be extracted, the roots have to undergo a thorough trituration, the purpose of which is to destroy the cells and other texture, and to allow the free escape of the juice. The accompanying figure shows the construction of a trituration mill of this kind.

The macerated beet-root appears as a white thin emulsive liquid, and contains naturally the whole of

Fig. 567.



the constituents of the root. The soluble portion is separated from the insoluble by pressure. Woollen, linen, or, for the reason mentioned in the manufacture of cane sugar, cotton cloths or bags are employed to hold the juice. When cloths are used the process of *packing* is as follows :—A plate of iron of the size which the cake is destined to have is placed upon the press-table—see below. Around this plate a movable wooden frame is placed, of the appropriate depth. The frame and plate are covered with the cloth, which is smoothened into the edges and corners of the box so formed; the corners of the cloth being of sufficient length to cover the box again when folded back. A measure of the crude juice is then poured upon the cloth smoothened down by the hands, and the corners of the cloth are folded back upon it. The wooden frame is then removed; another plate is placed upon the top of the first cake, the frame adjusted round it, and the same process is repeated. In this way a pile of cakes, inclosed in cloths, is formed, alternating with iron plates. Sometimes, instead of iron plates, a disc of plated osier, or a series of rattan canes lightly bound together is used. The latter contrivances are less likely to break the bags when the pressure is applied, but the juice is not so perfectly expressed as when metal ones are employed. When bags are used they are filled with the juice, the mouth squeezed together, and the whole turned over upon the plate, so that during pressure the mouth is held together.

The piles of cakes are next submitted to pressure, usually that of a hydraulic press. The piston of the press is made to descend and to squeeze the pile between itself and a firmly fixed metallic slab, rather larger than the cakes. The surface of the press table is nearly on a level with the top of the slab. The press table is surrounded by a rim, through one part of which a hole is cut, connected with a pipe for carrying off the juice. It has been proved that the best presses

leave at least twelve per cent. of the theoretically extractable juice in the cakes. A portion of this may be recovered by steeping the cakes which have undergone the first pressure, in a shallow vessel of water, or submitting them to the action of steam, and subjecting them to a second pressure. But even then by no means the whole of the sugar is separated. Moreover, the greater dilution of the juice so produced increases the expense of its subsequent working. Perhaps the centrifugal drying machine may find an application to this end; or perhaps the passing of long bags of the juice through cane crushing-mills might extract the juice more effectually. But the importance of the perfect separation of the sugar is not of so much moment as is the case with canes, because the spent cakes are generally used in beet-root sugar manufactories as food for the cattle employed on the estate, and their value for this purpose is greater the more sugar they contain.

An exhaustive method for obtaining the juice from beets has been proposed, in which the roots are sliced and macerated without destroying the integrity of the slices. The weak juice thus extracted is employed for macerating a fresh portion of slices, and so on until the extract is sufficiently strong for defecation and filtration.

Probably on account of the greater quantity of albuminous matter contained in the beet over that in the cane; in part, also, on account of the greater dilution of the natural sirup—the oxidation and fermentation of the former proceeds more readily. Hence extraordinary care must be taken not only to submit the extract from the beet as speedily as possible to the subsequent operations, but the press table, *et cetera*, must be thoroughly cleaned after each pressing, and the bags or cloths perfectly purified.

The processes for defecating the juice of the beet-root, are so analogous to those already described with the juice of the cane as to need no special description. The scum is submitted to pressure in a screw press, in order to separate the juice which it retains mechanically.

The employment of bone-black, also, resembles almost completely its use with cane sugar. In the beet-root sugar manufacture, however, the filtering cylinders have usually a longer and narrower form than is the case with cane sugar.

Perfectly pure sugar made of beet cannot be distinguished from perfectly pure sugar made of canes; but the imperfectly purified sugars may be distinguished—first, by the analysis as shown in the composition of the juices; and second, by the taste; which is in the case of the beet-root bitter and unpleasant; in the case of the cane sugar extremely sweet, with a pleasant vegetal aroma.

When beet is taken from the ground, it is used at once for sugar; if not used it rapidly germinates, and the sugar diminishes. For this reason SCHUETZENBACH introduced the method of slicing the beet in small pieces and drying it rapidly. When dry it may be preserved. When this plan is adopted, the manufacture may be carried on during the whole year, instead of during a few months only, or from October to March.

By the process of SCHUETZENBACH three hundred kilogrammes of beet are dried every twenty-four hours on a square metre, losing eighty to eighty-four per cent. of their weight. When used it is dissolved into a juice containing thirty-eight to forty-two per cent. sugar at 42° Twaddell, so that there is much less of water to be evaporated than with the green juice. The dried beet is macerated in a closed vessel.

100 kilogrammes of beet give 18 kilogrammes dried beet.	
	Francs.
40 hectolitres of coals, at 1.50 francs for a hectol.,	} 60
dry, 40,000 kilogrammes of beet	
20 days of a woman's wages at 80 cents	16
14 days of a man's wages at 1.5 francs	21
Interest on the kiln—costing 14,000 francs—for	
9 days, at 7 per cent.	11
	108

100 kilogrammes of dry beet cost 11 francs 11 cents.

M. SCHUETZENBACH has now made an immense establishment in Galicia. It is calculated to produce forty million kilogrammes of sugar yearly. There is a central sugar refinery and fourteen drying establishments in a circle of seven leagues, in order not to carry the wet beet far. He obtains a dry produce containing fifty per cent. of sugar. It is dissolved in closed vessels, and gives a juice of 52° Twaddell. He obtains six per cent. of sugar from the root. Such an establishment keeps a large circle of ground occupied.

It has been said that it is better to cut the beet into cubes. This plan is not adopted at Waghäusel, one of the most complete establishments, and certainly their slices being thin must dry readily. The plan adopted there is to dry for preservation; this is done in six hours on the wire gauze. Then when making the solution, it is at first obtained at 32° Twaddell, and boiled in vacuo down to 41.5 Twaddell, lime water added, boiled half an hour to remove ammonia, and kept alkaline with lime.

The establishment of Waghäusel, near Carlsruhe, employed in 1855 three thousand people; twelve hundred of these were in the drying department. One drying department was at the works, and six others at different distances. The works covered twenty-five morgen of land—about twelve acres. There were in it one hundred horses, one hundred cattle, and from thirty to forty pigs. A hundredweight of raw roots cost the establishment seven-pence. There were nine cylinders for refined sugar, and thirteen for commoner, twelve feet by six. There were twenty infusing vessels, twelve to fourteen feet deep and seven wide. The dry beet contained forty-six to forty-seven per cent. of sugar. Five per cent. were lost in making; by the old way the loss averaged eleven per cent. The capital was about eight million francs.

Maple Sugar.—In the Western State of North America, a great portion of the sugar required for home consumption is extracted from the maple. The season at which the collection of the juice takes place is the early spring—February, March, and April, when a light snow is on the ground. The trees most fit for tapping are those which have reached the age of twenty to thirty years. At the south side of such trees two or more holes are bored about four or five inches apart, three-quarters of an inch in diameter, and about two feet above the ground. The holes run

radially into the tree, and are inclined upwards, penetrating the inner white bark to a depth of about half an inch. Into these holes tubes of elder-wood are inserted. The upper portion of the part of each tube which is in the tree is slit off, so that it forms a semicylindrical canal or trough. Troughs are placed below the projecting ends of the tubes to receive the juice as it flows out. The average yield of a tree is about one quart in twenty-four hours. A tree may be tapped for twelve years in succession, the average yield being between two and three quarts annually. The crude juice is usually boiled down without defecation or filtration in copper cauldrons, which may contain fifteen or eighteen gallons. When the examination of the concentrated juice shows incipient crystallization, it is poured out into shallow moulds, about two inches in depth. When set, the sirup is usually ladled out of a depression made in one portion of the cake. This maple-sugar sirup, which corresponds to the molasses of cane-sugar, is, however, more highly prized than the sugar itself; it has a delicate aromatic smell and taste, and is greatly sought for making confectionery. The sugar sells at the rate of fourpence per pound. Some years ago enough cake maple-sugar was manufactured in the State of Vermont to inclose the whole State with a wall of sugar eight inches high, and eight inches in thickness. The North American Indians push the evaporation of the juice rather further than the whites, and after the removal of the sirup, the cakes are chopped up for the market.

SUGAR OF STARCH AND WOOD.—Crystallizable sugar is converted by boiling and by acids into glucose or grape sugar, a substance difficult to crystallize. Sulphuric acid converts cellulose, inulin, starch, sugar of milk, straw, sawdust, and such materials, into dextrin and sugar. BRACONNOT obtained from 20.4 of rags 23.3 of dry sugar. Cotton and linen being nearly pure cellulose, would give more than sawdust; about one hundred and forty parts of strong acid are used to one hundred parts of cellulose of rags, cotton, *et cetera*. The change is at first into dextrin—see STARCH—then into the sugar.

Sugar is made from starch by boiling it with water acidulated with one per cent. of sulphuric acid. The conversion takes place in half an hour. The amount of starch is about fifty per cent. of the water. At the same time the quantity is varied, as given by KNAPP that two and a half of sulphuric acid is used to one hundred of starch, and three hundred to four hundred of water. Makers are not precisely agreed as to the time, but it is different according to different degrees of solution. The sulphuric acid is removed by lime. The juice, clarified, is boiled down to 105° Twaddell, and crystallized in flat vessels. Crystallization commences in about a fortnight. The sugar is then drained and dried. This sugar is seldom sold as such. It is manufactured for conversion into alcohol.

The conversion of cellulose and starch into sugar, by the action of sulphuric acid, giving to them some of its water, may be better understood by examining the composition of both, as already given.

CAUSE OF THE LOSS IN THE MANUFACTURE OF CANE-SUGAR.—*Decomposition of the Juice.*—The albu-

minous matter in the juice is the chief if not the only cause of its rapid decomposition, and this is promoted by a heat which is not less than 80°, as the liquid flows from the crushing mills. Lactic acid in the case of beet juice is abundantly formed, and a viscous substance which has no sweetness. At the same time, also, there is formed a little mannite. An enormous loss of sugar is known to occur from this change of the juice. The one to two per cent. of alkaline salts can scarcely be said to act prejudicially to any extent. There is no known way of removing them.

To prevent the decomposition of sugar, especially in the case of Colonial juice, in warm climates, it is important to use an antiferment. PROUST proposed sulphite of lime in 1810; and DUBRUNFAUT took a patent for using sulphurous acid in 1829. MELSENS of Brussels has lately proved the great value of bisulphite of lime in the manufacture of beet-root sugar. The use of this is becoming general for beet-root. It would, no doubt, be found still more valuable in the Colonies, if no unlooked-for harm was occasioned; although care must be taken not to send the sugar over with sulphites in it. The bisulphite of lime resists the coloring of the juice, and even removes some of the color. Acids readily remove the color of sugar; but such color returns as soon as neutralization takes place. MELSENS believes that by means of this salt he will be able to reduce the molasses so much, that he will not remove the salts in solution in it as now, but by taking out ninety per cent. in a crystalline form, he will return the most of the salts to the earth. The small amount of molasses left could be returned to the pressed out beet before using it as food for cattle. The bisulphite of lime does not destroy the quality of the beet as food. LUDERSDORFF prefers sulphuric acid, afterwards to be neutralized by lime.

It is well to add that a French commission examined the action of bisulphite of lime on cane juice in Guadeloupe, and found that the amount of good well-grained sugar was diminished by it. If they used it as acid, as some do, it is not surprising.

KUHLMANN proposed to prevent the decomposition of sugar by adding an excess of lime, and then throwing it down with carbonic acid. This is again brought forward by M. ROUSSEAU. Three to four times the usual amount of lime is added, making a sugarate of lime; when the juice has reached 131° Fahr. the lime is added, mixed with six times the amount of water; the temperature then is raised to 180° or 190°, and the liquid filtered. Carbonic acid is added, a voluminous precipitate takes place, and the juice is now put on the charcoal filter without removing the chalk. M. ROUSSEAU had it brought before a commission of the French Academy, which reported a favorable result, but considered that the alkalies would act injuriously on the compounds of lime and organic matter not precipitated. To avoid this ROUSSEAU adds ammonia, which is converted into carbonate. The carbonate of ammonia decomposes the combination of the lime, and carbonate of lime is thrown down, leaving ammonia free. But this addition of ammonia is no improvement, and indeed the whole objection is a most uncertain one.

KUHLMANN believes that the free alkaline salts are hurtful, but has found it impossible to remove them by means of strong acids, or by sulphate of magnesia, sulphate of ammonia, or chloride of ammonium. He prefers phosphate of ammonia.

This process—one cannot speak for the phosphate of ammonia, but only for the carbonic acid—is a good deal used in France.

MAUMENÉ says that if lime is added in quantity sufficient to form three of lime and one of sugar— $3 \text{ CaO C}_{12} \text{ H}_{11} \text{ O}_{11}$ —the sugar is preserved, and nitrogenous matter falls with the lime. However this may be, if boiled with the lime the color is rapidly deteriorated.

Precipitation.—Attempts have been made to precipitate sugar from its solutions. DUBRUNFAUT and R. DE MASSY have a process depending on the union of sugar with baryta. Caustic baryta is added to the sugar till it is all thrown down. A pure compound of baryta and sugar falls, and this is decomposed by carbonic acid. It is not at all proved that all the sugar can be thrown down in this way; it is said only to be done at a boiling heat. NICKLÈS says it cannot be done with uncrystallizable sugar.—See further in accounts of *Patents*.

USES, PHYSIOLOGICAL EFFECTS, AND IMPURITIES.—Sugar exists in the juices of many plants, and is in part the food of many animals. As an article of food it has highly fattening properties, and as such it must be considered as serving mainly for the production of warmth in the body. Animals which eat it appear sleek and comfortable, and it tends to promote digestion. At the same time there are many persons who cannot use it as food to any great extent, on account of its inclination to produce acidity. The negroes, and even whites, who suck the sugar cane are not found to be troubled with these symptoms, whilst the teeth of the negro never suffer from the constant use of the sweetest liquids. Such, however, is not the case in England, where a great amount of sugar is found to be hurtful to the teeth. It is perhaps scarcely correct to say this of sugar in the diet, as it is not well known that the same effects would be produced by sugar used in abundance—in pies, for example—as would be produced by sugar taken alone and long retained in the mouth. Persons engaged in sugar works are in the habit of eating sugar very frequently. With some it is a part of their duty, as the value is to some extent measured by the taste; but whether as a duty or a pleasure, such persons are almost invariably doomed to lose their teeth at an early period. It may be said that sugars, until dried or thoroughly crystallized, have a certain amount of acidity in them; but this is in general too small to stand as a reason: much more acid is taken in other species of food. There can be no doubt that sugar in large quantities peculiarly affects the digestive organs, and causes also a distinct taste, other than sugar, to be perceptible some time. The cause may be that as an article of food it does not associate well in large quantities with the food used in this country. But, again, its valuable qualities are many, and the amount fitted for individuals must be found by experience.

The excessive use of sugar, that is, to the extent, with a healthy man, of about a pound per day, produces effects not apparently much studied. One effect is a tendency to giddiness, without any observed additional inconvenience. It is possible that this may arise from the large amount of carbonic acid generated during its decomposition, causing at the same time frequent eructations.

When the throat is irritated, a solution of sugar slowly flowing over the surface prevents irritation and allays coughing. Sugar and treacle are valuable for covering burns, acting chiefly, as Mr. CROMPTON of Manchester believes, as non-conductors of heat. It is sometimes used in a powdered state for ulcers or rather proud flesh, and for specks on the cornea. It has a considerable power of reducing metallic oxides, and has been used as an antidote for poisoning by metallic salts, such as those of copper; mercury, silver, gold, and lead may be included; but this action has been referred more to its physical than to its chemical properties. It is highly antiseptic, no doubt, because it covers from the atmosphere. It is much used in pharmacy for imparting flavor to bodies, and to conceal taste. It is also found useful for giving form and consistence to some medical substances. It is employed as a medium of bulk to convey smaller substances, as in opium, lozenges, *et cetera*, and notably so by the homœopaths, whose medicines may sometimes be distinguished from sugar. Many animals delight in it. Horses put their noses into the sugar bags, and even suck them, whilst the fowls fight for the fallen pieces.

Sugar is also employed for fermentation. Indeed, properly speaking, it is the only thing used for fermentation; but sugar from the cane, and still more the less crystallizable portion, is now considerably used. It has been employed for the purpose of making oxalic acid by oxidation with nitric acid; but starch or cheaper substances are more commonly employed. Enormous quantities are used in preserving fruits. Preserved fruits are becoming daily more and more accessible and more used. Formerly fruit was preserved only by such careful and well-to-do housewives as could spend some considerable time and money on the luxury. Now the conservation forms a branch of industry or manufacture. Marmalade and preserved oranges are sent from Scotland in great quantities, and are everywhere prepared. Preserved fruit is also sent from various parts of Europe, especially the shores of the Mediterranean, and it has begun to appear at our dessert tables after arriving from the East and the West Indies. England, as usual, takes up this manufacture with great vigor. One house made a small experiment last year with thirty tons of preserved plums, and finding it successful made next year a hundred tons. The preserves were of an excellent kind, and cheaper than those made by the usual methods in smaller quantities.

The amount of sugar used in the form called sweetmeats, comfits, and bonbons is very great, and more so on the Continent, according to accounts, than here. At the same time, although one finds in France, Germany, and Italy some very handsome confectionery shops, it strikes the Editor that the amount of comfits in

them is very small, and the variety very limited. The sugar may be pure and unadulterated with arsenic and sulphate of lime, or any other noxious or poisonous substance; but the shops seem to depend a good deal on their sale of beverages, and in some places on their restricted number. No country offers such great varieties of excellent sugar sweetmeats as England, or in such rich diversity. In China the variety is said to be very great. The only fault in England is that there exist so many qualities to suit the purses of every man, rich and poor. The inferior qualities are mixed with flour. This, of course, diminishes the sweetness. This would be a small evil, if the makers did not sometimes use instead of flour sulphate of lime or plaster of Paris. Even this, however, is innocent in comparison to the coloring matters used at times. Sweetmeats are colored by ignorant people with common paints of any kind that come in the way. These are painted roughly on the sugar. Some of them contain copper, some arsenic and copper, and some lead. Several cases of death have occurred from the use of such substances; and there can be no doubt of the propriety of a surveillance over the manufacture or sale of articles liable to be so abused. The best confectioners use only innocuous colors, and these vegetal.

The unfiltered sugar, or Muscovado, as it comes from the Colonies, contains many impurities, and should never be used. Many peculiar species of beetles are found in it. One especially infests abundantly all sugar-houses. But the *acarus sacchari* is the animal that, of all others, is the most to be avoided; it is not found in filtered sugar. It is an animal somewhat like an itch insect, and a drawing would not be pleasant in an article on sugar. The grocers' itch is in all probability produced by the handling of Muscovado sugar, and the attacks of this insect. Dr. HASSALL advises the use of refined sugar only. The Editor is able to state that, in Lancashire at least, purified or filtered sugars, of various shades of color, are everywhere to be had, and they are as free from insects as the purest white lumps.

Sugar itself for domestic purposes is not now adulterated, or very rarely. There was a time when sand was used to adulterate the brown qualities; but such a practice would not now be tolerated for a moment. A very ingenious adulteration came into vogue for a while; but the Editor believes it is not resorted to now. It was the custom of using starch, or starch made into gum. When this is used in tea or coffee it is not readily distinguished from true sugar. If starch is employed it is readily found by dissolving the sugar in cold water, in which the starch is not soluble. If British gum be used it is less easily detected; it has small granules, not hard and crystalline like those of sugar, and is soluble in cold water. It also becomes gummy in drying, instead of becoming sirupy, and then crystalline like sugar. This adulteration cannot be made with pure white sugars. A microscope assisted by an ordinary good taste is perhaps the best guide to its discovery. The most general use of sugar is for sweetening tea, coffee, and chocolate; but it is also largely used in sweetening mixtures of strong drink, as well as in numberless

articles of cookery. Its abundant introduction into Europe has changed the whole system of cooking and must have largely assisted in rendering food pleasant in an age when the arts of peace have somewhat taken away the violence of appetite which is connected with rude times, and is satisfied more with quantity than quality. For the poor especially is this remarkably true.

A LIST OF SOME OF THE LATER MORE INTERESTING AND CURIOUS INVENTIONS RELATING TO SUGAR, WITH REMARKS:—

1845.—JAMES JOHNSTON patents an ingenious plan of emptying a vacuum pan without destroying the vacuum by a pipe twenty-five feet long. He also has the sugar running down an inclined plane whilst in the vacuum.

FREDRICK GYE presses sugar into suitable forms for use.

1846.—RICHARD WRIGHT patents exposure to hydraulic pressure and steam.

1847.—JAMES JOHNSTON patents polygon shaped sugar moulds, cast-iron crystallizing pots coated with tin, zinc, or enamel. The latter would be good if the enamel did not break off into the sugar.

H. K. CLAYPOLE.—Saving fuel with two generators like locomotive boilers, heated by a fire that first passes over three open boilers. A current of high pressure steam to make a draught. A hot iron tube heated by steam in the clarifying boiler. A canal in the teache for running out sugar. Galvanized iron coolers. These are for the Colonies.

JOHN SCOFFERN.—Combined use of lead and sulphurous acid as separately described.

1848.—J. A. STEINKAMP patents the use of cotton in small pieces of one-eighth to one-fourth of an inch for clearing sugar.

1849.—JOHN OXLAND patents acetate of alumina boiled with sugar at 220° till the acid is removed. The alumina remaining is removed by tannin and a little carbonate of lime.

REECE and PRICE patent hyposulphites with alumina or acetate, hyposulphite of alumina, and various hyposulphites and sulphides of magnesium to precipitate lead. Also hyposulphites and sulphurous acid to remove the sulphide of hydrogen which has been used for removing lead. The bicarbonate of lime for defecation and many other things.

A. V. NEWTON.—Bones dissolved in sulphurous acid for completely extracting the crystallizable sugar. Other antiseptics, as mustard, creosote, horseradish, nitrous acid gas, with or without salts of iron or other salts. Tannin, lampblack saturated with creosote, products of the distillation of certain albuminous matter, tars, wood essence of turpentine, aldehyde, and analogous bodies, chlorine combined with oxygen. Separating ninety-seven per cent. of pure sugar by baryta, and decomposing by carbonic acid or sulphurous. Oxide of strontium, it is said, requires a long time; oxide of lead does it imperfectly. The process gives fifty to sixty parts of hydrate of baryta to one hundred of sugar. Still the sugarate obtained contains fifty per cent. sugar, twenty-two baryta, and twenty-eight water. It is decomposed by a solution of twenty-five quarts of water and twenty-eight pounds of sulphuric acid. It may be

washed till the solution has the strength of 23° to 31° Twaddell. If lime is used, twenty-eight per cent. is taken. The sugarate is filtered out in TAYLOR's filter, or in presses warmed to 100°; it contains five equivalents of base to one of saccharic acid.

The baryta does not offer to be cheaper than animal charcoal, and baryta, at least as a soluble salt, is no less dangerous than lead, whilst it is not so easily detected. Several patents have been taken for removing the baryta, but on this point, the last traces excepted, no difficulty has been found.

C. W. FINZELL—Patent to introduce steam to clear the sieve of the centrifugal machine.

1850.—JOHN SCOFFERN makes a valve of elastic material over a perforated tube.

GEORGE GLYNNE grinds sugar with litharge, and makes a saccharide of lead.

Sugar is a very tender substance chemically. It is easily destroyed. It also readily dissolves many substances. As little of any substance should be added as possible, and as little heat should be given and as little motion.

D. T. SHEARS makes loaf sugar at once on boiling down the juice; purifies sugar by alkaline liquids and sulphurous acid gas; uses also lime and a West Indian plant called *wassama*. Puts a *rouser* in the vacuum pan for stirring round.

HERMAN SCHRODER—a combination of revolving discs on pipes heated by steam to evaporate the sugar.

1851.—R. and J. OXLAND.—When acetate of lime is used, remove by superphosphate of lime or lime. Aluminate of lime to defecate, or phosphate of alumina.

R. A. BROOMAN—Centrifugal apparatus in a vacuum pan; centrifugal drum for evaporation; centrifugal apparatus for cleaning charcoal.

1852.—HENRY BESSEMER.—The claims in this patent being nineteen, are too numerous to mention, and so complicated as to require an article for themselves. It is believed that they rather tend to load a refinery with machinery. Invention will rather simplify the machines, or altogether dispense with some of them; but there are good and ingenious thoughts amongst those of Mr. BESSEMER worth studying, although not as yet found successful.

R. A. BROOMAN.—Endless bands for carrying the sugar to be cleansed.

ROBERT GALLOWAY.—Using plumbite of lime instead of lead.

R. W. LIENIER.—Patent for applying sulphurous acid to the pulp of beet-root or cane before boiling it, adding excess of lime. Use of vessels of wood, slate, stone, glazed metal, or earthenware for boiling juice.

WILLIAM MILLER.—For never allowing the sugar to come in contact with metals; evaporating by surfaces formed of cloth or textile fabric.

BROOMAN.—Removing excess of lime by soap.

GERD JACOB BENSEN.—Hot air passed through the sugar to dry it. Crystallized sugar placed in a vacuum pan. Crystals thus got are mixed with a clear sirup produced from refined sugar; the mixture put into moulds and stored.

In 1852 J. BRANDEIS took a patent for removing lead from sugar by animal charcoal, thus being able to use lead to purify sugar. The Editor believes that the destruction of the animal charcoal soon follows. The oxide of lead, on heating, melts in the pores. This, although possible, would be very expensive.

JOHN ASPINALL proposed lifting the sugar solution in thin layers on an endless band of wire gauze, exposing it to heated air, and drawing off the water. This has not been much used. Even thin layers of sugar may become covered with a pellicle not easily broken. HOWARD's vacuum pan, by keeping up ebullition, allows no hard surface to prevent evaporation. This, however, may be the germ of something good not yet completed.

JAMES HADDEN YOUNG presses sugar between two unyielding surfaces, one of them perforated; he uses a vacuum. The beet-root system is a similar one, but mechanical pressure is used.

HENRY BESSEMER also proposed contact of warm air, raising the sugar in thin layers on screws or discs instead of on wire gauze, as Mr. ASPINALL. He proposed also in his patents to use wooden troughs for crystallizing, and to moisten the crystals with a deliquescent compound of sugar and chloride of sodium, or with gelatine, glucose, or molasses. He adds, also, the use of hot water instead of steam to heat sugar, and warm air below 212°, and tinned vacuum pans. Tin is too easily dissolved. What might be more useful than any of the above is the enamelled vacuum pan, if such large vessels could be covered with enamel.

GEORGE DIXON has a number of perpendicular tubes, in which is placed the sugar and heated by steam; but there is a want of exposure for evaporation. Perpendicular tubes are found to heat the sugar more equally.

JEAN BAPTISTE MOINIER allows the sirup or liquid to fall over spheres, thus obtaining surface, and he allows it to *descend from amongst the spheres*, and exposed to warm air.

1853.—WILLIAM PIDDING patents hydrate of alumina, or silica, or a mixture incorporated with a fatty acid, and adds a little oxide of iron. He seems to wish to include the impurities of the sugar in a kind of fatty salt or soap. This answers for some liquids, but the iron will not improve sugar.

FRANK CLARK HILLS removes the lead from sugar by filtering through sawdust, or by dissolving it out with nitric or acetic acid. Animal charcoal much treated with acid soon loses its texture.

LORD HOWARD DE WALDEN cleanses crystals by hot air and steam. This is, in fact, bleaching with the atmosphere. Air bleaches many substances, but the Editor has not heard if it has been found to act favorably on sugar.

CONRAD W. FINZELL.—Defecation in vacuo. Not yet proved to general satisfaction to be of any benefit.

MANIFOLD, LOWNDES, and JORDAN—Reducing the cane to sawdust, then dissolving the sugar out by steam. This does not seem the right direction, as the great loss is in reality in the juice; it is not left in the cane.

JAMES MAGELSTON—Atmospheric pressure to remove crystals from sugar. This is in fact equal to a vacuum.

ROBERT GALLOWAY—Removing lead by tannic, gallic, and pectic acids, or the soda and potassa compounds.

JOHN and J. E. A. GWYNNE dry beet on an endless band, in one heated cylinder after another.

JOHN THOMAS WAY—Soluble silica to remove the excess of lime in defecation; filtering through a bed of Surrey silica or sand. This would add another operation, as it is supposed it would still require to be passed through the bag filters.

EDWARD BEANS puts the beating tubes into his vacuum pans vertically, and filters through a false bottom covered with sand, powdered flint, or road sweepings.

1854.—CHARLES H. COLLETTE proposed to defecate with lime and superphosphate of lime.

JOSEPH BOUR evaporates by a series of hollow vessels revolving in sirup and internally heated by steam; very much used, especially in the Colonies.

JAMES WRIGHT makes a centrifugal machine, where the outer case revolves with the inner, and a partial vacuum is formed to help the drainage of the liquid without the air-pump.

JOSEPH NASH adds an air-pump to his charcoal filters; fills the centrifugal machine without stopping.

W. A. ARCHIBALD consolidates sugar by exposing to cold air and agitation.

D. T. SHEARS—Another plan for filling and emptying the centrifugal machine without stopping.

PIERRE ANDRÉ DECOSTER has a patent for cutting up the canes; he then presses and mashes by centrifugal power.

L. WRAY wished to take a patent for making sugar from *Holcus saccharatus*, called *impee* on the coast of Africa. Refused.

1855.—R. A. BROOMAN.—A filter of cotton or other fibre between two perforated plates or frames.

JAMES STEELE says that the pin at the apex of the sugar mould is now inserted to make an outlet for the drainage. He inserts it at first, and draws it out when it is desired. A cavity is thus left which assists in drainage. By the insertion of a pin too large a hole is made.

There are many patents for the mode of cutting up sugar into lumps.

JOHN ASPINALL drives the sugar in at the apex of the cone, burning it out at the top.

C. W. FINZELL's patent for the use of NEEDHAM and KITE's apparatus in the filtering of sugar. It is the combination of grooved plates or planks, with filtering cloth, which is laid between two.

ALEXANDER W. ANDERSON precipitates sulphate of copper by tin, and obtains sulphate of tin for sugar refining; then precipitates tin by lime. Removes tin from the sugar at last by animal charcoal.

GARTON and PARSONS.—To treat sugar for distilling they add sulphuric acid, and keep the liquid at 140° for five days, then remove by lime.

STATISTICS OF THE UNITED KINGDOM.—The following, from Messrs. REID's circular, of Liverpool, with alterations, will give some interesting details relating to the United Kingdom:—

Sugar being an article of luxury rather than a necessary of life, the extent of its consumption is affected by the condition of the people as well as by market value, and any increase from the first of these causes is a satisfactory indication of prosperity. Reverting to the early years of the present century, one finds that a long continuation of high prices in addition to periodical privations among the laboring classes gradually reduced the average consumption in the United Kingdom from twenty-two pounds per head in 1801 to sixteen pounds in 1844. A combination of favorable circumstances then arose to cause a reaction; the duties were greatly reduced; production increased; prices ruled low; and an enormous influx of gold commenced pouring into the country, thereby so largely adding to the means of procuring extra comforts and luxuries, that the average consumption per head more than doubled during the last fifteen years.

CONSUMPTION AND IMPORTS.—The following statistical table, made up as far as possible from official returns, will more particularly show the changes which have taken place. The figures for the present year are only approximate, as the return had not been made out when the tables were calculated. The prices and duties quoted are for West Indian Muscovado:—

Years.	Population of United Kingdom.	Consumption of Sugar.		Prices and Rates of Duty.			Duties paid on all Descriptions.	Per Head.
		Total Tons.	Lbs. per Head.	Gazette Average Price.	Rate of Duty.	Total per Cwt.		
1801	16,371,554	159,916	22	59s. 5d.	20s. 0d.	79s. 5d.	£3,066,163	3s. 9d.
1811	18,548,476	187,092	23	39s. 8d.	27s. 0d.	66s. 8d.	4,652,824	5s. 0d.
1821	21,302,392	170,612	18	33s. 2d.	27s. 0d.	60s. 2d.	4,188,997	3s. 11d.
1831	24,319,811	203,812	19	23s. 8d.	24s. 0d.	47s. 8d.	4,650,606	3s. 10d.
1841	27,021,949	202,899	17	39s. 8d.	25s. 2d.	64s. 1d.	5,114,390	3s. 9d.
1851	27,721,921	328,581	26	25s. 6d.	13s. 3d.	38s. 9d.	3,979,141	2s. 10d.
1859	30,000,000	450,000	33	27s. 0d.	12s. 0d.	37s. 6d.		
					12s. 8d.	39s. 8d.	6,000,000	4s. 0d.

IMPORTS INTO THE UNITED KINGDOM FROM 1841 UP TO THE END OF 1859.

	1841.	1842.	1843.	1844.	1845.	1846.
Sugar Raw—	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
Of or from British possessions	4,057,617	3,868,334	4,028,231	4,129,345	4,779,317	4,617,509
Of or from foreign countries	261	103	76	98	77,307	602,739
Total of raw sugar	4,057,878	3,868,437	4,028,307	4,129,443	4,856,624	5,220,248
Sugar refined and sugar candy	22	37	19	6	56	18,408

IMPORTS INTO THE UNITED KINGDOM FROM 1841 UP TO THE END OF 1859—*continued.*

	1847.	1848.	1849.	1850.	1851.	1852.
Sugar raw—	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
Of or from British possessions	4,805,489	4,921,332	5,409,209	5,183,097	4,854,506	6,216,341
Of or from foreign countries	974,019	1,220,964	496,478	908,395	1,379,041	682,526
Total of raw sugar	5,779,508	6,142,296	5,905,687	6,091,492	6,233,547	6,898,867
Sugar refined and sugar candy	26,130	46,191	75,137	116,335	338,079	273,991

	1853.	1854.	1855.	1856.	1857.	1858.	1859.
Sugar raw—	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
Of or from British possessions	5,740,854	5,589,467	4,934,343	5,695,363	5,325,975	5,323,580	5,458,380
Of or from foreign countries	1,531,979	2,439,291	2,319,879	2,065,877	3,064,721	3,775,300	3,552,420
Total of raw sugar	7,272,833	8,028,758	7,254,222	7,761,240	8,390,696	9,098,880	9,010,800
Sugar refined and sugar candy	214,756	303,649	287,520	187,211	329,122	262,460	386,820

UNITED STATES.

CONSUMPTION OF FOREIGN AND DOMESTIC CANE-SUGAR, FOR THE YEAR ENDING 31ST DECEMBER IN TONS.

Year.	Foreign.	Domestic.	Total.	Average increase for the ten years, 6½ per cent.
1859 ..	239,034 ..	192,150 ..	431,184 ..	
1858 ..	244,758 ..	143,634 ..	388,492 ..	
1857 ..	241,765 ..	39,000 ..	280,765 ..	
1856 ..	255,292 ..	123,468 ..	378,760 ..	
1855 ..	192,604 ..	185,148 ..	377,752 ..	
1854 ..	150,854 ..	234,444 ..	385,298 ..	
1853 ..	200,610 ..	172,379 ..	372,989 ..	
1852 ..	196,558 ..	118,659 ..	315,217 ..	
1851 ..	181,047 ..	107,438 ..	288,485 ..	
1850 ..	143,045 ..	126,421 ..	269,466 ..	

Oregon and California not included.

PRODUCTION OF CANE AND MAPLE SUGAR IN THE UNITED STATES FOR 1850.

	Cane-sugar in hogsheads.	Maple-sugar in pounds.
Maine,	—	87,541
Missouri,	—	171,943
Maryland,	—	47,740
Alabama,	28	—
New Hampshire,	—	1,292,429
Vermont,	—	5,149,641
Massachusetts,	—	768,598
Connecticut,	—	37,781
New York,	—	10,310,764
New Jersey,	—	5,886
Pennsylvania,	—	3,178,373
Virginia,	—	1,223,905
North Carolina,	$\frac{1}{2}$	27,448
South Carolina,	150	200
Georgia,	1,273	50
Florida,	1,741 $\frac{1}{2}$	—
Mississippi,	278 $\frac{1}{2}$	—
Texas,	7,017	—
Arkansas,	—	8,825
Tennessee,	—	159,888
Ohio,	—	4,521,643
Michigan,	—	2,423,897
Indiana,	—	2,921,638
Illinois,	—	246,078
Iowa,	—	31,040
Louisiana,	262,486	—
Kentucky,	—	386,233
Wisconsin,	—	661,969
Minnesota,	—	2,950
	272,974	33,677,061

This has much increased. Louisiana produced in 1858 three hundred and sixty-two thousand two hundred and ninety-six hogsheads, at sixty-nine shillings per hogshead, and value of twenty-four millions, nine

hundred and ninety-eight thousand, four hundred and twenty-four dollars. A hogshead is half a ton. Total Maple sugar produced in 1859 is believed to be twenty-seven thousand tons, or sixty millions four hundred and eighty thousand pounds.

The annexed extracts from the commercial review of Messrs. DE CONINCK, Brothers, and Company, furnish some interesting particulars of the statistical position of sugar in France.

The importation of foreign sugar into that country rose in 1859 to eighty-two thousand tons against forty-five thousand tons in 1858, and sixty-five thousand tons in 1857.

From the Colonies, France received last year five thousand tons more than in 1858; while the manufacture of indigenous or beet-root sugar produced in the season 1858-9, was one hundred and thirty-two thousand tons, being twelve thousand tons in excess of the first estimates. During the last six years, the quantities received by France from her Colonies were as follows:—

113,000 tons in 1859	95,400 tons in 1856
108,000 tons in 1858	89,000 tons in 1855
92,100 tons in 1857	82,000 tons in 1854
99,500 tons in 1847.	

The sources of these supplies are subjoined:—

QUANTITIES STATED IN TONS OF 1000 KILOGRAMMES.

	Guadeloupe.	Martinique.	Reunion.	Cayenne, &c.	Total.
1859 ..	24,400 ..	27,900 ..	58,600 ..	1100 ..	113,000
1858 ..	29,500 ..	27,400 ..	52,000 ..	— ..	108,000
1857 ..	18,500 ..	22,300 ..	51,000 ..	300 ..	92,100
1856 ..	21,600 ..	26,600 ..	57,000 ..	200 ..	95,400
1855 ..	21,000 ..	18,500 ..	49,900 ..	600 ..	89,000
1854 ..	22,001 ..	24,300 ..	35,700 ..	— ..	82,000

The consumption of sugar in France in 1859 is thus estimated:—

	Tons.
Sugar—Indigenous.....	120,000
" From French Colonies.....	95,000
" " "	60,000
Total.....	275,000
Deduct export of refined sugar.....	52,000
Remains for consumption in France.....	223,000

The season of 1858-59 produced of indigenous sugar—

132,600 tons against 156,000 tons {1857-58
1856-57
1855-56

It is not thought that the quantity produced in the season 1859-60 will exceed that of the preceding one, *videlicet*, one hundred and thirty-two thousand tons.

ZOLLVEREIN CUSTOMS RECEIPTS ANNUALLY FROM 1834 TO 1857, BOTH INCLUSIVE.

Years.	Total population of the States of the Zollverein.	Gross receipts in account of export, import, and transit duties.	Average sum per head of the population, derived from custom dues, <i>et cetera</i> , tax on beet-root.
		Rix-dol.	Groschen. Pf.
1834 ..	23,478,120	14,815,723	18 11
1835 ..	23,478,120	16,880,180	21 7
1836 ..	25,150,216	18,462,873	22 0
1837 ..	25,150,898	17,997,295	21 6
1838 ..	25,048,970	20,419,287	23 6
1839 ..	26,048,970	20,869,488	24 0
1840 ..	26,048,091	21,606,191	24 11
1841 ..	27,142,116	22,255,204	24 7
1842 ..	27,578,730	23,653,269	25 9
1843 ..	27,623,815	25,720,761	27 11
1844 ..	28,498,136	26,778,300	28 2
1845 ..	28,499,566	27,721,436	29 4
1846 ..	28,508,436	26,569,214	28 3
1847 ..	29,461,381	27,552,996	28 3
1848 ..	29,460,764	22,699,299	23 6
1849 ..	29,461,628	23,649,730	24 7
1850 ..	29,800,063	22,948,809	23 8
1851 ..	29,800,063	23,256,058	24 11
1852 ..	29,800,063	24,649,721	26 6
1853 ..	30,492,792	22,016,154	23 10
1854 ..	32,559,173	23,157,407	24 9
1855 ..	32,559,164	26,323,372	27 9
1856 ..	32,721,344	26,156,450	28 0
1857 ..	32,940,780	26,595,788	29 5

The duty is now seven and a half groschen for one hundred pounds, and brings nearly three shillings per head.

AMOUNT OF RAW BEET-ROOT USED FOR THE PRODUCTION OF SUGAR, AND AMOUNT OF DUTY RECEIVED IN THE STATES OF THE ZOLLVEREIN.

Years.	Amount of beet-root used for sugar. Cwt.	Produce of the tax in rix-dol.
1842 to 1847	4,322,712	232,991
1847 to 1853	13,998,570	1,156,744
1853 to 1856	19,832,679	3,966,536
1856 to 1857	27,551,207	5,312,856
1857 to 1858	28,915,133	5,783,033

CONSUMPTION OF BEET-ROOT SUGAR IN THE STATES OF THE ZOLLVEREIN.

Years.	Consumption of colonial sugar. Zollverein cwt.	Consumption of beet sugar. Zollverein cwt.	Total consumption of sugar. Zollverein cwt.
1844 to 1846 ..	1,278,421	264,283	1,542,704
1847 to 1849 ..	1,154,005	646,650	1,800,655
1850 to 1852 ..	739,958	1,219,718	1,959,676
1853 to 1855 ..	654,386	1,487,452	2,141,838

In 1856-57 there were two hundred and thirty-three manufacturers of beet-root sugar in the Zollverein. In 1839-40, four and four-fifths pounds per head was consumed; in 1853-55 there were six and a quarter pounds consumed.

The shipments of beet-root sugar, according to BARUCHSON and Company of Douai, to Great Britain, were little more in 1858-59 than half those of the preceding season, owing to the prices in England being at several periods below those of France. They consist as follows:—

FROM 1ST NOVEMBER, 1858, TO 31ST OCTOBER, 1859.

To Liverpool	about 3218 tons.
To the Clyde	" 2240 "
To London	" 1614 "
To West of England	" 1234 "
To Hull	" 37 "

Total..... " 8343 "

A good deal of this was re-exported, as it could not compete with Colonial.

PRICES CURRENT.

Low brown, equal to No. 7 to 8 Dutch standard—very scarce	21s 0d to 22s 6d
Light brown, equal to No. 10 to 10½ Dutch standard	23s 6d to 24s 0d
Grey and yellow, equal to No. 12 Dutch standard	25s 0d to 25s 6d
Per cwt., cost, freight and insurance to cover average.	

In Russia the consumption has nearly doubled within a few years; but even now it is only two pounds per head.

DR. ANGUS SMITH of Manchester kindly rendered his valuable aid during the progress of this article, and for which the Editor is indebted to him.

SULPHUR—*soufre*, French; *schwefel*, German—is one of the elements of modern chemists, and was a still more important one in the theory of the alchemists.

OCCURRENCE.—It is found in nature, both in a free state and in combination with metals, as sulphides and sulphates. In the free state it occurs in volcanic regions, large quantities being imported to this country from Sicily. The native sulphur occurs both amorphous and crystallized. In the latter state it usually occurs in right rhombic octohedra, although it does not assume this shape under all conditions; it crystallizes in many

forms, almost as varied as the methods of procuring the body in the crystallized state. Native sulphur is far from being pure, containing a considerable quantity of adhering soil and other matter from which it is purified by different methods dependent on the purposes to which it is to be applied. Large quantities of sulphur exist in combination with metals as sulphides; of these may be mentioned the sulphides of copper, lead, iron, and zinc; these bodies, in fact, forming the ordinary ores or minerals of these metals, from which the sulphur has to be burnt off before the metal itself can be obtained. Sulphur occurs also in nature in saline combinations as sulphates of the alkalis and earths; for instance, the sulphate of soda and potassa, which are comparatively rare, and the sulphates of baryta and lime, which occur in immense quantities.

PROPERTIES.—Sulphur is a pale yellow, solid, very

brittle, becoming negatively electrical by heat or friction; it was at one time, in an earlier period of electrical history, used, when formed into globes and mounted as glass cylinders and plates are at the present day, as a source of electricity. Its specific gravity is variously stated, but most writers agree in considering it as 1.98—probably its density is dependent on the degree or stage of heat to which it has been carried while in a fused state. It is perfectly inodorous unless when rubbed, when a peculiar smell is developed. This was once supposed to arise from a hydrogen compound formed by friction; it is now ascribed rather to the production of ozone. Owing to its brittleness, as well as from conducting heat badly, it soon splits into innumerable cracks when held in the warm hand; by inclosing a stick of cast sulphur in the hand, and holding it close to the ear, this is easily detected, a continued series of very slight cracklings are heard similar to the cracklings of an electric machine when in work, only much fainter. Sulphur, though perfectly insoluble in water, is soluble in a variety of liquids, most of which are capable of dissolving a greater quantity of the body when hot than they are when cold, in consequence of which they, on cooling, deposit this excess in the shape of crystals. Oil of turpentine is capable of dissolving a considerable quantity. In fact, it has been proposed to take advantage of this property in the analysis of gunpowder; for by heating this body with turpentine in a warm state, having previously dissolved out the nitrate of potassa with water, we can dissolve out the sulphur, leaving the charcoal, which is not soluble in this menstruum, behind. Bisulphide of carbon will also dissolve a considerable quantity of sulphur, which can be again obtained in crystals by allowing the solvent to evaporate gradually. Fat oils are also capable of dissolving it. A compound called *oleum sulphuratum*, or balsam of sulphur, once figured in the Pharmacopœia of the London College, though now omitted. This was formed by dissolving sulphur in olive oil, employing a tolerably high temperature to effect the combination. Ether, petroleum, and fused paraffine, may be mentioned as solvents of sulphur.

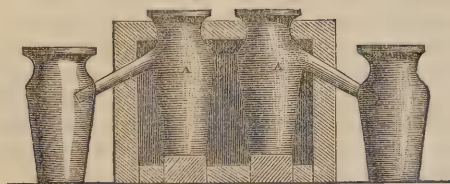
Pure sulphur exhibits some curious phenomena in connection with heat. Although perfectly solid at the ordinary temperature, it fuses at a heat little more than that of boiling water, and at a higher heat passes through various physical changes; and finally, on raising the temperature still higher, it volatilizes completely, without leaving anything behind. The following experiment is interesting, as displaying some of the peculiarities of this body:—Procure a small saucepan, and partly fill it with fragments of sulphur; place this over a gentle fire, having first put on the lid; after a while it will fuse. This takes place at a temperature of about 228°, forming a thin brownish-yellow transparent liquid. On heating still higher a very perceptible change takes place; the sulphur, instead of remaining in the very liquid state, becomes of a thick consistence, so much so that the vessel containing it may be completely inverted without fear of loss. This occurs at a temperature of between 428° and 482°. At a still higher degree the action is reversed, the melted sulphur becomes thinner and thinner until it reaches the boiling point,

when it begins to pass off as vapor. Other phenomena may be noticed by interrupting the experiment at various stages; for instance, if it be wished to obtain crystals of sulphur, it is only necessary to take the sulphur while in the first liquid stage, to pour this into a basin or other vessel with sloping sides, and there allow it to stand. In a few minutes after the top portion has solidified and formed a crust, break two holes through this crust at opposite sides of the vessel. If the basin be now inverted partially, the sulphur, which still remains in the liquid state in the interior, will run out of one hole while air rushes through the other. Let the vessel stand until cold, carefully detach the solidified mass from the containing vessel, and by means of a saw divide it into two halves. These will be found to be full of beautiful crystals of sulphur. It is possible that the first experiment may not be very successful, but a few trials will enable the operator to procure a mass of crystals, radiating into, and interlacing each other in every direction from the external crust. If the sulphur, immediately after passing, or perhaps better, while scarcely through the thick stage, be poured into water, it does not solidify and assume the ordinary yellow brittle appearance which it would do were it so treated while in the first liquid state; instead of doing so it remains in this plastic condition even when cold, bearing a stronger resemblance to caoutchouc than sulphur. In this state it is perfectly elastic, may be pulled out to a considerable length without breaking, and, in fact, does not in the remotest degree resemble sulphur. But for its color, it might be mistaken for wheat gluten, possessing the same soft elasticity as that body. It will remain in this state for some time, not resuming its ordinary aspect until after the lapse of some days.

PURIFICATION.—Sulphur occurs in commerce in several states of purity, the native sulphur being the most impure. In order that it may be more fit for the several uses to which it is applied, it is partially purified from the grosser extraneous matter, such as gravel, sand, *et cetera*. This is done, according to some authors, by throwing a quantity of the crude native sulphur into a suitable iron vessel or pan, and heating this pan until fusion takes place. The sulphur when fused, of course, occupies much less space than it did in the heap, so the operator keeps filling up the pan until it is full of the fused sulphur. A high heat is not advantageous. This may be inferred from what has been said before respecting the changes which take place during the fusion of sulphur at different temperatures. For the purpose of purification the lowest heat consistent with perfect fusion is the one to be employed. The liquid sulphur is thus in its thinnest state, easily allowing the heavy particles with which it was contaminated to fall to the bottom of the pan, while any light particles rise to the top, and are skimmed off. When some time has elapsed, and the operator considers that sufficient subsidence has taken place, he proceeds to remove the upper stratum of tolerably pure sulphur, running it into moulds, from which it is removed as solid blocks of sulphur. That the method is not perfect is easily ascertained by burning a piece of ordinary commercial sulphur in a porcelain capsule. A quantity of light dust will remain,

consisting to a large extent of sulphate of lime; yet, though the purification is not absolute, it produces an article pure enough to be employed for almost every purpose required in the arts. In order to procure an almost absolutely pure article, such as is necessary for medical and a variety of other purposes, distillation, or rather sublimation, must be had recourse to. Sulphur, as has been before stated, is perfectly volatile; a ready method therefore exists of separating it from all bodies which are not so. It is said that the following apparatus—Fig. 567—is employed to effect this. A A, are two earthenware or fire-clay jars,

Fig. 567.

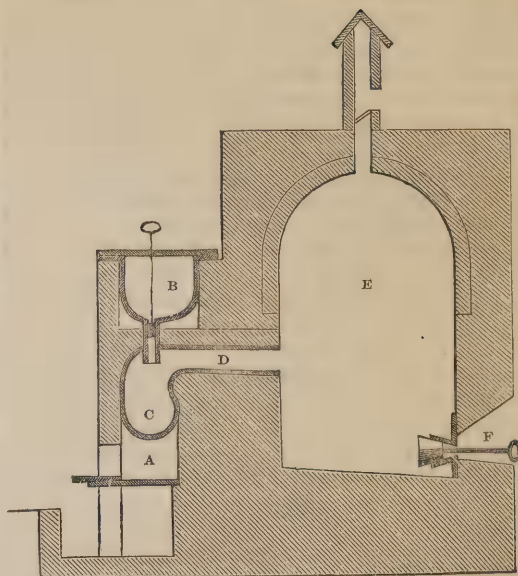


standing on a raised support of bricks. The mouths of these jars protrude slightly over the top of the furnace. This is for the purpose of readily enabling the operator to fill in the charge, and to remove the earthy residuum. A hollow tube or arm projects laterally and slightly downwards from each of the pots or retorts, which arm is thrust into another pot or vessel to receive the sublimed sulphur which condenses into it. When the subliming pot has received its charge, the lid is luted on and the furnace lighted. As they become heated, the various changes of fusion take place up to the last, when sublimation begins. The vapor then passes over into the condensing jar, and becomes solid. All the extraneous matter is left in the subliming pot, from whence it is removed prior to the introduction of another charge. This apparatus, *if actually employed*, could certainly furnish only a small quantity of sulphur. It is hardly possible to imagine a large gunpowder work using such an apparatus.

In 1815 a manufacturer named MICHEL, of Marseilles, devised an apparatus which, with some slight modification, is used up to the present day. The drawing—Fig. 568—represents it, and which, like the one previously described, contains a retort wherein the sulphur is converted into vapor, and a condensing chamber in which this is reconverted into solid sulphur. The apparatus, as in the drawing, consists, first, of a retort, C, beneath which is a furnace, A; this retort is filled with liquid sulphur from the reservoir, B, wherein the crude sulphur is melted by the waste heat of the furnace to facilitate its introduction to the retorts. When the retort has become sufficiently hot the sulphur begins to pass as vapor through the tube or opening, D, into the condensing chamber, E. This chamber is built entirely of brick, with a well-cemented brick floor; on its upper part a small chimney is erected; this chimney contains a sort of wooden valve or door, capable of opening outwards, to allow the expanded air to escape, and in case of explosion to allow the gases produced immediate exit. This apparatus when cold allows solid sulphur

to form at once in the shape of the ordinary commercial *flowers* of sulphur; the vapors immediately on coming into contact with the cold chambers are chilled, and fall as a minutely divided solid. These flowers, as they

Fig. 568.

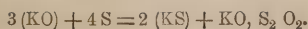


are called, are removed before the chamber gets hot, which is the case after a few days' working, the whole of the heat which the sulphur had taken up, in order to become vapor, being given out to the walls; they thus acquire so high a temperature as to fuse sulphur, therefore it can no longer become solid in contact with them, but condenses on their surface in a liquid form, and runs to the bottom, where it collects. When the operator is satisfied that sufficient has distilled over, he proceeds to remove it; this he does by means of the plug apparatus, figured at F, which is simply an iron plug with a tolerably long shank or handle, as is shown in the drawing; by pushing this plug inwards he opens the passage for the flow of the liquid sulphur, which runs into suitable moulds, to form the *stick or roll* sulphur of commerce. The residue is raked out of the retort, which is immediately charged again by removing the plug which closes the tube or passage between the vessel, B, and the retort. An apparatus better calculated for the purpose than the above, is figured in PAYEN's *Precis de Chimie*, in which two retorts are attached to one condensing chamber; these retorts are cylindrical, and resemble to a certain extent ordinary gas retorts. A portion of the door which closes the outer end of the retort is movable, to enable the operator to rake out the debris left after distillation, the other end of the retort rises like a swan's neck before opening into the condensing chamber. Over these openings or orifices within the chamber hangs a damper or register in such a manner that it can, from the outside, be placed over them, thus cutting off all communication between the retort and the chamber.

A fusing vessel heated by the waste heat is attached, as in the drawing just given. This description of apparatus has the advantage, that by its means the operation can be rendered continuous. For instance, let one retort be called A, the other B; suppose retort, A, charged at a certain hour, and retort, B, charged some two hours later, it is certain that were they charged with an equal weight of raw material, the retort, A, would be ready for recharging two hours before retort, B. Supposing this to be the case, the damper or sliding plate is allowed to fall over the opening of retort, A, thus closing the passage between it and the condenser, and preventing the rushing back of any sulphur vapor. The cover is removed from the front opening, the impure residue raked out, after which it is again closed, the entrance into the condensing chamber is again opened, a charge of sulphur is run in from the fusing vessel, and the distillation again commences. During the whole of these operations retort, B, has been uninterruptedly at work; but eventually the same operations have to be performed in connection with it as have been detailed with respect to retort, A. Thus between the two a constant stream of sulphur vapor is being perpetually driven into the condensing chamber, the work going on almost without interruption, as the retorts never want charging simultaneously.

Sulphur thus produced is almost pure. It is true that the sublimed sulphur in powder—that is, the flowers of sulphur—contains a small quantity of sulphurous acid, which for some purposes it is necessary to remove by washing with water, but this is pretty nearly the only body it is contaminated with; the roll sulphur is free from sulphurous acid.

Sulphur occurs in commerce in another form intended expressly for medical use. When in this shape it is called *milk* of sulphur, and consists of sulphur in a very minute state of division. It is obtained in this state by dissolving ordinary roll sulphur bruised, or the flowers, in any caustic alkali, either soda, potassa, or lime; the latter used as being cheaper, and furnishing, as will be explained hereafter, a convenient adulterant. Sulphur does not dissolve in the alkaline solutions in the same manner that it does in turpentine, or any of the before-mentioned solvents. When boiled with an alkali a series of chemical compounds or salts are formed; in spiritous liquids it is a case of simple solution, exactly the same as dissolving sugar or salt in water, whereas in the other, a series of definite chemical phenomena takes place. If to a boiling solution of caustic potassa there is added as much sulphur as it will possibly take up, a liquid will be obtained containing sulphide of potassium, and hyposulphite of potassa, according to the following equation:—



In the first instance, while there is an excess of alkali, and little sulphur taken up, there is formed only sulphide of the alkaline metal and sulphite of the alkali; but this sulphite, by being boiled with an excess of sulphur, takes up another equivalent of it, being itself converted into hyposulphite. The clear liquid obtained in this way must be filtered or poured off the sediment, and excess of sulphur, and either sulphuric or hydrochloric

acid added until the liquid reddens litmus paper, when the dissolved sulphur is again precipitated in an exceedingly fine state of division. This is washed, drained, and dried at a gentle heat. It remains to examine the reaction by which the sulphur is again obtained. To do this, it will be well first to notice what the effect would be of adding acid to separate solutions of the two salts which form the mixture. If a solution of sulphide of potassium be taken, and an acid be added, a copious evolution of sulphide of hydrogen ensues, and there is obtained very little, if any, precipitated sulphur. Again, if acid is poured into a solution of hyposulphite of potassa, only a little sulphur will be separated. Hyposulphurous acid consists of sulphurous acid plus one equivalent of sulphur. Now hyposulphurous acid can only exist in combination; when set free it is instantly decomposed into sulphurous acid and sulphur— $\text{S}_2\text{O}_2 = \text{SO}_2 + \text{S}$. This is the case on adding an acid to hyposulphites. In the first place, the alkali is detached from its combination, and this hyposulphurous acid being set free gradually resolves itself into sulphurous acid and sulphur.

It is well known that when sulphide of hydrogen and sulphurous acid are brought into contact with each other a decomposition ensues, water and sulphur being the result, as shown in the following equation:—



Thus is explained the reproduction of the whole of the sulphur employed. Hyposulphurous acid and hydrosulphuric acid, or sulphide of hydrogen, are set free in the first instance; the hyposulphurous acid splits into sulphur and sulphurous acid, the latter immediately reacts upon the sulphide of hydrogen, producing together sulphur and water. This reaction is not very complete, although it is nearly so—the more correct reaction is given under *Pentathionic Acid*. In ROYLE'S *Materia Medica* it is recommended, in order to obtain milk of sulphur, to boil one part of sublimed sulphur with two parts of slaked lime and sufficient water, and to add hydrochloric acid to the clear liquid obtained.

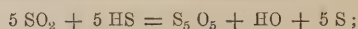
Lime is almost invariably used by the manufacturers as a solvent, but they are guilty of substituting sulphuric acid for hydrochloric as a precipitant. By so doing, instead of forming the soluble chloride of calcium, which is easily removed by washing, they form the very insoluble sulphate of lime which, mixed with the sulphur, forms the article commonly sold by druggists as milk of sulphur, and thus what should be pure sulphur is contaminated by this worse than useless sulphate of lime, often to the extent of more than fifty per cent. In one sample obtained from a druggist, and which was stated to be pure, fifty-six per cent. of sulphate of lime was found. It is useless to argue that such a sophistication is harmless; for, although not positively poisonous, the introduction into the stomach and bowels of a quantity of this insoluble matter cannot but be productive of harm. Sulphur is used in medicine as a mild purgative, and in some skin diseases. The stores of sulphur which this country possesses, in one form or another, has not been overlooked by practical scientific men.

EXTRACTION OF SULPHUR FROM ITS ORES.—The immense quantities of sulphur stored up in the shape of sulphate of lime and baryta, as well as the sulphides of iron, zinc, lead, and copper, is almost beyond calculation. There is good reason to suppose that at some future time the sulphur combined with these metals, and which at the present time is separated from them only to be thrown into the air, will be recovered in a tangible solid form, at a price low enough to compete with foreign sulphur. The attempts to do this already have been numerous. In many parts of the country iron pyrites is plentiful, and this mineral appears to have been a favorite material with inventors. It is a mixture of bisulphide and protosulphide of iron. The second equivalent of sulphur of the bisulphide is held rather loosely, so much so that a red heat, continued for some time, will drive it off, leaving one equivalent of iron combined with one of sulphur, forming the protosulphide. Here, it would appear, a process for obtaining sulphur readily is at hand; but if it be considered that the sulphur ores of this country rarely contain more than thirty per cent. of sulphur, and that, at the most, but two-thirds of this exist as bisulphide, and that only half of this latter quantity can be expelled by heating with exclusion of the air, it will at once be apparent that the process could never be rendered remunerative. Such a method is, however, pursued in some parts of the Continent, where sulphur ores are found of a much richer kind, and in which there is also a greater proportion of bisulphide, but not exactly by the same method that sulphur is purified. The process appears to be one of slow distillation of one part of the sulphur, at the sacrifice, by combustion, of the other. It is stated—KNAPP—that not more than one-fourth of the sulphur actually contained in the pyrites is obtained. This process has formed the base for several improvements. It would appear that inventors are quite aware of the benefits that would result from the discovery of a process whereby sulphur could be separated from the pyrites on the spot, even if only the saving the expense of carriage, if nothing else, of the vast quantity of iron. The following process was invented by Mr. LEE. He first converts the sulphur in the pyrites, or other mineral, into sulphurous acid, and then proceeds to recover the sulphur from this by passing it through a quantity of coke heated to bright redness. The oxygen of the sulphurous acid combines with the incandescent carbon, forming carbonic oxide, *et cetera*, while the sulphur is left in a free state, and in vapor. It passes on to a suitable condenser, in which the bulk of it is recovered in a melted shape; that which escapes melting is received into a vaulted chamber similar to the one employed in the refining of sulphur by sublimation, and in these obtained solid in the form of flowers of sulphur.

This process, or rather the apparatus, appears to be of a very complicated character. Mr. SPENCE of Manchester, in a process patented by him a few years ago, has materially simplified it, although he works on precisely the same principle. Mr. SPENCE'S apparatus consists simply of an ordinary pyrites burner, such as is used in the manufacture of sulphuric

acid, to which is attached a number of condensing vaults. He charges his burner with alternate layers of charcoal and the pyrites under treatment; having first heated the brickwork of the burner up to the proper pitch. When at work, the action is very simple—the pyrites burns with production of sulphurous acid; each atom of this gas has to traverse a bed or layer of red-hot charcoal. Now, as just before stated, carbon having a greater affinity for oxygen than sulphur has, forces this sulphurous acid to yield up its oxygen, thus setting the sulphur free. The sulphur passes on with the current of gases, and is deposited in a state of powder in the condensing chambers. This plan appears to be more feasible, and better capable of working on a large scale than the one preceding.

While speaking of precipitated sulphur, it was shown how it was possible for sulphide of hydrogen and sulphurous acid gases to react upon each other, the eventual products being water and sulphur. This reaction has been taken advantage of in a process patented by Mr. DUCLOS of Swansea. He proposes to conduct into a leaden chamber, such as is used in the production of sulphuric acid, a mixture of two volumes of sulphide of hydrogen and one volume of sulphurous acid, a quantity of steam being at the same time admitted into the chamber. This, at first sight, appears to be very workable. It is easy to see that the two gases could be regulated to each other, and a constant action go on: the sulphur in a fine state of division would be deposited on the floor of the chamber, while the excess of atmospheric air, *et cetera*, would go out through proper openings at the end of it. But it unfortunately happens that only about one-half of the sulphur actually contained in the two gases is obtained. When these two gases are brought together, water being present, the results actually are water, sulphur, and pentathionic acid—an acid of sulphur with the formula S_5O_6 . Its production may be explained as follows—

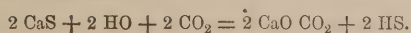


that is to say, that five equivalents of sulphurous acid and five equivalents of sulphide of hydrogen produce, by their mutual reaction, five equivalents of water, five equivalents of sulphur, which are deposited, and one equivalent of pentathionic acid. By calculation it is thus found that by this only one-half of the sulphur would be obtained in the solid state, for in the sulphurous acid there are five equivalents of sulphur, and five more in the sulphide of hydrogen; and for these ten equivalents of sulphur one recovers only five, the rest going to form the pentathionic acid, a body for which no use in the arts has yet been found. Thus, instead of burning the pyrites, or other minerals, and endeavoring to separate the sulphur from the sulphurous acid produced, it would be more economical to convert it into sulphuric acid at once.

Mr. GOSSAGE surmounted the pentathionic acid difficulty, by causing the reaction to take place at a high temperature. His process is peculiarly applicable to the reproduction of the sulphur contained in the lime compound or alkali waste thrown away by the soda manufacturers. As is well known, the whole of the sulphur used in the manufacture of the alkali finds

its way into the vat waste. Mr. GOSSAGE proceeds to decompose this vat waste by means of carbonic acid. The action of this acid causes sulphide of hydrogen to be evolved. A portion of this sulphide of hydrogen is converted by burning into sulphurous acid, which sulphurous acid is made to react, at a high temperature, on a fresh portion of sulphide of hydrogen, when water and sulphur are produced. His apparatus consists of four distinct portions—the first for the production of the requisite carbonic acid; the second for the decomposition of the alkali waste; the third is for the decomposition of the sulphide of hydrogen; and the fourth for the collection of the sulphur produced. The apparatus for the production of the carbonic acid is an ordinary lime-kiln, with some additions to render it more fit for the special purpose to which it is to be applied. It is fed with a mixture of common coke and limestone, air being admitted for the purpose of combustion in the usual manner. The apparatus is of the continuous kind. It is fed constantly at short intervals with the above materials, the quicklime produced being removed from the bottom of the kiln at stated periods. The action of this kiln is simply the decomposition of the limestone, the carbonic acid evolved, together with that furnished by the combustion of the coke, being carried to where it is needed in the next stage for the decomposition of the vat waste.

The composition of this compound may be considered definitely settled. It seems to be tacitly allowed with DUMAS that its composition is $2 \text{CaS} + \text{CaO}$, or two equivalents of sulphide of calcium, united to one of lime; but the research of Mr. J. W. KYNASTON lately in the Editor's laboratory, has indubitably proved it to be simply a protosulphide of calcium with carbonate of lime. This substance, the composition and properties of which have been fully discussed under the article SODIUM, though insoluble in water, is capable of being decomposed by carbonic acid, especially when in a loose porous state; one equivalent of the lime compound, and three equivalents of carbonic acid producing three equivalents of carbonate of lime, and two of sulphide of hydrogen, as follows:—



The apparatus employed, or proposed to be employed, in the decomposition of this compound by Mr. GOSSAGE, consists of two large chambers, or rather large columns, filled with numerous perforated floorings or stages on which the alkali waste is placed; these chambers or columns are placed side by side, and so connected together, that the carbonic acid which is admitted at the bottom of one column, emerges at the top, and is conducted by a proper passage to the bottom of the adjoining column, up which it passes, as in the previous case. The material to be operated upon is laid on the perforated floors, in a loose open manner, to facilitate the passage of the carbonic acid; this ascending from the bottom of the column, penetrates through each of these separate masses, decomposing each particle with which it comes in contact. This course it pursues until it reaches the terminal point of this portion of the apparatus, at which time the carbonic acid is supposed to have been completely absorbed, and replaced by the

liberated sulphide of hydrogen which has now to be decomposed. In order to this effect, the inventor has constructed a furnace of a rather peculiar character. This furnace has a closed ash-pit, or an ash-pit whose inlet can be closed or not, at pleasure, by means of a damper or register; the flue or passage for the gases leading from the waste decomposer is divided into two at this point, one part of the sulphide of hydrogen is drawn into this ash-pit, and so through the bars and fuel of the furnace, while the other portion is admitted immediately above the burning fuel; by this means a quantity of sulphurous acid is produced, which, in coming in contact with a fresh portion of sulphide of hydrogen at this high temperature, decomposes it, forming, as shown before, sulphur and water. This sulphur, of course, is in the state of vapor, mixed or diluted with a variety of other gases; it now remains to separate this valuable ingredient from the mass of inert and useless gases which accompany it. For this purpose an apparatus similar to the one last described is employed. This column is built of bricks or other suitable material, and is filled with coke; a cistern of water is placed on the top, by means of which, with the assistance of an apparatus for the spreading of the water in the form of rain over the whole area of the column, the coke is kept drenched with a stream of water. The vapors issuing from the furnace, consisting, as before stated, of sulphur vapor, mixed with other gases, is forced or drawn in at the bottom of this column, when, meeting with the cold wet coke, their temperature is almost instantly brought below the melting-point of sulphur, and this body is deposited in the solid state in the form of an impalpably fine powder, which mixes with the stream of water, and is finally carried out with the stream, forming with it a milky liquid, which falls into a proper cistern or reservoir, from which the sulphur is separated by deposition; from thence it is removed, and fused into a coherent mass, to fit it for the purposes of commerce. Between each of the different portions of the apparatus just described, the inventor places an ordinary draught or blower-fan, which rapidly removes the gaseous products from one portion, forcing them into the next. The various columns, *et cetera*, are of such dimensions as to insure a sufficiently quick passage for the products.

In theory this would appear to be perfection, inasmuch as we have here the recovery of the sulphur, which is the main object; and also the recovery of the lime, this body being left as carbonate after decomposition. As most alkali manufacturers are also manufacturers of bleaching powder, or chloroxide of calcium, this process offers an unfailing supply of lime; or if the recovered carbonate of lime just spoken of should not be found to answer for the soda decomposition a second time, that produced in the kiln could be used in the black-ash furnaces, instead of the limestone usually employed. It thus offers a considerable advantage if it should turn out to be as practically valuable as it is theoretically interesting.

Messrs. M'DOUGALL and RAWSON, in a patent, dated May 21, 1849, claim a process for the reproduction of sulphur from sulphide of hydrogen, from whatever source obtained. This they effect by passing it through

a pipe, heated to a red-heat, wherein the gas is split up into its constituent elements, sulphur and hydrogen; the sulphur is collected in any convenient manner. This process does not appear eminently practical, if the experiments of CORENWINDER be correct. He states that by passing sulphur vapor and hydrogen over or through porous bodies, kept at a red-heat, he obtained sulphide of hydrogen, exactly the reverse of this process. At any rate in a laboratory M'DOUGALL'S operation answers perfectly.

Messrs. DYAR and CHISHOLME secured a patent in 1839, for the recovery or reproduction of sulphur from sulphurous acid. It consisted in submitting the gas while at a red-heat to the action of hydrogen, which latter seized upon the oxygen, forming water and liberating sulphur. Two furnaces of proper construction were erected, side by side, one adapted to the combustion of pyrites, the other constructed in such a manner that it afforded a stream of hydrogen, mixed with carbonic oxide, obtained by passing a current of steam through or among incandescent coke. The gases were brought together at a point of junction kept sufficiently hot by the combustion of the materials themselves. At this point the decomposition took place, the sulphur vapor passing on to a proper condensing apparatus.

Amongst a most numerous array of methods for procuring sulphur, or for separating it from natural combinations, perhaps one of the most theoretically ingenious is that mentioned by PARNELL as being devised by M. THAULOW. It is for producing sulphur from the natural sulphate of lime. He proposes to reduce this to the state of sulphide of calcium, which salt he then decomposes by means of carbonic acid, obtaining by this means sulphide of hydrogen and carbonate of lime. He effects the deoxidization of the sulphate of lime, or its reduction to sulphide of calcium by mixing it, in fine powder, with coal-dust, exposing this mixture to a red heat for a sufficient length of time in a retort of clay or iron; the carbon unites with the oxygen of the sulphuric acid and lime, and becomes carbonic acid, which he reserves, or immediately uses for the decomposition of a previous charge. Carbonic acid, as stated while describing Mr. GOSSAGE'S process, is able to decompose sulphide of calcium, driving off sulphide of hydrogen. Thus M. THAULOW proposes to burn sulphide of hydrogen in lieu of sulphur for the production of sulphuric acid. There are reasons for supposing that this process can never be successfully carried out. In the first place, as PARNELL observes, if the exact quantity of carbon only necessary to combine with all the oxygen present, is added, the reduction would be extended over a great length of time, and would probably never be complete; and again, were an excess of carbon to be employed, so as to hasten the decomposition, carbonic acid would not be obtained, for carbonic acid passed over red-hot carbon would part with half its oxygen, becoming carbonic oxide—CO—a gas which could not possibly be substituted for the carbonic acid in this case. By a little addition the process can be made theoretically possible; still, the probabilities are that it will never be practically worked, unless sulphur should rise in price much higher than it is likely to do.

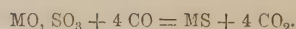
As an instance of the manner in which old and useless, or exploded inventions again arise, one may mention the re-invention or revival of this very process by OTTO KÖHSELL, who patented it for the kingdom of Hanover in 1856. The process, as detailed by this inventor, is precisely the same in every detail as that of M. THAULOW—not the main principal only, but in every minute particular it is a perfect copy.

In 1857 Mr. GOSSAGE invented, and secured by patent—dated September 12th in that year—another process for obtaining the sulphur from the sulphide of calcium of alkali waste. In the place of hydrochloric or carbonic acid, as in his method of decomposition before mentioned, he liberates the sulphur in the form of sulphide of hydrogen, by acting upon the waste with steam at a high temperature. The following equation represents the change that ensues—



The sulphide of hydrogen so obtained he applies instead of sulphur, in the production of sulphuric acid by burning with atmospheric air, so as to form sulphurous acid gas; or he obtains the sulphur itself from the sulphide of hydrogen by causing sulphurous acid to act upon it, when mutual decomposition takes place.

When carbonic oxide gas is passed over the sulphates of the alkalis or alkaline earths in a state of ignition, the salts are reduced to sulphides with the simultaneous conversion of the carbonic oxide to carbonic acid, thus—



Now, as Mr. GOSSAGE has shown, if steam at a high temperature be caused to act upon the sulphides of the alkaline earths, sulphide of hydrogen is liberated. If, therefore, a mixture of steam and carbonic oxide gas be passed over the ignited alkaline, or earthy sulphates, the sulphur of the sulphate will be obtained as sulphide of hydrogen, and may afterwards be obtained in the free state. This method has been lately proposed by M. JACQUEMIN, for the production of sulphur from sulphate of lime, and also for obtaining, at the same time, soda in the caustic condition from sulphate of soda.

The author appears to think that by means of this process he will revolutionize the soda manufacture, as he anticipates the recovery of the whole of the sulphur in an available form without the production of any waste whatever. Even if this process would answer on a small scale, its success on a larger one is very doubtful. Were its success an absolute and undoubted fact, and the reaction clean and exact, it would be capable of considerable extension. The sulphur from sulphate of lime might be recovered in like manner. It would only be necessary to mix it in the manner M. THAULOW proposes to do with small coal, or other carbonaceous or reducing matter; heat to bright redness in a closed retort for some hours, until it was reduced to the state of sulphide of calcium; then to pass steam over and drive off the sulphur as sulphide of hydrogen, while lime would remain behind as

quicklime. This process, which is tacitly indicated by the author, should be much superior to that of M. THAULOW just mentioned; but it would appear that a like fate has awaited both processes; in fact, that they are each impracticable on a large scale, or, what is the same thing, they would not pay at present.

These are not the only methods which have been proposed for the recovery of sulphur from its various combinations; but they serve to show, to a certain extent, the industry of the various inventors who have turned their attention to the subject; and though success has not followed to the extent no doubt expected by the sanguine chemist, there is no reason for despair. It is still to be hoped that some one, more successful than his predecessors, may yet, in some fortunate moment, hit, either upon a yet latent reaction, or by some perhaps trifling variation of an already known mode of procedure, bring forward a simple and easily-worked process, that shall be all that could be desired, producing sulphur at a price sufficiently low to compete successfully with the imported article. Sulphur, in a state of combination, exists in this country in almost inexhaustible quantity. To separate this, and to produce it in a state of comparative purity, is what is wanted. When this is done, English manufacturers will be in a state of great independence. It scarcely need be added that by such a discovery the fortunate individual would be more than repaid for a life's industry.

COMBINATIONS OF SULPHUR.—Sulphur enters into many combinations, both simple and complex; it combines, with a few exceptions, with all the metals, forming with them proper insoluble compounds. The sulphides of the alkaline and earthy metals are soluble in water. Some sulphides are decomposed by acids, while others again are insoluble in these liquids. Of these peculiarities chemists avail themselves largely in analysis; for, by this property of forming insoluble compounds with sulphur, they are enabled to separate into classes several groups of metals, from which again, by a series of subdividings and subclassings, they can separate individually each element. The larger groupings are made chiefly through the instrumentality of sulphide of hydrogen. This gas, when passed through a solution of metallic oxides, in many cases throws down the metal as a sulphide, the gas being decomposed. As an example: if a current of sulphide of hydrogen be passed through a solution of a salt of lead, the following reaction takes place—

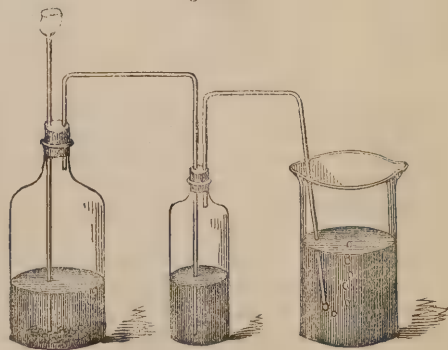


Sulphide of lead and water are the products of this decomposition. The following metals are thrown down as sulphides by sulphide of hydrogen from an acid solution—gold, platinum, mercury, silver, lead, bismuth, and copper, black; antimony, orange; arsenic, tin, and cadmium, yellow. The following metals are converted into sulphides when sulphide of hydrogen is passed through their alkaline solutions, or a slightly alkaline solution, in which their hydrated oxides are suspended—nickel, iron, and cobalt, yellow; tin, black; manganese, flesh-colored; zinc, white. Sulphur enters into the vegetal kingdom; it is found in more or less

quantity in many plants, chiefly in connection with nitrogen, with which it would appear to act in consort, at least in the organic world. In the animal kingdom it occurs pretty extensively also, and there too it is principally found in nitrogen compounds. Animal and vegetal products of the albumen and fibrin class contain it as an essential element, while its existence in the form of salt, as sulphate, *et cetera*, is still more diffused. It combines, as will be presently shown, with several proportions of oxygen, and with hydrogen in at least two proportions—the sulphide of hydrogen spoken of so repeatedly in this article when treating of the recovery of sulphur, and another body containing much more sulphur, its formula being given as HS_2 . This body is produced, appearing in the form of oily drops, which subside when a solution of pentasulphide of potassium is poured into dilute hydrochloric acid; it is very unstable; the greatest care and precaution cannot preserve it longer than a few weeks, even though it be sealed hermetically in a glass tube; it simply forms a link of the chain of combinations which sulphur is capable of forming.

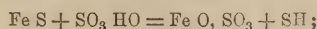
The simpler combination with hydrogen is a well known body; it is the result of many decompositions, natural and otherwise; it is permanently gaseous, possessing a most nauseous odor, easily recognized as being the characteristic of several mineral springs, such as those of Harrowgate, *et cetera*. It is a product of the decomposition of many organic bodies, is evolved by putrid bodies, and is the cause of the smell of rotten eggs, the albumen of which, as before stated, contains a quantity of sulphur, is undergoing decay, and gives off its sulphur, or a part of it, as sulphide of hydrogen. This gas is prepared by adding an acid to any soluble sulphide, such as those of the alkalies, or of the alkaline earths. The most convenient, and consequently the most general method, consists in adding dilute sulphuric acid to sulphide of iron, placed in a bottle, closed with a cork, perforated with two holes, one for the passage of a tube funnel, through which sulphuric acid can be poured; while through the other is passed a tube for the exit of the gas—Fig. 569. If a slow

Fig. 569.



and constant stream of the gas is required, large lumps of the sulphide should be employed; but if, on the contrary, a rapid stream is needed, smaller lumps should be used. When the sulphide is introduced, the cork should be put in its place, and the requisite

quantity of dilute acid poured down the funnel; if the sulphide be good, a stream of gas bubbles will immediately begin to rise, and passing through the exit tube, can be directed through any solution, or to any required point. The decomposition which produces this gas from these materials is very simple—

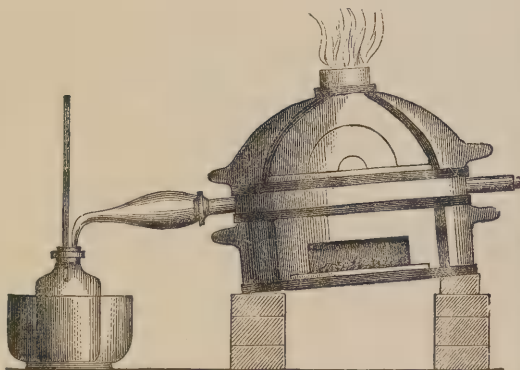


that is, one equivalent of sulphide of iron, one of sulphuric acid, and one of water, produce one equivalent of sulphide hydrogen, and one of protosulphate of iron.

The combination of sulphur with nitrogen alone is of scarcely any importance, and need not be dwelt upon.

Sulphur and Carbon.—Sulphur forms several combinations with carbon; the one most marked and of the greatest importance, inasmuch as it is used in the arts, is the bisulphide of carbon or sulphocarbonic acid— CS_2 . It is formed by passing the vapor of sulphur over or through red-hot charcoal. This is effected by filling an iron or porcelain tube placed across a furnace—Fig. 570—with fragments of charcoal. One end of this tube is connected with a condensing apparatus—LIEBIG's tube will do—plentifully supplied with cold water. The other end of this tube must be capable of being closed tightly with a cork. When the tube is sufficiently hot the cork is removed, and small

Fig. 570.



pieces of sulphur are pushed through near to the charcoal. The orifice being again closed, the sulphur is converted into vapor, and in passing through the *interstices* of the *incandescent* carbon, combines with a portion, forming the body in question, which, passing on to the condensing apparatus, collects as a liquid. After sufficient time has elapsed a fresh portion of sulphur must be introduced, the operation being continued in this manner until sufficient has been prepared. This product is by no means pure, containing more or less sulphur which has escaped combination, and from which it must be freed by distillation in a glass retort placed in a water bath.

Bisulphide of carbon has a density of 1.272. It is, as obtained above, a transparent, colorless liquid, of a strong disagreeable odor. This odor is due to a foreign

body, the true smell being of a vinous or ethereal character. A considerable portion of this smell may be removed by shaking it up in a bottle with a quantity of strong sulphuric acid and bichromate of potassa. Bisulphide of carbon is a very volatile body, its boiling point being 110° . It rapidly evaporates, almost equaling sulphuric ether in this respect, diffusing its odor through the apartment. It is a very effective solvent fatty matter. Grease stains may be removed by it from paper or woven fabrics. It is only necessary to place a piece of blotting paper below the stain, and drop the bisulphide of carbon on it; it dissolves the grease, and the blotting paper receives the solution. When brushed the fabric must be exposed to the air, when the odor rapidly and perfectly disappears. Bisulphide of carbon is also a solvent of phosphorus; when a little bisulphide of carbon is warmed in a test tube and a piece of phosphorus dropped in it, it rapidly dissolves. This is a case of true solution. The phosphorus is again deposited unaltered on the evaporation of the solvent. It has been proposed to employ this solution in warfare. Shells filled with the solution were to be thrown into or on any combustible part of the enemy's premises, such as a wooden building or a ship's sails. The solvent evaporates, leaving a thin layer of phosphorus, or, in the case of a ship's sails, leaving every thread or fibre covered with a coating of phosphorus. This quickly begins to oxidize, and finally takes fire, which fire will communicate to the surrounding parts. The experiment may be performed on a small scale by wrapping a little tow round the end of a wire, and dipping this into the phosphoric solution, when, on taking it out and waving it about, the bisulphide of carbon almost instantly evaporates, and in a few seconds the tow takes fire, the phosphorus having ignited first.

Sulphur and Chlorine.—Sulphur also combines in a variety of proportions with other bodies, as well as those named. It forms combinations with phosphorus, boron, iodine, bromine, fluorine, and chlorine. One of its combinations with the latter body is used in the manufacture of caoutchouc; it is prepared by passing chlorine gas through melted sulphur, forming the dichloride of sulphur, which is found to contain also sulphur in solution. From this it must be freed by distillation, at a low temperature, and, if necessary, the rectification repeated until its boiling point is stationary at 228.2° . This chloride of sulphur has some curious properties; by means of it, a species of artificial india-rubber may be produced. To procure this body take a quantity of vegetal oil, say linseed or rape, and mix it with one-tenth its bulk of chloride of sulphur, and slightly warm the mixture; a strong reaction takes place. Hydrochloric acid is disengaged, and a mass remains, which, when washed with water, becomes white, and is as elastic as genuine caoutchouc, with precisely the same appearance. This curious body resists the action of boiling alkalies; ammonia and concentrated acids are without action on it, and it resists the solvent powers of alcohol, ether, sulphide of carbon, and oils.

Compounds of Sulphur and Oxygen.—Sulphur appears to have a great affinity for oxygen, with which it combines in many proportions, forming a series of

compounds, all of which are acids. The following are known to exist at present :—

Hyposulphurous acid,.....	$S_2 O_2$
Pentathionic acid,.....	$S_5 O_5$
Tetrathionic acid,.....	$S_4 O_5$
Triithionic acid,.....	$S_3 O_5$
Sulphurous acid,.....	$S O_2$
Hyposulphuric acid,.....	$S_2 O_5$
Sulphuric acid,.....	$S O_3$

Of this series two members have been already noticed—hyposulphurous acid and pentathionic acid. Hyposulphurous acid cannot be obtained in the free state, as already mentioned. When set free it splits up gradually into sulphur and sulphurous acid. It is commonly met with in the form of hyposulphite of soda, a compound employed to a considerable extent by photographers, it being a solvent of certain silver salts, which are insoluble in water, such as the chloride, iodide, and bromide. Hyposulphite of soda will also dissolve sulphate of lead, and in analysis affords a ready means of separating this salt from sulphate of baryta.

Hyposulphurous acid is comparatively stable when combined with a base. The hyposulphites of the alkalis and of the alkaline earths are those most frequently occurring. They are prepared in a variety of ways, the most common methods being either by exposing an alkaline or earthy sulphide to the air, when it absorbs oxygen, forming a quantity of hyposulphites and other salts; or by boiling a sulphite of the base with sulphur. The reaction in the latter case is very simple. Take the sulphite of soda for instance. This has the formula NaO, SO_2 . Add to this one equivalent of sulphur— $NaO, SO_2 + S$; and hyposulphite of soda— $NaO, S_2 O_2$ —is produced.

The following method appears to be a favorite one for preparing the hyposulphite of soda in small quantities :—One pound of pure crystallized carbonate of soda, is dried as perfectly as possible. When powdered, this is mixed with five ounces of pure sulphur, the mixture heated in a glass or porcelain basin to the melting point of sulphur, and kept at that temperature for some time, stirring constantly in order to bring every part into contact with the air. The sulphide of sodium formed at first absorbs oxygen from the air, and is converted with feeble incandescence into hyposulphite of soda. The mass, when cold, is dissolved in water, and boiled with sulphur for some time, and the liquid evaporated to the crystallizing point. Very fine and pure crystals are obtained in this manner. If the heat be too strong, part of the sulphur is burned off, and carbonate of soda remains undecomposed. In this case a second crystallization is requisite. Hyposulphite of soda can easily be obtained by passing a current of sulphurous acid through a solution of sulphide of sodium, boiling, filtering, and evaporating to the crystallizing point.

The earthy hyposulphites, as above stated, are formed by exposing their sulphides to the air; for instance, in a solution of sulphide of calcium exposed for some time in this manner, a considerable quantity of hyposulphites form by double decomposition. The hyposulphite of soda or potassa may be formed by adding to a solution of the sulphide of calcium a solution of the carbonate of these alkalies.

Hypsulphite of soda is used to a small extent in

analysis as a reducing agent, also as a means of separating iron and alumina, dependent on the fact that hyposulphite of alumina is not stable at much above the ordinary temperature. For instance, suppose iron and alumina are both contained in a solution; to this solution is added as much hyposulphite of soda as will convert these bases into hyposulphites; this is done while cold. The solution is now heated to boiling. Hyposulphite of alumina decomposes at this temperature into sulphur, sulphurous acid, and alumina, while the iron salt being more stable remains intact. The whole is now thrown on to a filter; when the iron salt passes through, while the alumina remains on the filter; and it is washed, dried, and ignited. The iron is separated from the filtrate in the usual manner.

This reaction is used, also, to a very small extent in calico-printing. A hyposulphite of alumina is formed in the cold by adding a solution of chloride of aluminium to a solution of hyposulphite of soda. The result is a solution of chloride of sodium and hyposulphite of alumina. This is thickened in the regular manner, and printed on the fabric. The piece is then exposed to a temperature of 212° by means of steam, when the salt is decomposed, alumina being deposited on or in the cloth. This alumina so deposited dyes up with madder precisely like the alumina precipitated in the ordinary manner from the acetate.

This method does not offer any advantage over that usually followed, except in certain cases, where it is a convenient course, on account of the ordinary method being inadmissible.

The rest of these sulphur and oxygen compounds, with the exception of sulphurous and sulphuric acid, are at present useless in the arts, but are valuable in a scientific point of view.

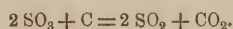
Sulphurous acid is composed of one equivalent of sulphur and two equivalents of oxygen. It is the irritating vapor or gas given off by burning sulphur. It may be prepared in a variety of ways, according to the purpose for which it is required. Two general principles may be followed, either the addition of a sufficient quantity of oxygen to sulphur, or the abstraction of oxygen from sulphuric acid.

When sulphur, as just stated, is made to burn in oxygen gas or common air, sulphurous acid is obtained. If it is desired to pass a stream of this gas through any liquid intended to absorb it, the sulphur must be burned in a close vessel or apparatus, which has a strong aspirator attached. The Woulf's bottle, or other vessel, must be placed between the vessel containing the sulphur and the aspirator, or, supposing this to be inconvenient, the sulphur may be mixed with some body containing oxygen loosely combined, and this mixture heated. A body possessing these requisite qualifications is found in peroxide of manganese. To obtain a stream

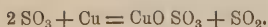
Fig. 571.



of sulphurous acid, it is recommended to make an intimate mixture of one part powdered sulphur, and seven or eight parts of black oxide of manganese. This mixture is placed in an iron retort, which is set on the fire. There is given off sulphurous acid, oxygen, and sulphur vapor, the matter in the retort being probably sulphide and sesquioxide of manganese. This method, not giving a very pure product, is not well adapted for many purposes. The method generally adopted is that of robbing sulphuric acid of one equivalent of oxygen by any convenient body. A mixture of strong oil of vitriol and charcoal heated in a flask, which has a conducting tube—Fig. 571—attached, serves very well, if absolutely pure gas be not needed. The gas given off by the mixture is a compound of SO_2 and CO_2 . The following being the reaction—



But sulphurous acid as nearly pure as possible, in fact quite pure, if made to traverse a little water to take up any sulphuric acid, may be obtained by heating sulphuric acid with one-third its weight of copper, in the shape of turnings or clippings. One atom of copper takes up one atom of oxygen from one atom of sulphuric acid, and becomes oxide of copper, which itself immediately combines with another equivalent of sulphuric acid, forming sulphate of copper—



Mercury may be substituted, but with no advantage—a like reaction takes place. The sulphurous acid so obtained is permanently gaseous at the ordinary atmospheric pressure, but is capable of assuming the liquid form, like carbonic acid, sulphide of hydrogen, and sundry other gases, at an increased pressure with a very low temperature. FARADAY employs a pressure of from three to five atmospheres; WACH places in a long glass tube, sealed at both ends and bent in the middle, a mixture of anhydrous sulphuric acid and sulphur. This is heated, while the opposite end is kept immersed in a freezing mixture. Sulphurous acid is formed under strong pressure, and condensed in the cooled end of the tube. In order to obtain it pure, it must be run to the other end of the tube, and again distilled to free it from sulphuric acid. Sulphurous acid in the liquid state is only of scientific interest; it is like many other rare chemical preparations, which are only made at a cost of great labor, and when made, can only be preserved conveniently for a very short time. As a liquid its boiling temperature is 14° .

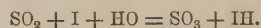
As far as all the useful properties of sulphurous acid are concerned, they may be studied from its solution in water, this liquid taking up, at mean temperature, thirty-three times its bulk of the gas.

Sulphurous acid solution is obtained by passing a stream of the gas through cold water, employing for the generation any of the methods just given. A series of WOULD'S bottles, or other convenient apparatus, may be employed for the condensation. The contents of the first bottle should always be rejected, as it will contain a considerable quantity of sulphuric acid, carried over both mechanically and in a state of vapor; the other will be a nearly pure solution of sulphurous acid.

Sulphurous acid is capable of forming a crystalline hydrate with water. It is procured by exposing sulphurous acid vapor with water, in a tube or other apparatus, to a low temperature, by placing this tube in a freezing mixture. Solid sulphurous acid may be procured by rapidly evaporating the liquid acid—it forms white flakes. It is heavier than the liquid, and freezes at *minus* 110° . It is composed of—

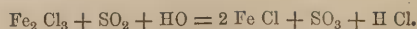
Sulphur vapor, ... 1 } forming 6 vol. of spec. grav. 2.2113.
Oxygen gas, ... 6 }

Sulphurous acid is a powerful deoxidizer, instantly decoloring acid solutions of the manganates and chromates—in the latter case reducing them to the state of green sesquioxide of chromium. For analyzing the commercial sulphites, it is only necessary to weigh out a stated quantity of the sulphite or hyposulphite to be examined, dissolve it in water, make it acid with hydrochloric acid, and then to note the number of measures of a normal solution of bichromate of potassa required to be added to convert the sulphurous into sulphuric acid, and data are obtained from which the amount of sulphurous acid contained in the sample may be easily calculated. This reducing property of sulphurous acid has been turned to advantage by BUNSEN, in the indirect analysis of various bodies—for instance, in the valuation of manganese. He places the manganese in a flask, treats it with hydrochloric acid, passes the evolved chlorine into a solution of iodide of potassium; each atom of chlorine sets free an atom of iodine. When the operation is over, he disconnects the vessel containing this iodine, and adds from a burette a normal solution of sulphurous acid until the precipitated iodine has disappeared. Each equivalent of iodine converts an equivalent of sulphurous into sulphuric acid, as follows—



Thus, tracing the reaction back, one equivalent of sulphurous acid represents one equivalent of binoxide of manganese—this principle is applied in a variety of ways. The deoxidizing power of sulphurous acid is taken advantage of by the chemist in the estimation of arsenic. When arsenic exists as arsenic acid, it is very slowly thrown down by sulphide of hydrogen; whereas arsenious acid is easily precipitated. Sulphurous acid possesses the power of abstracting part of the oxygen from arsenic acid, reducing it to arsenious; so that, if a stream of sulphurous acid be passed through the arseniate to be analyzed, after making it acid with hydrochloric acid, it is converted into arsenious acid, which facilitates its precipitation when one comes to employ sulphide of hydrogen.

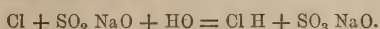
Sulphurous acid, passed through a dilute solution of yellow sesquichloride of iron, quickly reduces it to a protosalt—



Sulphurous acid reduces salts of gold, throwing down the gold in the metallic state. It is capable of taking up the second equivalent of oxygen from almost every metallic binoxide.

Sulphurous acid, in the shape of sulphite of soda, has been an article of commerce for some time, under

the half-fanciful and half-true appellation of antichlor. It has derived its name from the use to which it is applied, being used to correct the evil effects of an overdose of chlorine. In the bleaching of paper pulp, if any excess of chlorine or hypochlorite has been used, the sulphite, on being added, neutralizes it. If, for the sake of illustration, we imagine chlorine to have been used, then—



This hydrochloric acid can be taken up by any alkali, or will itself decompose a fresh portion of the sulphite, driving off sulphurous acid.

Sulphites are used by some in the manufacture of beet sugar. PROUST recommended them and a sulphurous acid solution as being antiferments, and having also other advantages. The following method of procuring it in large quantities was proposed by CALVERT, in a lecture lately delivered before the Society of Arts. He constructs a sulphur oven, such as is used in the manufacture of sulphuric acid. Within this oven the sulphur is burned, producing sulphurous acid. An earthenware tube, immersed in water, leads from this burner or oven to a tall wooden column filled with pumice-stone, or other suitable porous body. A cistern of water is placed on the top of this column, to which cistern a tap or valve is attached, by means of which a shower of water can be sprinkled on the pumice-stone, keeping it in a moist or wet state. The mixture of gases issuing from the burner, consisting of sulphurous acid, atmospheric air, and residual nitrogen, pass along the conducting tube, enter the column near the bottom, and pass up its whole length, thus meeting with the descending water; the sulphurous acid is absorbed, and a constant stream of the solution issues into a cistern placed at the bottom for its reception, while the residual gases pass out into the atmosphere.

Some brewers employ a solution of sulphurous acid to rinse out beer barrels after washing, as it possesses the property of arresting the acetic fermentation.

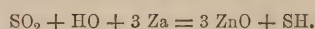
Sulphurous acid, when present in a free state in small amounts, is easily detected by its suffocating odor. It does not, like sulphuric acid, give any reaction with a salt of baryta, except when combined with a base. This is on account of the sulphite of baryta—unlike the sulphate—being soluble in free acid. When sulphuric acid is added to a salt of baryta, sulphate of baryta is formed, and the acid with which the baryta was previously combined is set free. But this acid can exert little or no action on the sulphate of baryta. Now, on adding sulphurous acid to a salt of baryta, the sulphite of baryta would dissolve in the acid set free, and which was previously combined with the baryta. But in the case of a salt having sulphurous acid in its composition, this does not occur. No acid is set free to exert a solvent action. For instance, if to a solution of chloride of barium is added a solution of sulphite of soda, a white precipitate of sulphite of baryta will be produced—



Supposing it to have been doubtful whether the salt employed was a sulphite or a sulphate, one can now determine the point by the addition of an acid, say

hydrochloric acid. Sulphite of baryta being soluble in this acid, the precipitate will disappear if the salt was a sulphite; if the precipitate is persistent, a sulphate is indicated. Of course, both may be present.

An old specimen of sulphite is sure to contain a quantity of sulphate, formed by oxidation, even though pure originally. To determine absolutely the presence or absence of sulphurous acid in a body, it is only necessary to dissolve it in hydrochloric acid, if solid, or if a liquid, make it acid to the same extent, and add a few scraps of zinc, such as is used in the production of hydrogen gas. If the body under examination contain sulphurous acid, the hydrogen going off will be accompanied by sulphuretted hydrogen, which may be detected by the smell, or by its blackening paper dipped in a solution of a lead salt. This test will discover very minute quantities of sulphurous acid. Such is its delicacy that sulphurous acid may be detected in much of the commercial hydrochloric acid; it arises from the action of the strong sulphuric acid on the iron decomposing vessel employed. The reaction may be explained as follows, leaving out the hydrochloric acid:—



One method of estimating sulphurous acid has been given, but the ordinary method is to convert it into sulphuric acid, and then proceed in the manner followed in the estimation of that acid. This may be effected by several oxidizing bodies. It is sometimes recommended to employ nitric acid, but there is a chance of error by doing so, inasmuch as a quantity of the sulphurous acid may escape whilst heating it. Perhaps the best method is to pass through the sulphurous acid or the sulphite to be analyzed a current of chlorine until the liquid smells of the latter gas, placing it on a sand bath until all smell has disappeared, then precipitate with a salt of baryta, collect, wash, ignite, *et cetera*, exactly as indicated under the head SULPHURIC ACID.

Sulphurous acid forms, with bases, a series of salts called sulphites, one of which has been already mentioned, the sulphite of soda. These sulphites have been shown by the Editor to bear a strong resemblance to carbonates, being also isomorphous with the latter salts. The following list proves the analogy:—

Sulphites.	Carbonates.
KO, SO ₂ + 2 HO	KO, CO ₂ + 2 HO
KO, SO ₂ + HO, SO ₂	KO, CO ₂ + HO, CO ₂
NaO, SO ₂ + 10 HO	NaO, CO ₂ + 10 HO
NaO, SO ₂ + HO, SO ₂	NaO, CO ₂ + HO, CO ₂
NaO, SO ₂ + HO, SO ₂ + 8 HO	NaO, CO ₂ + HO, CO ₂ + 8 HO
BaO, SO ₂	BaO, CO ₂
SrO, SO ₂	SrO, CO ₂
MgO, SO ₂ + 3 HO	MgO, CO ₂ + 3 HO
MnO, SO ₂ + 2 HO	MnO, CO ₂ + 2 HO
PbO, SO ₂	PbO, CO ₂
AgO, SO ₂	AgO, CO ₂

Sulphite of soda is the only salt—with the exception of a mixed sulphite of lime and magnesia—which is manufactured on a large scale. Sulphite of soda is made by passing a stream of sulphurous acid gas through a solution of carbonate of soda; the carbonic acid is displaced, and sulphite of soda is formed. On the large scale, the same method as is pursued in the

manufacture of bicarbonate may be followed for the production of the sulphite. A chamber or suitable large vessel is so constructed with appliances that a stream of sulphurous acid from burning sulphur may be drawn through. This chamber or vessel is filled with crystals of carbonate of soda; the stream of sulphurous acid in its passage through the interstices of the mass is taken up, carbonic acid being evolved. The passage of the gas must be continued until a sample taken out of the chamber, on being dissolved, has an acid reaction with litmus paper. The mass of what was originally carbonate of soda has now become a mixture of sulphite and bisulphite of soda. This is now dissolved in water, and brought to the boiling point; a solution of carbonate of soda must now be added, until the last addition causes no evolution of carbonic acid; the whole is now brought to the state of neutral sulphite; and after standing to deposit any mechanical impurities may be run off into a suitable vessel to crystallize.

The sulphites of potassa and ammonia may be prepared in a similar manner to that of soda, by passing sulphurous acid through a solution of the alkalies or their carbonates.

The sulphites of the alkaline earths are prepared either by exposing the moistened, or better, the hydrated oxides, to gaseous sulphurous acid, when this gas is absorbed; or the oxides or carbonates may be suspended in water, and a stream of sulphurous acid passed through; or they may be produced by double decomposition from a soluble alkaline sulphite, and a chloride of the earthy metal. These sulphites are all more or less nearly insoluble in water and alcohol, but are rendered more soluble by an excess of sulphurous acid, in this respect resembling the carbonates. The only practical purpose to which any of these earthy sulphites have been applied, is as disinfectants. For this purpose, a mixture of the sulphites of lime and magnesia is used. Mr. M'DOUGALL seems to have a method of producing sulphites much more readily than any other maker.

The sulphites of the metals proper, such as iron, zinc, lead, bismuth, *et cetera*, are produced by analogous processes; they, like the earthy sulphites, are more soluble in a solution of sulphurous acid than in pure water.

SULPHURIC ACID—*acid sulphurique*, French; *schwefelsäure*, German—is the most stable and the best known oxide of sulphur. It appears to have been known from very early times. BRANDE, in speaking of it, says that the honor of its discovery is due to BASIL VALENTINE. He frequently mentions it and its mode of preparation; and PARACELUSUS, and the authors who immediately followed, talk of it as well known and in common use, though it is probable that it bore a high price, and was but scantily supplied by a few awkward and unintelligent operators. But KOPP shows evidently that VINCENTIUS DE BEAUVAIS had an idea of the substance obtained by distilling alum. BOYLE first recognized in it a relation to sulphur. MAYOW pointed it out with great clearness, but he was far before his time in penetration. STAHL believed sulphur to consist of sulphuric acid and phlogiston, a theory in conformity with the rest of his system.

LAVOISIER showed the formation of acid by sulphur taking up oxygen, but it had been made by burning sulphur in the air, at least since the time of LEMERY and Dr. WARD. Sulphuric acid exists, as free acid, in two states, liquid and solid—the liquid being a combination of dry acid and water. The right of the dry body to be called sulphuric acid is doubted, as it exhibits no acid characters until combined or mixed with water. The character of the acid is sufficiently shown in the reactions of the monohydrated sulphuric acid— SO_3HO —or the purified oil of vitriol. This body is a heavy fluid, above three-fourths heavier than water. It flows when poured from one vessel to another, in a heavy, smooth, *oily* stream. This oily appearance has, doubtless, given it its name; and although this appellation, oil of vitriol, has been much ridiculed, it cannot be disputed that it is very expressive, and serves well to distinguish the strong vitriol from the dilute acid, which bubbles like water when poured. Oil of vitriol has a strong attraction for water, so much so that a bottle containing it, if left open, rapidly attracts moisture from the air, becoming itself much weaker. This property is often taken advantage of in analytical operations. When a stream of dry gas is needed, it is simply requisite to pass it through strong sulphuric acid, or through a wide tube filled with fragments of coke or pumice-stone saturated with the acid. This is a very effectual mode of drying a gas. It is not applicable to certain gases, between which and the sulphuric acid a reaction might take place. In the simple and elegant apparatus, devised by FRESSENIUS and WILL, for the estimation of carbonic acid, sulphuric acid is employed for the purpose of desiccating the carbonic acid before it emerges from the apparatus. It has been stated that sulphuric acid possesses the property of absorbing carbonic acid, and that consequently the operations in which its drying property has been taken advantage of cannot be correct. This, again, has been refuted; and, inasmuch as most chemists are in the habit of using this apparatus, it would appear to be tacitly allowed that if any error from this source does exist, it is so small as to be of no consequence.

This attraction of sulphuric acid for water also brings about some curious decompositions with organic bodies. For instance, if any of that class of bodies, such as sugar, starch, *et cetera*, which contain carbon, hydrogen, and oxygen, in such proportions that, for the sake of simplicity, they may be considered as being composed of carbon and water, be mixed with strong sulphuric acid, and heated, a black mass will be obtained; and if this mass be thoroughly washed with water, so as to remove every trace of sulphuric acid, it will be found to be pure carbon, the whole of the elements of water having been removed. So effectual is the process, that the principle has been proposed as a method of obtaining peat charcoal without the ordinary charring process. This charcoal is then washed and dried. To this same property is due the occasional brown color of commercial vitriol. If particles of organic matter fall into it, a portion of their hydrogen and oxygen is abstracted, forming a humus-like body, which, dissolving in the vitriol, colors it. This attraction for

water seems to be the principle by which it acts upon the skin, and animal and vegetal matter generally. The density of this monohydrated acid is 1·850, and it boils at a temperature of 620°. Its boiling point diminishes with its density. The strong acid is perfectly volatile, and thus capable of being distilled. It freezes at a temperature of 29°, yielding often six-sided prisms of a tabular form.

This acid has the power of supplanting or displacing almost every other acid known, so great is its affinity for bases. It produces great heat when mixed with water, the compound becoming denser than the mean of the two liquids. If equal volumes of strong sulphuric acid and water be mixed, and then allowed to cool, it will be found that the resulting liquid will not make up the original two volumes; it now occupies less space, contraction having taken place. During this contraction a portion of the latent heat of the water has been given off. PARKES made a series of experiments on this matter, the results of which are given in the following table:—

HEAT PRODUCED BY THE ADMIXTURE OF SULPHURIC ACID WITH WATER, TEN POUNDS OF SULPHURIC ACID BEING USED IN EACH EXPERIMENT.

Sulphuric acid in pounds.	Temperature of the mixture in degrees of Fahrenheit.
1	78°
2	100
3	110
4	128
5	138
6	144
7	156
8	168
9	186
10	204
11	214
12	222
13	229
14	236
15	241
16	246
17	250
18	253
19	256
20	258
25	266
30	264
35	254
40	248

But FAYRE and SILBERMANN have lately examined the question more thoroughly, and shown that the following amount of heat is given out:—

HEAT EVOLVED BY MIXING $\text{SO}_3 \text{ HO}$ WITH WATER.

Atom of water.	Heat units.	Differences.
With the first $\frac{1}{8}$	94·0	0·6
second $\frac{1}{8}$	88·0	
With the first $\frac{1}{4}$	18·8	1·6
second $\frac{1}{4}$	17·2	
With the first $\frac{1}{2}$	36·7	8·4
second $\frac{1}{2}$	28·3	
Atoms of water.		
1	64·7	29·9
2	94·6	17·3
3	111·9	10·3
4	122·2	8·5
5	130·7	5·5
6	136·2	4·4
7	141·8	3·3
8	145·1	3·4
9	148·8	0·0
10	148·4	0·0
20	148·6	

When four of the monohydrate are mixed with one of water by weight the temperature rises to 300°.

GRAHAM gives the following list of the hydrates of sulphuric acid—

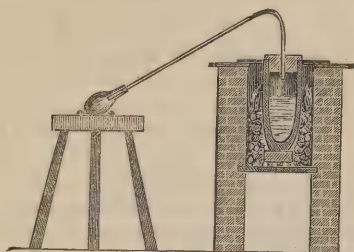
Nordhausen sulphuric acid,	= $\text{HO}, 2 \text{ SO}_3$
Sulphuric acid, specific gravity, 1·850,	= HO, SO_3
“ “ 1·78,	= $\text{HO}, \text{SO}_3 + \text{HO}$
“ “ 1·632,	= $\text{HO}, \text{SO}_3 + 2 \text{ HO}$

The third hydrate in the above list corresponds nearly to the commercial brown oil of vitriol, the density of this latter being 1·758. It is formed by heating a dilute acid to 400°. Its properties are almost identical with those of the monohydrate. It has the property of solidifying at the temperature of melting ice, or a little above this point. It is no uncommon circumstance for a sulphuric acid manufacturer to find a carboy of brown vitriol converted almost into a mass of crystals, if exposed to the cold in frosty weather. These crystals are the well-defined hydrate in question. This crystallization has been proposed as a method of obtaining pure sulphuric acid, as will be seen hereafter. Little seems to be known of the lower hydrate. It is formed by heating a dilute acid at 212°. This amount of acid and water causes the greatest condensation of volume.

Neither dry nor fuming acid can be obtained by the ordinary mode of concentration, it being impossible to drive off the last equivalent of water. Dry acid may be obtained by distilling the Nordhausen acid— $\text{HO}, 2 \text{ SO}_3$. But Nordhausen acid is not now a common commercial product; it is often necessary for the operator to make his own. This may be done either by distilling the protosulphate of iron or the sesquisulphate, artificially prepared; bisulphate of potassa or soda may be also used. This latter salt is the cheapest, and perhaps the most convenient. It may be procured by heating one equivalent of common salt in a crucible with two equivalents of sulphuric acid, taking care to operate under a chimney, or in some situation where the hydrochloric acid fumes will be carried away quickly. When gas has ceased to be evolved from the mixture, the residue must be heated to a low red-heat, in order to drive off as much water as possible. The fused salt must be removed from the crucible and allowed to cool. This may be done by pouring it out into an iron dish, or other convenient vessel. When cold, it must be broken up, when it is ready for the next operation. Or, instead of this, the bisulphate of soda or potassa left in the retorts, when procuring nitric acid, may be preserved for the same purpose. Porcelain retorts being very expensive, it is well to substitute, if possible, some cheaper piece of apparatus. For this purpose an ordinary brassfounder's crucible may be employed; a lid may be formed out of a piece of ordinary fire-tile—this lid has a hole cut through, into which is inserted a piece of glass tube to carry off the vapor. The arrangement is shown in Fig. 571. To commence, a piece of brick is first laid on the bars of the ordinary laboratory furnace; on this the crucible is placed; this is filled with the broken pieces of bisulphate; the lid is luted on with clay, and the tube luted into the lid. A fire is lighted around the crucible, and this is gradually increased in power, until at length

distillation commences. Weak acid at first comes over—this is emptied out of the receiving flask; eventually the retort or crucible begins to attain a good red-heat; drops of strong acid fall, and hiss as they touch the weaker acid in the flask. The flask is now

Fig. 571.



finally emptied of its contents, and replaced, the acid which now comes over being fuming acid, white vapors pour through the glass tube at a rapid pace, a portion condensing there, and a portion in the flask. The flask should be a thin one, and is all the better for being placed in a basin of cold water. After a time vapors cease to appear, and the operation is at an end. The glass tube should now be carefully taken away, as also the lid of the crucible, and the fused or softened mass, forming the contents of the latter, should be removed by means of an iron scoop. This done, the crucible should be allowed to cool slowly; when cold enough, it may be filled again, and the foregoing operation repeated. With care, a crucible will last three or four operations. The neutral sulphate may be reconverted into bisulphate, to be again employed.

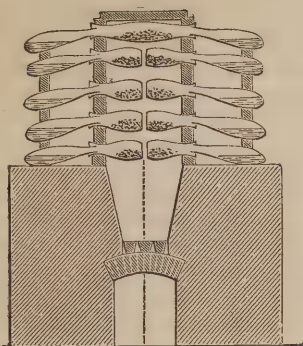
The fuming acid so obtained gives off white vapors. These white fumes are dry acid— SO_3 —vapor, combining with the moisture of the atmosphere. It makes a hissing noise when poured into water, very like the noise made when red-hot iron is plunged into a liquid. This acid is employed in gas analysis, on account of its possessing the power of absorbing certain hydrocarbons. For this purpose a piece of coke is wetted with the fuming acid and passed into the gas to be analyzed, standing in a graduated tube over mercury. To obtain the dry acid it is necessary to submit the fuming acid to distillation at a gentle heat. For this purpose a glass retort is partially filled with the fuming acid, the neck of the retort is inserted into a flask, placed in cold water, a gentle heat is applied to the retort, when the dry acid begins to come over. It condenses in solid fibres like asbestos, which are tenacious, and may be moulded by the fingers like wax. Its density at 68° is 1.970; at 77° it assumes the liquid state; and a little above that temperature it enters into ebullition. If a little of this *anhydrous* acid be placed on a slip of dry litmus paper no reddening results—coloration not taking place until moisture has been absorbed.

Manufacture of Sulphuric Acid.—The principle involved in the mode of working adopted by Dr. ROEBUCK, who may be considered the first inventor or improver, still continues in vitriol manufactories; in fact, from that time may be dated the actual rise of the sulphuric acid manufacture.

The earlier process, and, according to many authorities, the one still followed in a few places where natural advantages render it profitable, is one already alluded to, and which consists in distilling or driving off by intense heat the sulphuric acid from protosulphate of iron. This salt is dried and placed in fireproof retorts, which are built in suitable furnaces. Proper receivers are connected with them. These retorts are charged, and heat applied, until they become sufficiently hot. The sulphuric acid is driven off and condenses in the receivers, while oxide of iron is left in the retort. The following description, extracted from KNAPP's excellent work, will give a good idea of the process as followed at Radnitz:—The material operated upon is the mother liquor from the manufacture of alum. This contains a large quantity of protosulphate of iron. These mother liquors are first evaporated to a dry state, and then roasted at a gentle heat. During this latter roasting a considerable quantity of oxygen is absorbed, the protosulphate passing partially into basic persulphate of iron. These operations are conducted on the spot where the alum liquors are to be had. This roasted product, which is called *vitriolstein*, is sent to Radnitz for conversion into fuming oil of vitriol. This process consists in the dry distillation of the vitriolstein. The pots in which the distillation is effected are constructed of refractory stoneware, and after being baked in a kiln upon the premises, are about nine inches long, two and a half inches in diameter at the bottom, four and a quarter at the middle, and three inches at the mouth; they are about four-tenths of an inch thick in the sides. Before being used they are covered with a lute, or luting material, which is easily fritted by the action of the fire. The receivers are of much the same shape, but are longer and narrower at the mouth. The upper row in the furnace is occupied by a single range of pots twenty-eight inches in length. The gallery furnace for the reception of the pots is rectangular in section, and is composed of two parts essentially distinct. The lower part is built of massive masonry, enclosing the ash-pit and the grate, which extends the whole length under the range of pots; the upper part consists of two vertical walls of perforated brickwork, which form the sides of the furnace and support the pots. This latter portion demands frequent repair. Fig. 572 represents a front vertical section. It incloses four tiers of the smaller sized pots, arranged with their bottoms in contact, and an upper tier of long pots, which extend from one side of the furnace to the other, and are open at both ends. The whole, therefore, contains two hundred and eighty-eight pots—thirty-two large, and two hundred and fifty-six small. The long sides of the furnace are divided into squares by vertical and horizontal bricks of the same dimensions, and four pots are placed in each square, separated from each other by small bricks, the interstices being luted with refractory clay. The arch of the furnace is constructed of flat bricks, simply placed alongside each other, and cut sloping at their extremities, to allow the flame to pass. A small chimney is sometimes built to the furnace, but it is more frequently without. The pots are charged with the vitriolstein, previously broken up with a hammer, by means of a

semicylindrical spoon, each pot receiving two spoonfuls. The coal for the first charge is then ignited below the grate, and is thrown upon the grate at the expiration

Fig. 572.



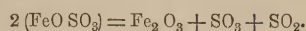
of about an hour or an hour and a half; the fire being carefully regulated by opening or shutting the doors. At the end of four hours the lower tier of pots is brought to a dark-red heat. The receivers are successively introduced into the pots and luted, those of the second layer resting immediately upon the first, and a wooden support being introduced between the second, third, and so on. The receivers are slightly inclined, and a small quantity of water is placed in each. This is sufficient to receive the acid from four successive distillations, after which it is in the state of concentration required in commerce. The fire is gradually increased, and after from thirty to thirty-six hours no more acid is evolved from the upper tier of pots, and the distillation is finished. The whole is then allowed to cool for twelve hours, and the receivers being removed the colcothar is taken from the pots. This contains about six and a half per cent. sulphate of lime, and amounts to about thirty or thirty-five per cent. of the vitriolstein employed.

The pots are now examined by the sound which they emit when struck. The broken ones are removed, and being replaced by fresh pots, the distillation is recommenced.

Each operation lasts about forty-eight hours, and three are completed in a week. From forty-seven to fifty per cent. of the vitriolstein is obtained in fuming sulphuric acid; five parts of coal are consumed for one part of vitriolstein distilled. About thirty pots and three receivers are replaced after each distillation, which is equivalent to 10·42 and 1·04 per cent. respectively.

Although such a mode of manufacture may be capable of being followed in some localities, yet it is far from possessing the general adaptability of the ordinary process. From the above description there appears to be little loss, except from accidental leakage or the breaking of a pot; but as the process is described by many, or in fact the greater proportion of writers, simply dry protosulphate of iron is employed— FeO SO^3 —not as in the method just described, sesquisulphate— $\text{Fe}_2\text{O}_3 \cdot 3\text{SO}_3$ —or rather a basic persulphate. The employment of one or the other must make a considerable

difference in the amount of product obtained, for if any protosulphate of iron be employed, only one half of the sulphuric acid contained in it will be obtained as *sulphuric acid*, the rest passing off as sulphurous acid. The following is the reaction:—



Two equivalents of protosulphate of iron are decomposed into one equivalent of sesquioxide, one of sulphuric acid, and one of sulphurous acid; one of the equivalents of sulphuric acid has parted with one of its equivalents of oxygen, in order that the two equivalents of protoxide of iron might become sesquioxide. This equivalent of sulphurous acid is said to escape through the joints of the apparatus; if so, and there does not appear to be any doubt of this being the fact, inasmuch as no other provision appears to have been made for its exit, one may naturally conclude that sulphuric acid vapor must escape at the same time.

Such was the method pursued for procuring sulphuric acid for some centuries. The next process—a modification of which remains in use to this day—consisted in converting sulphur by stages of oxidation into sulphuric acid. This differs materially from the process before described, in which acid already formed was simply separated from a combination; in the present case the operation commences with the prime element. The first step in this direction appears to have been the formation of sulphuric acid in small quantities by the combustion of sulphur in glass globes, moistened on the interior surface with water. It is true that under these circumstances a small quantity of sulphuric acid would be formed, but the amount would be very minute indeed; in fact, the combustion of sulphur in pure oxygen gives rise to little more than a trace. But a grand step was made in the right direction by the introduction of nitre in the manufacture. The use of sulphur and nitre together was said to have begun with LEFEVRE and LEMERY. Dr. WARD had the monopoly of it long in this country, and best knew how to manage the process. Instead of sulphur *per se*, a mixture of sulphur and nitre was made, and set fire to in or under a bell glass; by this proceeding a much greater quantity of sulphuric acid was obtained. It can easily be imagined, that even the most successful experiment could furnish only a small quantity of acid, on account of the very limited size of the apparatus. This must strike an observer when he contrasts in his own mind the largest jar or globe that could be blown, even now, with one of the vitriol chambers of the present time. But this difficulty of limited dimensions was surmounted by a Dr. ROEBUCK of Birmingham, who was the first to introduce leaden chambers, which he did as a substitute for the comparatively small globes; and as he was able to make them of any required size, a great relief must have been given to the manufacture. The manner of working was still precisely similar to that with the globe. The chamber had an entrance-door, which could be luted tight; this was opened, and a charge, consisting of a mixture as before of sulphur and nitre, was put on a proper stand placed to receive it in the chamber. According to some authors this was a sort of carriage, which could be pulled towards the door to receive the

charge, and then after ignition pushed towards the centre of the chamber; but it is difficult to conceive that this is true, as it would not be easy to find material of which to construct the wheels and other parts of such a machine, when it is considered that the floor of the chamber was covered with acid to the depth of several inches. It is certain that the proper charge was placed on a stand in the interior of the chamber; this was ignited, and the door was then properly fastened and luted. After a certain time had elapsed the door was again opened, and the residual gas or gases allowed to escape. This was repeated again and again, until the water with which the floor of the chamber was covered had absorbed sufficient of the acid, when it was run off and concentrated. Authors speak of a collapse of the sides of the chamber occurring, owing to the partial vacuum produced by the absorption of the oxygen of the contained air. But it can be scarcely believed that this accident could have occurred often, since it is hardly conceivable that practitioners of the chemical art at that time could have been ignorant of the fact that a very simple arrangement of a water-valve opening inwards would have remedied this.

This process, then, was the one followed by Dr. ROEBUCK, and such in principle it remains down to the present day; and had it possessed the advantage of a later invention, *videlicet*, the introduction of steam, it would no doubt have given an excellent result. Supposing there had been in the chamber twenty-four parts by weight of oxygen for every sixteen parts of sulphur introduced, watery vapor being also present in sufficient quantity, every particle of sulphur must have been converted into sulphuric acid, if sufficient time were allowed to elapse before the opening of the chamber door.

Having followed the manufacture to this point, one must now pass on to another step, from the intermittent to the continuous process, as practised at present. It is easy to see that had Dr. ROEBUCK burned his sulphur in a properly constructed apparatus, and introduced the resulting sulphurous acid into his chamber at one end, drawing off the residual gases at the other, he would have improved his method, and escaped many inconveniences.

If one views the gigantic scale in which this manufacture is carried on at the present day, by a TENNANT or a MUSPRATT, he must smile on looking back at the almost puny manner in which they operated in former times; but, then, add to their process the continuous system—the introduction of steam into the chambers by KESTNER, concentration in the platinum vessels, and GAY-LUSSAC's column for the recovery of the nitrous gas—and manufacturers have almost all that could be desired at present.

Much ingenuity has been expended in the construction of every piece of apparatus connected with the manufacture of vitriol. The ovens or burners, the chambers, and every part, have been tortured into a variety of forms, some of which would appear to have been devised in an idle moment, and constructed only to gratify a whim, or if any object has really been in view, it must have been imaginary. But in every manufactory where the process is understood, the difference,

except in little details, between the apparatus of to-day and that of twenty years ago, is very small. Improvement after improvement, which have turned out to be rather impediments, have been introduced, had their short reign, and disappeared, only to be succeeded by something else equally visionary. In fact, it would seem that the manufacture of sulphuric acid, though as extensively carried on as any business, yet seems to be the least understood; and the ignorance of some manufacturers appears to be only equalled by that of writers who, in their descriptions of the production of this acid, give figures of apparatus, and vaunt as improvements things which have been exploded for years. It is possible to find, in the works of eminent men, drawings of sets of apparatus for the production of sulphuric acid, *which never could possibly have worked one day*—some, in fact, could never have worked at all.

Production of the Sulphurous Acid.—This first step is effected by burning the sulphur in a close room or oven,

Fig. 573.

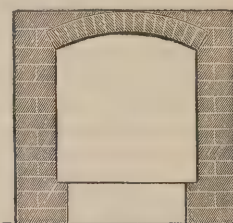
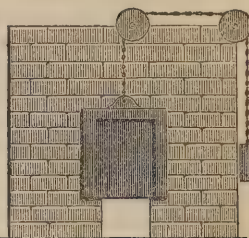
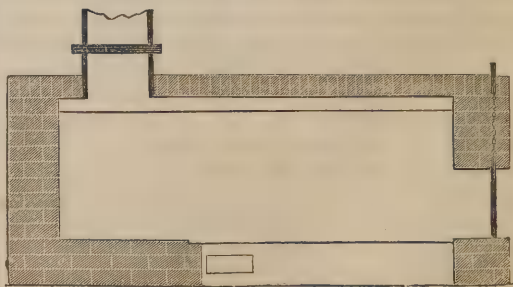


Fig. 574.



commonly called a burner. This burner is a simple erection of brickwork, with an arched roof, as shown in Figs. 573, 574, and 575. The size of the burner is regulated by that of the burner plate or iron flooring, and this latter by the quantity of sulphur proposed to be burned during seven days. The burner plate in the drawing is a rectangular iron, measuring eight feet by four feet. This burner plate is surrounded with a vertical edge or border, standing about an inch high; this border is at right angles to the plate on three sides, but on the fourth side, the one nearest to the door, it inclines outwards at an angle of about forty-five degrees—this is for the more conveniently raking out of the residual dirt and ashes left after the combustion

Fig. 575.



of the sulphur. The door of this burner is simply an iron plate, sliding in grooves in an iron framework, and is counterbalanced by a weight hanging at the end of a chain, which passes over pulleys.

As will be seen in the figure, the iron plate does not form the whole of the floor; still the sulphur is burned on it alone. The object of making the burner rather larger than the plate is to avoid, as much as possible, all risk of sublimation. To this end, also, there is a constant current of air passing beneath the burner plates and up a small chimney beside the burner. The opening through which the hot air escapes into this chimney is outlined in Fig. 575, below the burner plate. Four burners, such as this, with the burner plates of the size first mentioned, will easily convert into sulphurous acid one ton of sulphur per twenty-four hours. The quantity for each burner is divided into six portions, one of which is added every four hours.

Burners or ovens have been constructed of iron, sometimes with double sides, so as to include a sheet of air between the two plates. By this means the burners could be kept at almost any desired temperature; an arrangement could be made for causing a circulation of air if the burner should get too hot, or, on the contrary, should they get too cold, this air could be kept stagnant, and being a very bad conductor of heat, the burner would be allowed to rise to the desired temperature. It may be remarked here, that a burner should be kept so hot that each charge of sulphur, as thrown in, will ignite without any fire or heat being applied.

Iron ovens or burners have, however, almost disappeared, as they last a very short time. They gradually corrode, break into holes, and shortly become useless.

Some years ago a patent was taken out for a burner, the peculiar feature of which was its economizing, and converting to a useful purpose, the heat given off by the burning sulphur. The apparatus was very simple. It consisted of an ordinary two-flued steam boiler, for the usual fire-place of which was substituted a burner plate on which to burn sulphur. It was anticipated that by this means sufficient steam would be generated to supply the chambers. Whether it answered the desired end or not is not very clear; but from the fact that none appear to be in operation, it may be inferred that, if in use at all, it is not generally successful. In fact it is very probable that the action of the acid gases upon it would speedily destroy it, as it does the iron burners.

Combustion of Iron Pyrites.—Sulphur, *per se*, is not the only source of sulphurous acid for sulphuric acid. About the year 1835 the then King of Sicily thought fit to impose such a heavy duty on all sulphur exported from his kingdom, that the price of this article rose to an unprecedented height. It is said that at this crisis Dr. THOMAS THOMSON proposed the employment of the iron pyrites, with which different parts of this kingdom abound, as a source of sulphur. PARNELL states that Mr. HILL of Deptford was the first to employ this mineral, for the use of which he took out a patent in 1818. Since that time pyrites has come into very general use amongst one class of sulphuric acid manufacturers. The great objection to the use of pyrites lies in its containing a considerable amount of arsenic. This renders the vitriol objectionable for certain purposes, but this impurity does not prevent

its being used by the alkali manufacturers. A manufacturer of vitriol for sale would, were he to use pyrites, very likely have a quantity of his acid returned to him, and he would presently have to stop his manufactory. Not so the soda manufacturer; he is his own vitriol consumer—he uses all the acid he makes for the decomposition of common salt in the first step of soda-making. In his case the arsenic does not interfere in the least, it passes off as chloride of arsenic— As Cl_3 —with the hydrochloric acid gas, and condenses into a liquid state with this latter body. Again, most manufacturers of soda are also manufacturers of chloride of lime. In this case they use up their own hydrochloric acid, employing it for the production of chlorine, which is absorbed by hydrate of lime, forming the bleaching powder of commerce. If a little of the arsenic should pass over with the chlorine, it would be absorbed by the lime, forming an insoluble compound, arseniate of lime, which would fall out, with other useless matters, when the bleacher came to make his solution. The greater portion of the arsenic would remain with the chloride of manganese, and as at present this is a useless product; it is run into the nearest gutter or sewer.

The burning of pyrites is not quite so simple a matter as the burning of sulphur, as a red heat is required. Two varieties of pyrites are ordinarily met with. One kind, of which large quantities are to be found in Wicklow, Ireland, and is imported into this country, to a considerable extent, for the use of sulphuric acid manufacturers, has the crystalline form of a cube, and is of a bronze-yellow color, very hard, so much so as to strike fire with steel. The following is the composition of a specimen, on the authority of R. D. THOMSON—

	Centesimally.
Sulphur,	47.41
Iron,	41.78
Copper,	1.93
Arsenic,	2.11
Silica,	3.93
Zinc,	2.00
Insoluble matter,	1.43

This specimen is of a much richer kind than that usually obtained from this source. The proportion of sulphur very rarely exceeds thirty per cent. This ore contains protosulphide of iron in considerable quantity. The other variety of pyrites occurs in coal beds, and, in fact, is commonly known as coal brasses, fragments and seams of this mineral, may often be seen in coal, and, from their metallic and brassy appearance, have often misled the ignorant into thinking them of much greater value than they really are. According to the just quoted authority, they have the following composition:—

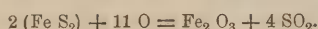
	Per cent.
Sulphur,	53.35
Iron,	45.07
Manganese,	0.70
Silica,	0.80
Loss,	1.18
	100.00

A variety of pyrites, known in the trade as Spanish pyrites, has of late been much employed. This is much richer in copper than the Wicklow species. On the introduction of this mineral, it was usual for the sulphuric acid manufacturer to engage to return the

spent or burnt material, for the purpose of having the copper extracted.

The general formula of either variety, when free from impurity, is Fe S_2 , that is, one equivalent of iron combined with two equivalents of sulphur, the chemical name of this compound being bisulphide of iron.

This mineral, when heated red hot, with access of oxygen, speedily loses the second equivalent of sulphur, being reduced to a simple or protosulphide— Fe S —the evolved sulphur being converted into sulphurous acid. If these favorable conditions are continued for a sufficient length of time, the second equivalent also becomes converted into sulphurous acid, sesquioxide of iron remaining. The whole decomposition may be represented as follows—



As may be imagined, the ordinary burner, as used for sulphur alone, lately described, is not adapted to burn pyrites; a burner of peculiar construction is required. The burner for this purpose is, in general structure, not unlike a lime-kiln. In the case of burning sulphur itself, the object is to spread a layer on a flat plate, so that, when fused and burning, it exposes a large surface for the current of air to sweep over; this is necessary on account of the fusion of the sulphur. But pyrites does not fuse except at a very high heat. The pieces retain their shape; and as it is imperative that they shall attain a red heat, it is necessary to burn them in such a manner that a mass of them can be kept together.

The structure of a pyrites kiln is shown in Figs. 576 and 577. In Fig. 577 the pyrites is shown as inclosed on two sides by two sloping walls, the back and front walls being vertical. The mass of pyrites rests on

for the purpose of arresting, as much as possible, the passage of arsenical vapors. The arsenic falling in a solid state is removed from time to time. Fig. 576 is a view of one of these kilns looking in another direction, endwise; *a* is the charging door through which fresh supplies of the mineral are thrown in at stated intervals. This door is kept closed, except for this purpose. At *b* another opening exists, but this is usually closed temporarily with bricks—it is only occasionally used. Sometimes the combustion goes on at a rate so rapid that the pyrites becomes fritted, or enters into a semifused state. Sometimes the whole mass gets fused together by its points of contact. In such a case the brick closure is removed for the purpose of introducing a crowbar, or other such instrument, in order to break up the mass or create a passage through. The coal pyrites is much more liable to this mishap than the Wicklow variety, partly on account of the bisulphide contained in it being actually rather more fusible, and partly because the coal brasses contain a certain amount of bituminous matter, which, in burning, raises the heat of the whole mass to a higher point than the Wicklow kind ever attains. The orifices, *c* and *d*, are those through which the sulphurous acid passes either into the next kiln or into the general passage.

It is not usual to see an isolated single pyrites kiln; there are often a number at work. Two are placed at the back of those shown in the drawing, forming a solid square. This answers a double purpose—it economizes brick and iron, and conserves the heat.

When commencing to burn, it is necessary to make a fire of coal or coke within the burners, having previously closed up the passage or entrance into the chamber, and opened one into the outer air. This fire heats up the sides, *et cetera*, of the kiln, high enough to ignite the pyrites when thrown in. The first few charges of pyrites are often mixed with coke to assist the combustion, until the whole mass has attained a red heat throughout. The carbonic acid resulting from this can do no harm.

The residual mass left after burning, and which consists principally of sesquioxide of iron mixed with more or less protosulphide, was at one time rather an annoyance than of any value to the manufacturer; but at the present time many of them have erected furnaces for the express purpose of extracting the small per centage of copper which it contains.

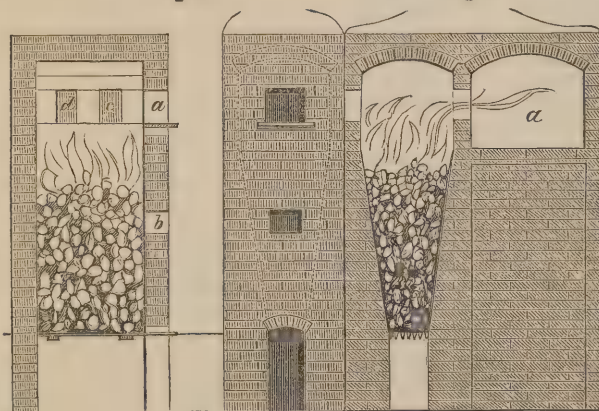
The quantity of sulphuric acid obtained from a given weight of pyrites of course cannot be as much as from sulphur, inasmuch as pyrites,

iron bars in the same manner as an ordinary coal fire, the air rushes up from what, in the case of an ordinary furnace, would be the ash-pit, and wends its way through the crevices and interstices of the mass to feed the combustion. The sulphurous acid from the first kiln passes over the next in the direction of the arrows, the gases from both flowing into the general passage, *a*, leading to the chamber. This general passage is often made of a considerable length, usually of from thirty to forty feet. This extreme length is

to take a general average, will not contain more than forty per cent. of sulphur; as a rule, a corresponding amount of sulphuric acid is not obtained from it. Much care and attention is required to burn pyrites well. It is no uncommon thing to find, on examining the waste pyrites heap of a manufacturer, that a great quantity has been removed little more than half burned. On breaking a lump a core or kernel of raw mineral may often be found; whereas well burned pyrites should not contain more than two and a half to

Fig. 576.

Fig. 577.

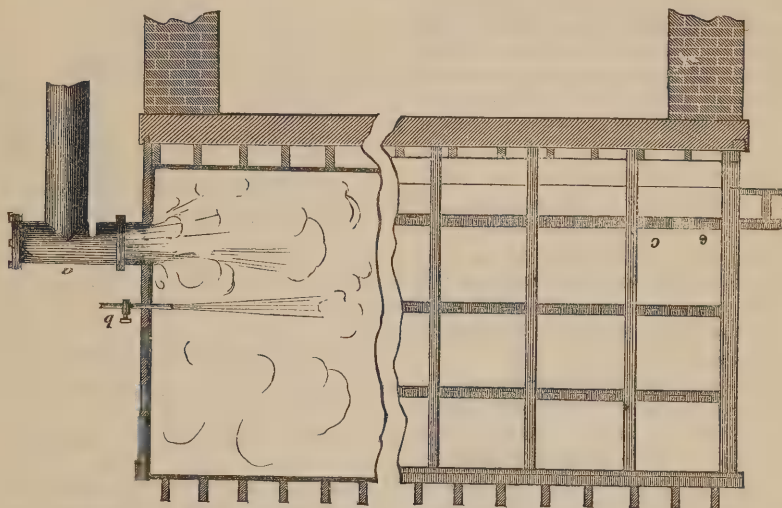


three per cent. of sulphur. Any amount more than this is in fact so much material thrown away.

General Construction of the Vitriol Chamber.—Having described the preliminary steps, the Editor now passes on to the chambers themselves. These have undergone many modifications. The chamber, as generally constructed, is simply a large room with leaden walls. A portion of one is shown in Fig. 578. These walls are generally formed of what is technically termed five-pound lead—that is, sheet lead weighing five pounds

per square foot—which walls are held up by a suitable framework of wood, to which they are fastened by what are called straps. These straps are pieces of lead, varying in number and size according to the dimension of the chamber. They are soldered or fastened by one edge to the sheet or sheets of lead forming the chamber side. The outer edge is pulled out over the wooden cross bar, and there nailed as shown at *a*, Fig. 578. The joints of the sheets of lead forming the chamber were formerly soldered with ordinary solder ;

Fig. 578.



but this entailed a long series of annoyances in consequence of the action of the acid on the solder. The chamber leaked perpetually, and great inconvenience resulted. Eventually the expedient of welding was hit upon. This consisted in rolling the two edges of the sheets together and beating this flat; but this at last gave way to the method at present followed, *videlicet*, fusing the two edges of the sheet together by means of the oxyhydrogen blowpipe. For this purpose an apparatus is constructed which furnishes a constant and pretty strong current of hydrogen gas. This when mixed with a proper amount of atmospherical air projected from a pair of bellows furnishes the blowpipe. To use it the workman proceeds as follows :—He lays the edges of the two sheets together as closely as possible ; every particle of dirt and oxidized or tarnished surface is scraped off ; the flame is now applied in a peculiar manner, acquired by practice, and the two edges are joined together ; thus making a solid joint of pure lead, as incapable of being acted upon as any part of the sheet. The plumbers who undertake the erection of these chambers are able to join two sheets of lead together even when the joint is in a vertical direction ; but as it is rather a difficult and tedious business, they contrive to do as much as possible of it in a horizontal direction.

No rule can be given for the shape or dimensions of a chamber. Manufacturers are guided partly by convenience, partly by the size of the lead sheets procurable, and partly by a desire to have as much space as

possible included in the chambers with the least expenditure of lead. It is with this view that many chambers of vast size, and in shape as near as possible a cube, are being built. Of course, the nearer a chamber approaches a cube in shape, the more absolute chamber room is gained for the lead expended. It is now becoming usual to build chambers of enormous size, with the view of economizing lead. In order that a comparison may be drawn between the old mode of manufacturing sulphuric acid, and the way of proceeding at the present time, some dimensions of chambers at present in work may be given ; but it is generally admitted that the best produce is obtained from a series of small chambers, in which one would burn equal to a ton of sulphur *per diem*.

Mr. SCHOLEFIELD, chemical manufacturer, of Bradford, near Manchester, possesses a chamber of the following dimensions—seventy feet long, thirty-five feet wide, and thirty-five feet high ; thus possessing the enormous space of eighty-five thousand, seven hundred and fifty cubic feet. The same gentleman has also another large chamber, rather less than this one. It is forty feet long, thirty-five feet wide, and twenty-five feet high. Mr. SPENCE, also, of Newton Heath, alum manufacturer, has a fine chamber of the following dimensions : seventy-five feet long, forty feet wide, and forty feet high ; containing, of course, one hundred and twenty thousand cubic feet of internal space.

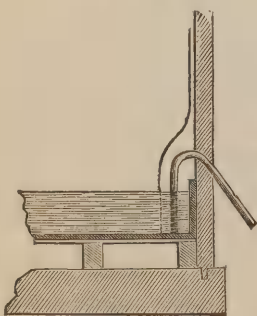
These are not the only ones—chambers of similar

magnificent dimensions are being built in many parts of Lancashire; and at Flint, North Wales, at the gigantic factory of MUSPRATT BROTHERS and HUNTLEY, chambers are of the following dimensions: one hundred and forty feet in length, twenty-four and a half feet wide, and nineteen and a half feet high; the internal space being therefore, sixty-six thousand, eight hundred and eighty-five feet. The above instances are singled out as illustrations of the chambers of the present day.

It will be easily understood that the size of the chamber, or rather the chamber space, must bear some relation to the sulphur burned. Some manufacturers are more successful than others in this respect, being able to produce more vitriol in rather less space than others, probably owing to some variation in working. In a Lancashire work, possessing chamber space to the extent of one hundred and twenty-four thousand, two hundred and sixty-eight cubic feet, they are able to convert eighteen tons of sulphur into sulphuric acid per seven days, the chambers being arranged in the form shown in Fig. 580, to be referred to hereafter. It may be well to notice, that when working with plenty of chamber space less nitre is needed. The reason will be seen when the theory of the action in the chamber has been studied.

As a general illustration of the construction or principle of a sulphuric acid chamber, it may be said to resemble a bell-jar, as used in the ordinary manner for gas experiments. In this case the bottom resembles a large square basin, into which the chamber appears to have been inverted, like the before-mentioned bell-jar in a saucer of water. This is shown in Fig. 578. The height of this basin edge, or turn-up, as it is technically termed, is about twelve inches. Into this, as in the figure, the side dips, and a light water lute joint is produced. By pushing the chamber side a little inwards—as in Fig. 579—from the turn-up,

Fig. 579

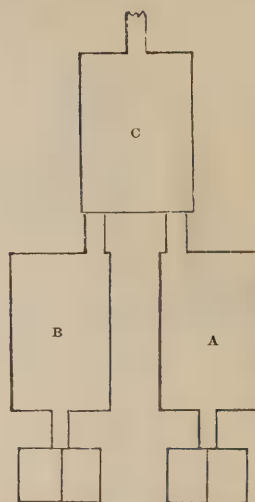


a space is formed in which the shorter leg of a siphon can be put, for the purpose of drawing off the contents of the chamber as wanted.

It is seldom that one single chamber is worked by itself, at any work, unless it be a very small one. The usual plan is to work a greater or less number from one into another. An arrangement is figured in PAYEN's work, in which some five chambers are represented as forming a battery, the gases proceeding from

one to another through the whole series. But it is not usual to see such a number connected together. In this country, at least, the number is often limited to two or three chambers working into each other. This answers very well. A favorite arrangement is shown in Fig. 580, which represents three chambers connected together. The chamber, A, has one or two

Fig. 580.

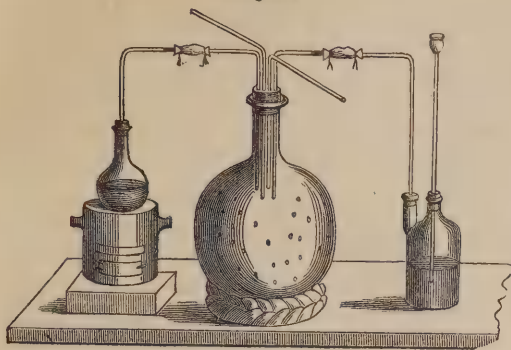


burners attached to it; the same with chamber B. The gases generated in these ovens rise through a cast-iron stalk or chimney into A and B. The portions which escape condensation into these chambers, are conveyed through the passages shown in the drawing into C—the third chamber. If any residue remains it passes with the waste gases into the chimney, through the tube at the end.

Theory of the Production of Sulphuric Acid.—The production of sulphuric acid in the chambers is the result of a series of rather complicated reactions. It was sufficient for the old manufacturers to know, that certain bodies placed in certain relative positions produced sulphuric acid; but for the present day this is not sufficient. The reactions of the different gases and vapors on each other, have been repeatedly studied, and much difference of opinion exists on this head. The reactions are very curious and interesting, the chief being the remarkable and useful property of the nitrous constituent of the chamber gas—of acting as a carrier of oxygen to the sulphurous acid. Were nitric acid capable of yielding up at once the whole of its oxygen to the sulphurous acid, it would require eighty-five parts of nitrate of soda to furnish nitric acid sufficient to oxidize the sulphurous acid produced from eighty parts of sulphur, so as to convert it into sulphuric acid. But in practice one hundred parts of sulphur are converted into sulphuric acid with the aid of from five to ten parts, according to the way of working, of nitrate of soda. This is rather startling; but chemists have traced out the fact, that though atmospheric oxygen is itself incapable of at once combining with sulphurous acid, eventually it is from

this source that the extra oxygen is supplied. The reaction may be studied on the small scale by the aid of the apparatus, Fig. 581, which may for the purpose be considered a sulphuric acid chamber in miniature. This apparatus consists of a large flask or balloon. In

Fig. 581.



thus the action is to go on, the flask is to furnish sulphurous acid, while the Woulfe's bottle is for the production of nitric oxide by the action of nitric acid on slips of copper. Tubes from both these pieces of apparatus conduct the respective gases into the large globe, which globe has also two other tubes inserted through its perforated cork—one is for the purpose of introducing atmospheric air, while the other is the exit pipe for the residual gases, *et cetera*. The apparatus is set to work in the following manner:—A small quantity of water is introduced into the large globe. This is turned about until the sides have been wetted. Copper turnings are placed in the two-necked bottle and in the flask, and the whole apparatus is fitted together as shown in the drawing. An ounce or two of strong sulphuric acid is now poured on to the turnings in the flask, and heat applied; as explained under sulphurous acid, this gas begins to be evolved. When a steady stream begins to be given off, a quantity of commercial nitric acid, diluted with about half its bulk of water, is poured into the Woulfe's bottles through the tube funnel with which it is furnished. A stream of nitric oxide— NO_2 —begins to be evolved immediately. This, soon as it comes in contact with the air in the globe, takes up another equivalent of oxygen, becoming peroxide of nitrogen— NO_4 . A reaction now ensues between this and the sulphurous acid from the flask. The NO_4 combines with the SO_2 —sulphurous acid—forming, it is supposed, a compound having the following formula— $\text{NO}_2 \cdot 2 (\text{SO}_3 \cdot 2 \text{HO})$ —water being present; or to follow the decomposition—



This, added to another equivalent of sulphuric acid already formed, the product of a previous action, makes up the formula before given. This latter body makes its appearance as an icy crust on the sides of the globe. Join one of the two open tubes on to a gas holder, or aspirator, and cause a small current of air to be drawn or forced through, to replace the oxygen absorbed by the nitric oxide— NO_2 ; remove this when done, and join on a small retort, or flask containing boiling water;

and now drive a small jet of steam into the balloon. Immediately the steam enters, the frosted coating will melt off the sides and decompose, streams of acid will run down the sides of the globe, and the whole interior will become filled with red fumes. If thought proper, the experiment can be repeated; it is only necessary to throw in a fresh quantity of sulphurous acid. This will again decompose the peroxide of nitrogen, forming the same compound as before—thus the experiment can be gone over several times. In this experiment, it is generally supposed that one has in miniature the action of a chamber; but this is scarcely the exact truth, inasmuch as the circumstances, though very nearly, are not quite the same as on the large scale; and daily experience teaches, that a small difference of circumstances will sometimes produce a great difference in a reaction. In the vitriol chamber itself, all the necessary re-agents are present at the same time, so that it is not unreasonable to suppose that some variation from the above described experiment may take place.

Almost every chemist who has studied the subject, has taken a different view of the question; though all appear to concur in supposing that the formation of the crystalline compound precedes the formation of any sulphuric acid. On this account most ingenious theories have been broached, explanatory of the decomposition which ensues. All concur in the opinion that it is nitric oxide which is evolved when the crystals come in contact with the water. With a view to elucidate the subject, these crystals have been repeatedly analyzed, but the analyses differ much. Dr. THOMSON gave their composition as— $3 \text{SO}_2 + 2 \text{SO}_3 + \text{NO}_5 + \text{HO}$ —a scarcely probable combination. Dr. HENRY again, from his examination, considered them to be composed of— $5 (\text{SO}_3 \cdot \text{NO}_5) + 5 \text{HO}$ —a more likely supposition. The analysis of these crystals must always be a difficult matter. It is impossible to procure them absolutely pure; and even were they obtained pure, they are so very prone to decomposition, that it is almost as difficult to keep them so for the purpose of analysis.

The theory of the chamber reaction just given, and which first originated with CLEMENT and DESORMES, is the one held by many chemists, including KNAPP, who gives it in his *Technology*; but there are others who hold that the decomposition and recomposition of nitric acid is an essential part of the chamber reactions. Amongst these latter may be named PELIGOT, quoted by R. D. THOMSON. PELIGOT considers that there are four phases in the process. The first is the mutual reaction of sulphurous acid and nitric acid, the products being sulphuric acid and peroxide of nitrogen— $\text{SO}_2 + \text{NO}_5 = \text{SO}_3 + \text{NO}_4$. Two equivalents of this NO_4 combine, forming nitric acid and nitrous acid— $2 \text{NO}_4 = \text{NO}_5 + \text{NO}_3$. This nitrous acid again, under the influence of water, is decomposed into nitric acid and binoxide of nitrogen— $3 \text{NO}_3 = \text{NO}_5 + 2 \text{NO}_2$ —which two equivalents of binoxide of nitrogen unite with two equivalents of free oxygen, becoming once more peroxide of nitrogen, which eventually becomes nitric acid by a repetition of the last three decompositions just traced out. The nitric acid formed at these several

stages acts, of course, exactly as in the first instance. Nitric acid is very easily decomposed by sulphurous acid. This may be illustrated by wetting the interior of a bell-jar with nitric acid, then placing it over a capsule of burning sulphur, and setting on a tile or plate; in a few seconds the jar becomes filled with red fumes, the sulphurous acid having abstracted a portion of oxygen from the nitric acid, reducing it to peroxide of nitrogen.

It has thus been attempted to indicate a possible means of one portion of nitric acid or nitrous gas acting *ad infinitum*, converting an almost endless quantity of sulphurous acid into sulphuric acid, without being itself diminished. Notwithstanding the amount of study and labor bestowed on this question, it is doubtful whether chemists have arrived at more than an approximation to the actual reaction in the chamber. When the very changeable nature of all the bodies which there react upon each other is considered, one can scarcely hope to attain the actual truth. The explanations just given of the formation of sulphuric acid, though doubtless such as take place, are probably only two of many; it is likely that a variation in the action of these bodies on each other is perpetually taking place, as there is a deficiency or an excess of nitrous gas, more or less steam, a greater or less quantity of atmospheric air present, a higher or lower temperature, and many other causes may vary these changes; yet one has a tolerably clear view of the general mode of action. It is a general and wide-spread opinion, that the formation of the crystalline body invariably accompanies the formation of sulphuric acid; whereas in practice its appearance is only accidental. That these crystals should be constantly formed under the ordinary working condition of the chamber is almost impossible, when their great instability when in contact with water is considered, and, as in the atmosphere of a chamber properly worked, a great amount of aqueous vapor always exists, their formation is not very probable; for one can scarcely imagine that a body can be produced under such circumstances, that, were the same body ready formed to be so placed, it would be decomposed. Still, these explanations serve to show how it is possible for a small quantity of nitric acid or nitrous gas to convert a large quantity of sulphurous into sulphuric acid, acting as a carrier between the oxygen of the chamber and the sulphurous acid, constantly taking from one and immediately delivering up its plunder to the other. In order to understand the extent of this action, a previous statement must be remembered of the amount of sulphuric acid which a given weight of nitre could produce, were its oxidizing powers limited to the oxygen contained within itself. It is only from this view that the beauty of the chamber reaction is seen; and perhaps no other metamorphosis is, when looked at in a scientific point of view, so beautiful. It is the hinge and turning-point of the whole manufacture; for were it not possible to produce such a large amount of vitriol with the expenditure of such a small quantity of the most expensive ingredient, the commercial value of vitriol would of course be proportionally higher; and as this acid is the starting-point of almost every other chemical salt or body manufactured, these various

salts, *et cetera*, could not be produced nearly so cheaply as at present. As a result of this, the value of all printed and dyed goods would be considerably enhanced, and would be placed out of the reach of many, or at least not easily attained. On the cheapness of this class of articles also, industry in many places depends; so that one may trace much of the trade and prosperity of the country to this beautiful, if not very simple reaction; for though it is possible to produce sulphuric acid without the intervention of nitric acid, none of the methods which have been proposed for the purpose, have gone much further than a laboratory experiment. In a later portion of this article some of these methods will be given.

Having now followed the theory of vitriol-making on an experimental scale, the subject next to be considered is the actual manufacture in the chambers. The construction, *et cetera*, of these, and their various appurtenances, has been already noticed. The chamber arrangement described previously—Fig. 578—has two burners to each chamber; that is, to each of the chambers, A and B. The mode of working these burners is such that a constant stream of gas is sent into the chambers. In order to effect this the burners are charged alternately. Thus, if the two burners attached to a chamber be designated A and B, they are charged at the following hours:—

Burner A.		Burner B.	
Charged at	6 A.M.	Charged at	8 A.M.
"	10 A.M.	"	12 noon.
"	2 P.M.	"	4 P.M.

The same proceedings are gone through with respect to the other two burners. By this mode of charging alternately, it is supposed that as the combustion in one burner loses in intensity the other increases, and *vice versa*; so that a stream of equal volume, or nearly so, is kept up during the whole time.

The burners are charged at the above intervals with a weighed or measured quantity of sulphur. The workman lifts the sliding door, and throws in the charge. Previously to this he inspects the state of the chambers, to enable him to judge what quantity of nitrate of soda he shall decompose simultaneously with the combustion of the sulphur. He puts as much nitre as he thinks necessary into one, two, or more hemispherical iron vessels, or cups, technically termed nitre pots. Immediately he has thrown in the sulphur, he closes the door to prevent the escape of gas; he then proceeds to add to each pot already containing nitre, as much sulphuric acid—from a vessel placed for convenience near the burner—as he considers necessary. This is not a nice or exact operation, the chief point being to add rather an excess of this acid, so as to insure the total decomposition of the salt, leaving a bisulphate of soda, or a mixture of neutral sulphate and bisulphate. When these pots are charged, the door is again opened, and the workman in charge lifts the pots by means of an iron hook, constructed for the purpose, and places them in the burner, in the midst of the now partially ignited sulphur. After a while the sulphur is in a gradually advancing state of thorough combustion, and considerable heat is evolved, which, acting on the nitre pots, causes the complete decomposition of

their contents; the nitric acid is given off, and passes simultaneously with the sulphurous acid into the chamber. A method common on the Continent, but rarely now, if ever, practised here, is the employment of strong liquid nitric acid, contained in basins, and placed inside the chamber at different parts on glass and porcelain triangles. Prefixed to the working chamber is another small one, through which the whole of the sulphurous acid has to pass, while in it are placed a number of earthenware dishes, containing nitric acid. In some instances they are not exactly dishes, but pieces of earthenware apparatus, constructed for the purpose, over which nitric acid is trickled in a slow stream. In either case the object is to expose as large a surface of nitric acid to the action of the sulphurous acid as possible. These two bodies, reacting on each other, produce gases which are carried forward to the working chamber. A rather peculiar arrangement is necessarily employed in order to get the nitric acid into the trays. This consists usually of a number of glass siphons, set into carboys of the nitric acid. These siphons convey the nitric acid into another glass apparatus, of which a bell-jar forms a part; the object of the whole being the conveyance of the nitric acid into the interior of the chamber without allowing any gas to escape. The whole affair is by no means simple, and would scarcely suit the manner of working in this country, as, from its construction, it must be very liable to derangement or destruction. Apart from this, it is not very evident what advantage is to be gained by using the nitric acid arrangement. In the first place, there is all the loss from escape, *et cetera*, incident to the manufacture of nitric acid, as well as the cost for labor, *et cetera*; while, by decomposing the nitrate in the burner, this are economized. Nothing can escape uncondensed, as in making the nitric acid every particle of vapor must pass into the chamber. The combustion of the sulphur affords the necessary heat, while the same labor suffices. On the other hand, it would appear at first sight that by this method the amount of nitrous gas necessary for the chamber could be more nicely regulated; but, on consideration, this advantage appears doubtful, for there would be a difference in the quantity passed through, according as the carboys were full, or otherwise, and the taps could, by a little carelessness of the workman, be left running when there was no occasion for them. Such occurrences have taken place to the destruction of the sides of the chamber.

The only part of the nitre system, if it may be so termed, which appears open to objection, or which may be cavilled at, is the contact of the nitric and sulphurous acids at a high temperature, and in consequence the possible decomposition of the nitric acid either into nitrous oxide or nitrogen, both totally inactive, and for the required purpose wholly useless gases. That such a circumstance has taken place is inferred from a fact which occurred in actual practice. A set of burners were worked to their utmost consumption; they became very hot, and required much more nitrate to keep the chamber in proper working order than previously. It would be difficult, in fact almost impossible, to prove the truth of such an opinion; but, nevertheless, it is

possible, and from the above incident probable; but if, for the sake of argument, the truth of this opinion be admitted, this appears, as far as practice goes, to be the only objection to this method of supplying nitrous gas to the chambers.

A Continental chemist, who employed the nitric acid process, saw the nitre process during a visit to this country, and on his return substituted it for the one he was previously employing; by so doing, he effected a saving of one-third of his nitrate of soda. This result could not have been obtained if there had not been some gross error or carelessness in the mode of working by nitric acid. It is possible that little care was exercised in the manner of working, and that, on employing a fresh process, more attention was directed to the subject; in either case the person was perfectly satisfied with respect to the advantages of working by the English method.

As before stated, however, the heat of the burning sulphur effectually drives off the whole of the nitric acid of the nitrates in the pots, leaving sulphate of soda. The nitric acid as soon as evolved comes in contact with the sulphurous acid from the burning sulphur, and is instantly decomposed by it; often, on looking into the ovens or burners, the whole of the upper portion appears filled with ruddy fumes. These, together with the sulphurous acid, pass up the stalk or chimney which conveys them into the chamber, there to react further upon each other, so as to produce sulphuric acid.

It has been attempted to be shown by the detail of the reactions on a small scale that, theoretically, one portion of nitrous gas is capable of converting sulphurous into sulphuric acid almost indefinitely, were it not that certain practical difficulties intervene; for instance, it must be apparent to the student of these experiments, that although one portion of nitrous gas can go on continually carrying the oxygen of the chamber to the sulphurous acid, yet this action must necessarily stop when the oxygen is exhausted. And this is possible, for were a close chamber taken, containing a limited portion of oxygen with the requisite nitrous gas, and the operator kept on introducing sulphurous acid, it would be found, on testing from time to time, that the quantity of oxygen was slowly diminishing, and that at length it had disappeared altogether.

This could easily have been the case with one of Dr. ROEBUCK'S close chambers, worked on the intermittent system. To supply this, it is usual at the present day to admit such a constant current of air, that there is sufficient to supply a stream of oxygen over and above what is requisite for the combustion of the sulphur; this finds its way into the chamber, there to effect the necessary change. This oxygen becomes gradually appropriated by the sulphurous acid, as the current of gas keeps slowly moving towards the exit with a regular and constant motion; and as this appropriation never ceases, necessarily the gases on passing out must get poorer in oxygen in the ratio of their nearness to the exit pipe. And this is found to be the case, for if a portion of the gases from this spot are collected, and the slight amount of sulphurous acid and nitric gases removed, the quantity of oxygen in the residue will be found to be considerably less than in com-

mon air. The quantity found differs even in the same manufactory, as no rule controlling the quantity of air to be admitted exists. In fact, it is considered advantageous to diminish it as much as possible, so as not to take up the space of the chamber with a useless superabundance of air. But whether this is judicious or not is matter of opinion; however, the reader is requested to bear in mind that, as before shown, the nitrous gas reaches the exit pipe unimpaired, and passes out with the residual nitrogen, excess of air, carbonic acid, and other matters. This is particularly mentioned, as this part of the subject will be again referred to, with respect to the method now in pretty general use for the recovery of this nitrous gas, and its replacement in the chambers, in order again to commence its labor. This invention of GAY-LUSSAC'S is the only improvement of any consequence which has appeared in connection with the manufacture of sulphuric acid for some years; in fact it leaves little to be desired, except the discovery of a material of which to construct the chambers, which, unlike lead, will be indestructible, or at least unacted upon by any of the bodies to the action of which it will be exposed; although, as will be seen in a later portion of this monograph, this problem has been attempted to be solved, its solution has not as yet been successfully accomplished.

Notwithstanding the number of years that sulphuric acid has been, it may be said, a staple manufacture of England, and so much opportunity has existed for studying this process, much misconception as to the true action of chambers exists. The forms, shapes, and other matters in connection with them which have been proposed and built almost exceeds belief—their name is legion; but the prevailing idea, which appears to have actuated many inventors of these ingenious constructions, appears to have been, that the action of condensation in a chamber was simply that of a distillation process; that as the vapor from a boiling liquid in a still or retort condenses on the cold surface of the worm or other refrigerating apparatus, so with a sulphuric acid chamber, the cold walls condensed the acid vapor contained inside. Evidently, with this idea in view, chambers have been built resembling flues; these, having a large surface of cold lead, were supposed to favor the production of the acid by condensing it immediately on its formation. It is related that a clever chemist across the channel constructed a most novel sulphuric acid apparatus. It consisted of an almost fabulous length of lead tube coiled round and round an apartment like a gigantic still worm; that sulphurous acid and nitrous gas were introduced at the highest end; these reacted on each other, the sulphuric acid when formed passing the whole length of the tube, a constant stream issuing from the other end.

It was not stated what length of time this system continued, but certainly on the face of it not long.

It is no uncommon thing to find long lead flues attached to the chamber, for the purpose of carrying off the residual vapors to the chimney. These flues invariably take a most circuitous course, many times longer than the direct route; and as frequently there is no obstacle or other such reason why the flue should not follow the most direct line, one is inclined to

inquire why this latter course was not adopted. If the question were put, the answer would probably be that a steam jet is introduced at the end of this tunnel nearest the chamber from which it issues, and that this length of flue, with the aid of the steam, is expected to condense any vapors not condensed in the chambers. If the product dropping out at the end of this flue be examined, it will very probably be found to be so weak as to be scarcely worth the coals required to concentrate it.

Let the true state of the case be examined. Is it absolutely necessary that there should be a surface for condensation? Is this necessary in all cases, natural and otherwise? Does the rain cloud, which, perhaps, in one half hour will come down in the shape of a heavy shower, require a surface for condensation. If it did, possibly rain would be more manageable; but this watery vapor needs no cold surface; it condenses into water, losing the vaporous and assuming the fluid state, without any assisting cold surface. And if this rain cloud be capable of so condensing, is it not possible for the like physical reaction to take place within a vitriol chamber? But further. Is it not probable, or rather certain, that the sulphuric acid in the chambers never was in the state of vapor. Sulphuric acid requires a heat of 620° to convert it into vapor. The highest point of heat a chamber could attain could be no approach to this; probably the heat of a chamber will not exceed 212° in the hottest part where the gas enters. Is it not possible that every atom of sulphuric acid produced passes from sulphurous acid gas to liquid sulphuric acid at once the instant it is formed—that the chamber is filled with myriads of these newly-formed particles—that these float about, and, like globules of running mercury, they gradually coalesce with each other, until they at last form a particle like a rain drop, sufficiently heavy to resist the sweeping influence of the currents which exist in the chamber; and that, finally, this drop falls into the acid on the floor of the chamber. Although it is impossible to see the process, and so prove the truth of this opinion, a very good inference of its justness may be drawn from an experiment which was tried on a chamber. A strip of lead about three inches wide was attached to the inner side of a chamber, in such a manner that it resembled a gutter or spout in an inclined position, one side of this gutter being formed by the chamber side, the other by the strip. This was placed about from two to three feet above the surface of the acid in the chamber, and was about nine feet long. In consequence of this position, the whole of the acid which formed or condensed on that side of the chamber above the strip would flow along it, and be carried by a small tube passing through the wall of the chamber into a vessel placed on the outside to receive it.

If the liquefaction of the acid took place almost wholly on the side of the vitriol chambers, a pretty rapid current of acid must have flowed along this arrangement, but this was not the case; instead of, as might have been expected, a constant stream passing along it, nothing more than isolated drops issued, probably at the rate of six drops per minute, an utterly insignificant quantity, when compared with the amount

of acid which must have been formed within the space over which this strip had the command.

In fact any observant manufacturer must, after a little attention to the subject, come to the conclusion that such is the case; that condensation goes on chiefly within the space of the chamber, although a small portion may condense on the walls; for when the acid particles are floating about in the chamber—driven hither and thither by the various currents which must exist—some must become attached to the sides and flow down into the acid already at the bottom, adding to the amount already formed. But the argument remains that all the acid is not brought to the liquid state by this means; that, in fact, the quantity thus formed bears a very small relation to the whole.

To many this will be already palpable, but evidently not to all, inasmuch as these strange abortions of chambers are not by any means as yet extinct, but still remain a testimony to the ignorance of many of our manufacturers. It must be apparent, that if anything more than the usual average amount escapes from the chambers, either they are badly worked or overworked. If the first should be the case, more attention must be directed to them to find out the error. If the second suggestion be correct, then, as the chambers have more material introduced into them than they can properly work, the amount of sulphur usually burned must be decreased, until the maximum amount which can be burned with a beneficial result is found. It needs little argument to prove, that the working space included in a tunnel could have been included in the chamber at much less expense.

The introduction of steam into the chambers has been already mentioned. Previously to the use of this reagent, the water on the floor of the chamber had all the work to do; every particle of the sulphuric acid and nitrous compound was compelled to pass in to the water from whatever portion of the chamber it was formed in order to be decomposed. The interior of one of Dr. ROEBUCK'S chambers, or any other chamber worked in the same manner, while in action would have been a pretty sight; the reactions must have taken place consecutively, as described in a preceding portion of this article when treating of the theory of the process. Every particle of sulphuric acid formed must previously have passed through the solid crystalline stage. The interior walls of the chamber must have been each time more or less coated and incrustated with the beautiful snow-like crystals, while the whole interior of the chamber must have resembled a snow-storm in an amber-colored atmosphere. The first manufacturer who introduced steam into his chambers did but exchange a beauty he could not see for a solid reality he could well appreciate. He introduced a most beautiful invention, which not only increased the production in the same chamber-space, but altogether simplified the operation. Instead of, as before, each equivalent of the double compound waiting to fall down into the cold liquid which covered the floor of the chamber in order to be decomposed, leaving, probably, a large per centage of the nitrous constituent behind; the bodies now never assume the solid state but on extraordinary occasions, and then only through

neglect. The whole of the reactions take place in a warm wet atmosphere, where everything is favorable to the intended purpose.

Sulphuric acid, when tolerably concentrated, has a tendency to combine with nitrous acid, forming a definite compound to be treated of hereafter; but unless the acid be concentrated, more so, in fact, than it is usually found in chambers, this compound is very unstable in the cold; heat it and the nitrous constituent flies off.

In a chamber worked on the old plan a great quantity of nitrous gas must have remained in the vitriol, causing a great loss of this body—the most expensive material the manufacturer employs. On the contrary, in the chambers of the present day, each particle of acid as formed must, if sufficient steam be present, be of such a density or strength and temperature as to be incapable of carrying down, and thus removing from its proper sphere of action, any of the nitrous bodies present. Again, in the old plan of working, the nitrous gas was only liberated at the surface of the liquid at the bottom of the chamber. Now, peroxide of nitrogen— NO_2 —the body into which the nitrous gas would become changed the moment after its liberation, coming in contact with the oxygen in the chamber, is a heavy gas, heavier than common air. It can be floated about and poured from vessel to vessel like carbonic acid. This then, on its being set free, would float about on the surface of the liquid, running the risk of being rapidly absorbed; whereas its sphere of action lies amongst the lighter sulphurous acid, on the upper portion of the chamber, to which point this NO_2 could only be conveyed by diffusion, or be carried up by getting entangled with the upward stream of gases emanating from the tube which conducts the sulphurous acid into the chamber. In the present system, whenever a particle of this peroxide or quadroxide of nitrogen meets one of sulphurous acid a reaction commences. Now there is no necessity for a descent to the bottom of the chamber; water, in the shape of vapor, pervades every part of the chamber; and as quickly as the crystalline combination forms, if it does form under these circumstances, it is as quickly decomposed. The resulting sulphuric acid falls, but the nitrous gas forms a second combination, and is then again ready to perform its purpose the moment it comes in contact with another particle of sulphurous acid. When carefully considered, it will be understood that it is not too much to call the introduction of steam into the chamber a great invention. It is not difficult to imagine how slow the process must have been in the old chambers when compared with the rate at which it proceeds now, and what enormous advantages manufacturers at the present day are possessed of over their predecessors.

Much difference of opinion exists as to the proper density at which the acid should be kept in the chamber, or rather what is the maximum density to which it may be allowed to rise? All manufacturers are aware that it is to their interest to keep up the strength of the acid in the chamber to the highest point possible, for by so doing there is a saving of fuel in the concentration. A writer has lately stated, on the authority

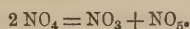
of an eminent manufacturer, that it is impossible to keep the vitriol free from nitrous gas if a density of 1.45 or 90 degrees. Twaddell is exceeded; while again in KNAPP's *Technology* it is stated, that the maximum density of 1.585, or about 112° Twaddell, should not be exceeded. A considerable margin exists between the two statements, but in such matters as these, which are not found capable of absolute and precise proof, the only course to be pursued is to take for a guide a near approximation to some recognized authority, or perhaps better, to be guided by the result of practice. A set of chambers now at work are kept at a general strength of from 110° to 112° Twaddell. It is not observed that more than a trace of nitrous gas is absorbed, except occasionally, and these instances may invariably be traced to either a slackening or a total cessation of the current of steam, either from the carelessness of the workman or by accident. In either case the pressure of steam has become so low that little or no watery vapor is being thrown in. Perhaps there is no manufacturer who has not at intervals found his chamber acid so highly charged with nitrous gas as to slightly effervesce when poured with violence from one vessel to another; in fact, it is not an extremely rare occurrence, under some circumstances, to find it perfectly green, from holding a large quantity of peroxide of nitrogen in solution. If, when this takes place, strict inquiry be made, it will be found, that such a state of things results from the chamber having been left for some time, possibly for hours, without steam. This point is worthy the manufacturer's attention, as it largely concerns his profits. The chambers, as at present constructed and worked, are not calculated to work on the old plan. As has been stated before, the steam materially quickens the process, and is the means of much more acid being made in a chamber than could be made were it worked on the old plan. When without steam, the excess which the chamber is not able to convert must pass up the chimney, being a loss of its value as well as risk of nuisance or damage. And not only does this occur, but nearly all the nitrous gas which is dissolved in the vitriol flies off when it becomes hot in the concentrating pan, to no purpose but to annoy the workman and surrounding neighborhood. Such a state of things is not an imaginary case, but a fact, as nearly every vitriol-maker can testify, and that to his material cost.

PAYEN gives a method for economizing this nitrous gas passing from the chamber dissolved in the vitriol. This he proposes to do by passing a stream of sulphurous acid over the surface of the vitriol while being concentrated; the sulphurous acid liberates any nitrous gas or decomposes any nitrous compound, and becoming mixed up and absorbed into this sulphurous stream, is carried into the chamber. The apparatus for effecting this purpose, though ingenious, renders the process of concentration too complicated, in fact, leaving a doubt whether the economy effected by its use is not more than balanced by the inconvenience entailed by its employment. Most manufacturers have a very wholesome fear of what is called a break down, and the general want of stability which this apparatus appears to have is not likely to make it a favorite.

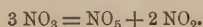
The Recovery of the Nitrous Gas.—The reader will no doubt have borne in mind, that whilst tracing out the reaction of the chamber it was possible to follow the sulphurous acid until it was completely converted into sulphuric acid, and that during this process the whole of the free oxygen of the chamber may become exhausted, but that, nevertheless, the nitrous gas still remains the same. This gas does not enter into, neither does it give up, any essential part of itself to the vitriol; its removal is only on account of its passing off with the current of useless nitrogen and other gases, and when removed it still possesses all its active properties, but diluted and incommenced with a quantity of gas of no value. Many have been the attempts to prevent this loss, and to bring this nitrous gas back into a useable form, and this idea has formed the principal feature in many patented improved methods of manufacturing vitriol. Perhaps the most successful worker in this direction was GAY-LUSSAC, the celebrated French chemist. His process, which was patented in this country, is at present in use in several works, and is found to be perfectly practicable, and to answer well the desired end.

In order that the reader may have a clear general idea of the invention, it is necessary to draw on the imagination a little. Let it be supposed possible to construct a filter through which to pass the unaltered air—nitrogen, trace of sulphurous acid, and nitrous gas—which forms the current constantly passing from a chamber; let this filter have the property of retaining the last-mentioned gas, and of letting all the others pass on to the chimney. When sufficient material has been collected on this filter, let it be possible to remove this retained material and to introduce it into the chamber again, there to renew its former labours, and a view is obtained of GAY-LUSSAC's invention. It has been shown that sulphuric acid, when tolerably strong, possesses the power of absorbing, retaining, or uniting with certain of the lower oxides of nitrogen. Most if not all works on chemistry treat more or less of these combinations, although not much appears to be known about them. GAY-LUSSAC studied them to a considerable extent, and perhaps gave the most just account of them; to this study manufacturers are doubtless indebted for the invention. The formulæ of these compounds are given very differently, arising no doubt from the difficulty of separating the different combinations formed, and then of analyzing them. But they appear to be generally considered as compounds of one, two, or more atoms or equivalents of sulphuric acid and nitrous acid, NO_3 . Some view them as compounds of sulphuric acid and peroxide of nitrogen, NO_4 . But whatever the composition, it is certain that peroxide of nitrogen forced into, or rather passed through strong sulphuric acid, is retained by this acid, and the body in question is formed. This is the principle of the process. It may be performed in miniature as follows:—First, fill a potassa bulb apparatus, or a small Woulfe's bottle with strong sulphuric acid—this is for the absorption—connect this with another Woulfe's bottle containing copper turnings; let a safety or tube funnel be put through a cork in the second neck of this bottle, the other neck being con-

nected by a short length of tube with the absorbing bottle, which also must have two orifices, one of which is to receive a short length of tube leading from the bottle just described to the bottom or lower portion of the sulphuric acid. The second neck must be connected with a suitable aspirator gas-holder. When all is complete, pour a little diluted nitric acid through the funnel on to the copper clippings, having previously set the aspirator at work, drawing a stream of air down the funnel and through the sulphuric acid; after a while, when the action appears to diminish in intensity, pour on a little more nitric acid, still keeping the aspirator at work, drawing the whole current of gases through the sulphuric acid. This must be kept on until the sulphuric acid appears to be becoming saturated; this is indicated by red fumes passing through in quantity. The apparatus may now be disconnected. The rationale, which has been partly described before, is simple. The nitric acid acting upon the copper produces nitric oxide, NO_2 . This, immediately on coming in contact with the oxygen of the current of air which is passing through, becomes converted into peroxide of nitrogen, and this is absorbed by the sulphuric acid, forming a compound with nitrous acid, another with nitric acid, being formed at the same time probably as follows:—



In this experiment the imaginary filtration has been really effected. Excess of air, nitrogen, *et cetera*, have passed on while the nitrous compound has been retained; thus one-half the problem is solved. When the apparatus has been disconnected, empty the bulb apparatus or bottle, as the case may be, into a convenient glass vessel, and pour into a beaker glass a volume of hot water, twice the bulk of the nitrous vitriol; pour this nitrous vitriol slowly into this hot water—a copious evolution of nitrous gas will ensue; in fact, if nearly boiling water be employed, almost all the nitrous gas absorbed will be again given off; a small portion will remain, having formed nitric acid as follows, supposing the liquid to be a compound of sulphuric acid and nitrous acid:—



This NO_2 becomes peroxide of nitrogen in contact with the air. The above reaction has been given before in connection with the chamber reaction, but still it is scarcely out of place.

This experiment then is exactly a representation on an experimental scale of GAY-LUSSAC'S invention. Sulphuric acid forms his filter, by which he separates the valuable nitrous gas from its useless companions, although not exactly in the manner just given. Columns for the condensation of gases are well known pieces of apparatus in all chemical works. They are usually tall hollow towers, constructed, according to the purpose for which they are to be used, of stone or lead. They are filled with pieces or lumps of any suitable material which offers a large surface, and at the same time are not acted upon by the acids or acid gases, or other corrosive substances with which they have to come in contact. Coke offers many points of advantage

in this particular, as it is acted upon in the cold by scarcely any chemical body; and it offers this additional advantage, that while offering more surface than perhaps any other material at all adapted to the purpose, it is at the same time very light. The column to be employed for the absorption of these nitrous gases is filled with coke, and by means of suitable contrivances, to be detailed hereafter, it is kept constantly moistened with a small stream of strong sulphuric acid, which is continually run on to it. The gases from the chambers are made to pass up or through this column or tower on their way to the chimney; and in order to do so, they have to wend their way through the many thousand passages and openings formed by the interstices existing between the pieces of coke. Thus they are split up into numerous streams, and have to come in contact with many hundreds of feet of surface wet with vitriol before they arrive at the exit pipe. The apparatus is built of such size and proportion that the gases in their course upward are brought into contact with sufficient sulphuric acid to absorb the whole of the nitrous gas contained in them. The acid containing the absorbed gas is collected in a proper reservoir or receiver, placed at the bottom of the column for its reception, from thence, as will be seen hereafter, to be removed, in order that it may be decomposed in such a manner that its nitrous constituents may be again used.

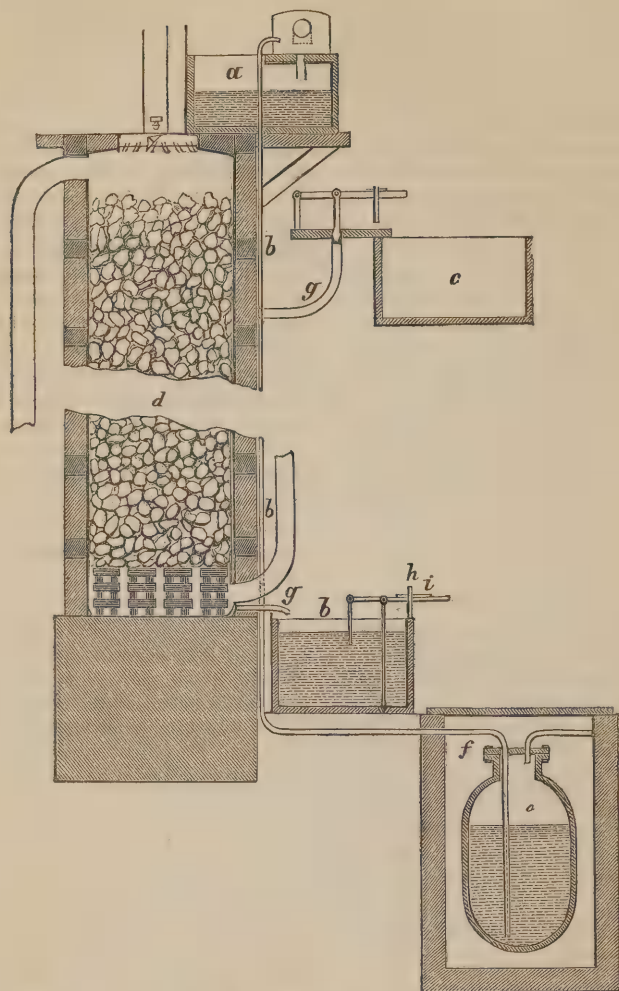
This apparatus seldom or never works well when applied on the small scale, as, for instance, when applied to one or two small chambers. This is a practical difficulty which, perhaps, in the hands of a careful and determined person, might be got over. It has been applied on a small scale at several works, and has been given up. On the other hand, several vitriol manufacturers on a large scale who use it, speak very satisfactorily of its performance. In some cases, by its employment, the consumption of nitrate of soda has been reduced from one-tenth the weight of the sulphur employed to one-twentieth—in fact, to the extent of one-half of that previously used. This is certainly a very good result.

The dimensions here given are those of an apparatus which is applied to a set of chambers, in which an average of eighteen tons of sulphur are consumed or converted into sulphuric acid per week of seven days. The apparatus is seen in Fig. 582. It consists essentially of the column or tower itself, three cisterns for holding or containing vitriol—*a*, *b*, and *c*—together with a large close cast-iron cylinder, *d*, employed in raising the vitriol to be used for absorption from the surface to the upper cistern at the top of the column, and also for removing this when nitrated or saturated with nitrous gas. The tower cannot be more appropriately described than as a tall cylinder of lead, five feet diameter, and thirty feet high, supported, like the lead of the chamber, by a suitable strong wooden framework. This leaden cylinder is completely closed in at the top, and stands in a suitable leaden dish or tray at the bottom, of such a depth that it always contains vitriol enough to lute it, and so prevent any escape of gas. The thickness of the lead is from a quarter to half an inch—some manufacturers preferring to use the thinner variety from motives of economy, while others, in order

to insure absolute safety, prefer to use half-inch lead. This cylinder, as stated before, and as shown in the drawing, is filled almost completely with large pieces

of coke. The quality of this coke is not by any means a matter of indifference: it must be in large firm pieces, for if it is either in small pieces of a rotten or soft

Fig. 582.



variety, it must be rejected; for, if small, sufficient space will not be left between the pieces for the proper passage of the gas, but will choke up the whole apparatus: besides the weight of the coke in the upper portion of the column will crush that near the bottom, and a similar result will follow. It will be, perhaps, well to mention, that if quarter-inch lead is used in the construction of the column, it would be well to line it with thin fire-tiles. These must be applied simultaneously with the filling in of the coke, as it would be impossible to hold them in their places otherwise; they must be placed as close as possible to the lead, and pressed to it, and held in their places by the coke pressing against them. This precaution of brick lining is necessary to prevent—what might otherwise occur—the cutting of the lead by the sharp edges of the coke; for although the column may be quite full at the first, yet, after a while, it will be seen that the whole mass

has subsided some inches, has in fact settled down, and were the tiles not in their places to protect it, it is possible that a sharp edge of coke might cut a slit in the lead.

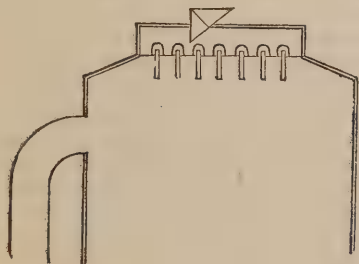
It is necessary to have some arrangement at the bottom of the column by which the gases from the chamber can have unobstructed entrance, for were the coke at once thrown in, without some contrivance for this purpose, it would fill up the entrance pipe, and prevent or nearly so, the entrance of the gases. A very good arrangement for this purpose may be made with fire bricks, which are almost unacted upon by acids. The lower part of the tower or column, to a few inches above the entrance for the gases, is filled in with these fire bricks—arranged in a systematic manner; in fact, built up in the most open and loose manner possible, so as to allow the greatest amount of inlet to the gases. The coke is piled above this. By this arrange-

ment the gases have all but a totally uninterrupted entrance; they rush up through the wide spaces left by the brick, and from thence divide themselves amongst the numerous passages which they find between the coke.

At the top of the column is placed the cistern containing the vitriol, which is run down it. Care should be taken, in the construction of an apparatus of this kind, that the timber work is sufficiently strong to bear the rather heavy weight of this cistern; but this, of course, is what few would overlook. Inserted into what may be called the roof of the column is a device for spreading the vitriol over the whole surface of the coke. In fact a good deal depends upon this, for were the vitriol run on just in one spot, it might possibly find its way down in one small stream not capable of taking up the nitrous gas, in consequence of its having little surface. KNAPP recommends this spreading to be effected by a series of cones placed within each other; these cones, which, as might be supposed, are constructed of lead, have each the apex removed, and the open ends of the whole system are placed immediately under an orifice in the roof of the column. The vitriol is made to enter these open ends in flushes; it rushes over the surface of the different cones, and finds its way to the interior, wetting the coke with a series of concentric circles of sulphuric rain. This will be understood by referring to Fig. 581.

A method which answers tolerably well is shown in Fig. 583. This is an arrangement actually in use. It will be better understood by supposing a broad flat dish, about two-thirds the diameter of the column

Fig. 583.



itself, to be placed on the roof of the column. Into this are inserted a number of tubes—about twenty or thereabouts; these tubes protrude both down into the column, and for a shorter distance up into the dish. The under portion of the tube can be bent, so that the stream which it delivers can be directed to any point desired; for instance, let the whole area of the column be mapped out, and twenty different equi-distant spots be marked; a tube is directed over each of these spots, so that when in action the coke is wetted in twenty different places, in this way increasing the chances of the whole body of it getting thoroughly moistened. Whatever mode of attaining this end may be adopted, the use of an oscillating box, or what the workmen, perhaps more expressively than elegantly, term a *tumbling box*, is almost absolutely requisite; for, in the

last-described scheme, without such an adjunct the spreading would be very inefficiently performed. The stream of vitriol which is run down a column of this description is, comparatively speaking, very small; and when this comes to be divided into twenty separate streams, they must naturally become very much less; so much so, in fact, that the chances are, that unless the ends of the tubes which project into the basin are exactly of one level, which practically is impossible, some three or four which happen to be the shortest, will take almost the whole of the stream. This casualty is put out of the question by the use of the oscillating box, the action of which is to deliver a comparatively large body of fluid at intervals, and this from a small stream. It is easy to see that each time the box oscillates and delivers, say a quart of fluid, the height of the liquid in the basin suddenly rises, and then immediately subsides, enough fluid having been delivered to furnish a current for each of the twenty different tubes.

It would, perhaps, be well here to describe the construction of one of these oscillating boxes, notwithstanding their being well known, and their action thoroughly understood. It is an old invention, and has been figured and described in many works on chemistry. It is constructed of a shape similar to that of two cones fastened together at the base and sectioned, with an axis connecting the apices; this will be seen by referring to Fig. 584. This apparatus, as depicted, is a diamond-shaped box, open at the two upper, and closed at the two lower sides. The box is divided into two by a partition, *a*, in the centre, and the whole is mounted on an axis, *b*, on which it can oscillate. It works, in this manner, one of the two spaces caused by the division, presents itself to the tap of the cistern, or other vessel, whence a small stream is issuing. It will be seen, by examining the figure, that the fuller one of these spaces becomes, the more to that side must the centre of gravity incline, until at length this centre of gravity gets thrown so far beyond the axis, as to overbalance the empty side of the box. When this occurs, the whole of the liquid which this division contained is emptied out suddenly, and the other side presents itself for filling; the apparatus taking the position indicated by the dotted lines. Of course, in a short time, this side becomes full, when a reverse again occurs, and so on as long as there is sufficient liquid to keep it in motion.

Fig. 584.



Another point of some importance in connection with the economizing powers of this column, is the regularity of the stream of acid which runs down. If the tap of the cistern, whence the acid flows, is set to a certain speed at the commencement of the space of time during which the acid is to last, it is certain that it will not run at the same velocity when the cistern is getting nearly empty; nor, according to the proper physical law which controls these matters, will it run with the same force during any two portions of time. According to the law, the rate decreases as the square root of the depth; or, to take a practical and easily understood illustration—suppose it is a cistern three feet deep, then whatever the

number of quarts, gallons, or other volumes per minute at which it runs, it will be delivering exactly half that number when the cistern has lowered to nine inches deep. Thus at one time there would be running down exactly half the quantity as at another; at one period probably supplying the apparatus with more vitriol than is necessary to take up the nitrous vapors, and at another time not giving it sufficient acid, thus allowing a valuable substance to escape.

This idea appears to have struck either the original inventor, or an early employer of this process; for in KNAPP'S *Technology*—which appears to be the only book in which a description of this process is inserted—a drawing of a method of obviating the defect is given. It is there proposed to employ a closed cistern, in principle resembling a bird's drinking fountain, where water can only be obtained by replacing the space occupied by it with air; and to cover this cistern with a top constructed of thick lead, supported in the interior by iron rods, sheathed in lead, to protect them from the action of the acid. When working, this apparatus must have had two alternate currents passing through the tap, one current of air into the receiver, to supply the place of the acid flowing out of it into the oscillator.

Several objections to this plan present themselves. In the first place, such a closed cistern must have been very inconvenient to work, in consequence of the increased amount of manipulation; for it was necessary to have an orifice in the cover through which to fill it. This aperture required to be made perfectly air-tight when the cistern was filled; for if this was not done, the whole principle involved became nugatory. Again, the construction of such a receiver must have presented many difficulties, not to speak of the great liability to leakage in the cover and other parts of the cistern. Besides, when the cistern leaked, a great portion of the cover would require to be removed, in order to admit a workman to repair it; the cover itself would also have to be repaired, taking up much time, during which the whole apparatus would be inoperative.

Many other objections present themselves on examination, but are scarcely worthy of remark, inasmuch as no cistern of this construction appears to be at work at this time, at least in this country.

An apparatus which answers the desired end very

well has been applied; and it has none of the objectionable features just described; it is shown in section in Fig. 585, where *a* represents the cistern containing the supply of acid. Adjoining this cistern is a circular vessel of lead, twelve inches in diameter, and of the same height as the cistern. Between these two, and from the bottom of each pro-

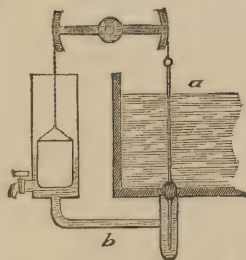
ceeds a tube, *b*, which forms a passage between them. This tube is not a whole piece of tube, neither does it take the shortest course between the two vessels, and

this for a reason which will be presently shown. The upper portion of the pipe opening into the cistern is of a conical shape, and into this is fitted a conical lead plug, which has been cast on a long iron rod, and turned up in a lathe very smoothly and with great nicety, so as to fit very accurately into its seat, the conical mouth of the tube just mentioned. This plug, as shown in the drawing, has the iron rod, which forms its stem, prolonged below the plug proper some eight or ten inches. This portion, as well as the upper, up to within an inch or two of the hook at the top, is coated with lead. This coating must be done very accurately, to insure the exclusion of the acid from the iron rod. This is best done by pushing the rod through a lead tube of the proper diameter, and fusing the extremities of the upper and lower portion to the plug proper by means of the blowpipe jet, described in that portion of this article which treats of the construction of the chambers. The lower length of the rod moves in the straight portion of the tube below the cistern, and is for the purpose of preventing the plug getting out of its seat, as well as for accurately guiding it in.

Within the tall cylinder before spoken of hangs a leaden bucket, for so it may be most appropriately called; the rim, or upper edge of this bucket, has an iron ring inserted into it, for the purpose of keeping it in its proper shape. To this ring are attached three iron chains, not unlike, in thickness and general appearance, to dog-chains. These chains are attached at a short distance to a single chain, which hangs in the centre of the cylinder. The upper end of this chain is in its turn attached to one end of a lever, moving freely on its axis, situated at the middle of its length. To the other end of the lever is attached another short length of chain, connecting the end of the lever with the hook at the extremity of the plug. This lever has semicircular pieces of iron attached to its ends, over or on which the chains rest, in such a manner that the plug and bucket have each, as near as may be, a true vertical motion, so that the plug may descend exactly into its seat, and that the bucket may move up and down precisely in the centre of the cylindrical vessel. This cylindrical vessel has the delivery tube fastened to it, and the tap from which the stream flows attached to it again.

In order to work effectually, imagine that the apparatus is newly attached, and has not been used before, and that this is the first trial. Let one imagine that the plug has been inserted unattached to anything else into its seat, and also that the cistern is full of vitriol; also determine that the vitriol shall run out at a pressure of some six or eight inches—vitriol pressure, not water. To do this, let the bucket hang down in the cylinder some six or eight inches from the bottom; attach the chain to the lever, and then attach the plug by means of the chain to its other end. In both cases this should be done so that the lever remains in a horizontal position; then let the bucket fall to the bottom. The result of this will be that the plug will be drawn from its seat, and the vitriol will run from the cistern into the cylindrical vessel through the communicating pipe. Now, watch

Fig. 585.



the action of the apparatus as the vitriol rises in the cylinder. As it does so the bucket will rise. Now, as first said, this bucket is fastened to one end of the lever, while the plug is fastened to the other—in point of weight the plug is the heaviest. Under these circumstances it naturally follows, that as the bucket *ascends* the plug descends, until at last the bucket ascends so high that the plug falls into its seat, and effectually closes the passage. If allowed to remain, and if the plug fits well, the liquid rises no higher in the cylindrical vessel. But if the delivery tap be opened the liquid in the cylinder will be seen to subside, the bucket descend, and the plug be lifted from its seat so high that it allows just so much liquid to pass it as is running out through the tap, whatever this quantity may be.

Thus, on examining the action of this apparatus, it will be found that it allows the cistern to be run almost empty at precisely one pressure, either six, eight, or any number of inches, thus obviating the misjudgment of the workman, or, what is probably oftener the case, the total neglect of its rate of running. A careful workman, from constant practice, soon learns to set the tap so that it shall run many hours without altering; he has only to notice the time required to run so many inches out of the cistern, it having a gauge with inches marked on it for this purpose; from this he can easily calculate, from the depth of the cistern, whether it will last out the required length of time. If the rate of running is not correct, it must be altered less or more accordingly. As this apparatus is not patented, it may probably find other applications.

Having now described the mode of running the acid down the column, let attention be turned to another and previous portion of the subject—the manner of placing it in the cistern. It is well known, and is a matter of no little regret, that as yet there is no real acid pump. Weak vitriol can be pumped with a pump of the ordinary description—the barrel formed of lead, the valves and all the flexible portions being formed of caoutchouc. But this latter body, and every other body which serves its purpose for ordinary liquids, is destroyed in a few hours, when placed in strong sulphuric acid even when cold. Such being the case, another contrivance is adopted—a very useful although not a very new one, it being at least as old as the chemist's eductorator, used in analysis for washing precipitates. This apparatus, as is well known, enables one to drive out a rather forcible though small current of water by atmospheric pressure applied on the surface of the water contained in the bottle. This is effected by closing the neck of the flask or bottle employed with a cork through which two tubes pass, one of which descends to the bottom of the flask below the surface of the contained water, while the other merely protrudes below the bottom surface of the cork. By means of the mouth, air is forcibly compressed within the bottle; this, in its efforts to escape, drives the water before it in a stream; and this is the principle of the apparatus by which the vitriol is elevated. A large cast-iron vessel, *e*—Fig. 582—replaces or rather represents the washing bottle. This vessel is for con-

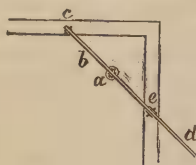
venience placed in a walled cell or space dug in the ground, and is made of such dimensions that it will hold rather more than the cistern it is destined to fill. It is formed not unlike a soda water bottle, this shape being the strongest, the lower and upper ends being rounded, the latter having a flanged neck cast upon it; this being about one foot wide. This flange has a number of bolt holes cast in it, corresponding to a like number of bolt holes in the lid. The lid has two perforations cast in it through which two two-inch diameter pipes can be passed and be secured, one of which pipes, as in the case of the wash-bottles, passes to the bottom, or nearly so, leaving a space of merely two or three inches; the other pipe merely passes through, terminating beneath the lid. Perhaps the best method of making a secure joint between this lid and the vessel flange is to insert an India rubber ring of such a size that it will lie within the circle of bolts; the ring being thus placed, the bolts are put in and screwed up tightly, thus compressing the elastic washer, and forcing it to fill up every crevice, so as to be effectually air-tight. The whole of this description will appear much clearer on referring to the figure—Fig. 582.

The drawing which accompanies this is scarcely complete, inasmuch as one cistern has been left out; this has been done purposely, so as not needlessly to complicate the figure. In order to explain the drawing the reader must consider himself working the apparatus. In the first place, suppose the iron cistern, *e*—Fig. 582—to be filled with vitriol of the density 1.750, or 150° Twaddell, this being the strength of vitriol to be used in the absorption of nitrous gas. At this moment it does not matter how it was filled. By means of a powerful air-pump, a strong pressure of air is forced on to the surface of this vitriol, driving or forcing it up the pipe, *f*, into the cistern, *a*, which it fills. From this cistern it runs, as has been already described, into the column, where, after traversing the coke with which it is filled, it runs into the dish-like vessel in which the column may be said to stand. From this it runs by means of the pipe, *g*, into the cistern, *b*; it is now by this time saturated, or nearly so, with nitrous gas, which it has gathered during its passage down the tower. From this cistern, *b*, it is once more run into the iron underground vessel; the air-pump is once more put into requisition, and it is forced from this vessel into the cistern, *c*, there to be reserved and run off as wanted, to be decomposed in the chamber.

As before stated, the cistern for the raw vitriol is not included in the drawing, but, as it is only a copy of the one at the foot of the column which is represented, a description of the one will serve for the other; it will also suffice to describe how the nitrous vitriol is conveyed from the cistern, *b*, into the cistern, *c*. It will be seen that from the bottom of the cistern, *b*, a short tube proceeds, which immediately joins on to the main pipe or artery, *f*; into the conical mouth of this pipe which opens into the cistern, a plug is fixed, which plug, like the one already described, is simply a conical boss or mass of lead cast on to the end of a sufficiently long rod of iron, and turned in a lathe to a fine surface, so as to make as accurate a fit as possible, the shank being sheathed in lead so as to

preserve it. The upper end of this rod is split, so as to embrace a lever, to which it is firmly attached by a hinge-like joint. This will be better understood by referring to Fig. 586, where *a* is the plug, as already described; *b* is the lever to which it is attached; *c* is a joint at one end of the lever, and which serves as a fulcrum; *d* is the handle at the other end of the lever; *e* is a guide in which it works, and which confines its movements to a simple vertical motion. The plug apparatus is fixed, as shown in Fig. 586, across the corner of the cistern. Now, to get the vitriol in *b*—Fig. 582—into the iron vessel, the workman simply

Fig. 586.



lifts the plug at the corner of the cistern; this he does by a sudden jerk, after loosening a little piece of apparatus, to be hereafter described, and which is for the purpose of keeping the plug in its place and preventing its rising when the pressure comes on to its under surface. Immediately he lifts this plug the sulphuric acid proceeds to run down this short tube into the main artery, and thence into the cylinder, driving out the air through a tap placed for the purpose. Immediately the cistern is empty, the workman by a forcible thrust fixes the plug in its seat, and for fear the pressure should force it out, he proceeds to fasten it down, as shown at the cistern, *b*—in Fig. 582—where in the upright, *h*, a number of holes are shown; into one of these a cotter, or piece of round rod iron, is thrust; then between this cotter and the lever he drives in the wedge, *i*, thus effectually preventing the rise of the lever, and consequently firmly holding the plug in its place. As soon as this is accomplished, he proceeds to set the air-pump in action, which air-pump injects air on to the surface of the vitriol; and when sufficient pressure has accumulated, the acid gradually flows along the horizontal pipe and main artery, *f*, until it arrives at the pipe, *f*, along which it proceeds, eventually emptying itself into the cistern, *c*, the air-pump being kept in action until all the vitriol is forced out of the cylinder, and a small portion of air following indicates when this has taken place.

The next part of the process is the conveyance of raw vitriol into the cistern, *c*. The details are precisely similar to those already described. Let the reader imagine another cistern precisely like cistern *b*, a perfect copy plug included, which said cistern has a short plug connecting it with the main pipe or artery, *f*. As in the case of cistern *b*, the workman removes the plug, and allows the vitriol to flow into the iron cylinder as before; when he has done this he proceeds to take measures for projecting this charge into the cistern, *a*, at the top of the column.

On the branch pipe leading to the nitrous vitriol reserve cistern, *c*, a plug apparatus will be observed. This is for the purpose of closing this branch pipe while raising the raw vitriol, and is taken out when the nitrous vitriol is being pumped up. It is scarcely necessary to remark that when the nitrous vitriol flows through this branch pipe, it naturally issues at the open end over the cistern, *c*, such being the lowest. In order to prevent

the raw vitriol taking the same course, the workman firmly inserts and fastens down this plug, and, when the acid to be used for absorption has filled the iron vessel, he sets the air-pump in motion, and the vitriol rises up to and flows into cistern *a*.

In consequence of the height of the column of liquid rising from the bottom of the iron vessel to the upper edge of the cistern, *a*—a space of nearly thirty-eight feet—and of its superior gravity, a pressure is exerted approaching to thirty pounds on the square inch. Hence it will be apparent that the cylinder and its appendages must possess a considerable amount of strength. It is usual to have them cast two inches thick in the sides in order to withstand this weight.

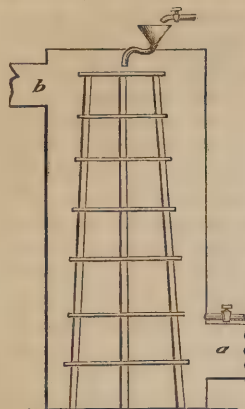
The air-pump used in this case, and which has been so often mentioned, is constructed on the model of an iron furnace-blowing engine, and differs from it only in dimension. The cylinder of this pump may be about eight inches diameter, the length of stroke being twelve inches, and it makes about fifty strokes per minute. It has a rather heavy fly wheel attached to it, to steady its action. This is necessary on account of the great resistance it has to overcome at the end of each stroke. It is necessary that the piston should fit very accurately, and that about the pump and the fittings generally great care should be taken to insure perfect freedom from leakage.

The quantity of sulphuric acid used in the absorption is rather variable, some manufacturers being more successful in this respect than others. Many who employ this apparatus recommend one-third of the make to be run down every twenty-four hours. In this case, for every hundred tons of acid made per week, nearly five tons would be run down per diem. One manufacturer finds in practice that about four hundred gallons, or seven thousand pounds, run down the column every twelve hours, will absorb the nitrous gas from a set of chambers which are converting eighteen tons of sulphur weekly into sulphuric acid.

To utilize the nitrous vitriol it is necessary to liberate the nitrous acid it holds, either within the chamber or contiguous to it, and in presence of the sulphurous and other gases entering it. Simple dilution with water effects this, as explained at page 1033. Still its practical working at first was found somewhat difficult, and much ingenuity has been expended in improving this part of the process, but still something further remains to be done before it can be considered perfect. The original inventor gave a method which, though theoretically almost perfect, was, unfortunately, not quite so, practically. It consisted in exposing the nitrous sulphuric acid in thin films or sheets to the action of the sulphurous acid which issued from the sulphur ovens. By this he proposed to liberate the nitrous gas, and in part he did so. The apparatus is shown in Fig. 587, which represents a sort of leaden column. Within this column a series of horizontal shelves or partitions are placed, which almost fill up the whole of the area; a funnel, furnished with an S tube, is inserted into the roof, and through this the nitrous sulphuric acid is poured on to the shelf immediately beneath. It runs from this first shelf on to the next one, and so it proceeds to the bottom, in exactly an opposite direction to that

pursued by the sulphurous acid current, fresh portions of which it meets at every point of its progress downwards. The funnel tube is of an S form, for the purpose

Fig. 587.



of preventing any of the gas escaping, a quantity of the liquid being retained in the curvature of the tube sufficient to prevent effectually the loss of any gas.

The sulphurous acid is admitted into this column through the wide tube at *a*, while immediately above this a jet of steam is thrown in; these together, after traversing the spaces between the shelves and acting on the downward stream, finally escape laden with nitrous gas into the chamber through the passage, *b*.

The jet of steam just mentioned is for the purpose of diluting the nitrous sulphuric acid, and so causing it to yield up more readily the nitrous gas.

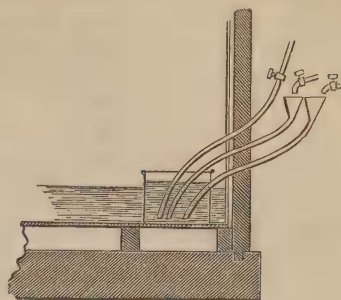
The acid, by the time it reaches the bottom, is supposed to be thoroughly denitrated, and is conducted thence to an evaporating pan to be concentrated, in order that it may be once more used for the absorption of a fresh portion of gas in the absorbing column. Theoretically considered, the nitrous vitriol ought to run from the lower portion of the apparatus without containing more than a trace of any nitrous body. On the contrary, it might be expected to be charged with sulphurous acid, but practically this does not appear to have been the case; for, from the statement of those who had ample opportunity of examining its action, it appears that the nitrous constituent was never thoroughly eliminated, that it still retained a considerable quantity of this gas after very slowly traversing the apparatus, and that this impossibility of thoroughly decomposing the compound acted as a strong barrier to the introduction of the invention. But, happily, this defect was not unconquerable, and was, by a reasonable amount of skill and patience, eventually obviated, at least practically so, if not perfectly.

The nitrous sulphuric acid is decomposed, but comparatively slowly, when subjected to the action of sulphurous acid in an undiluted state; and this appears to have been the cause of the failure in the commencement, inasmuch as the acid flowed from the decomposer almost of the same density as when introduced. It would seem inconsistent that the expedient of mixing it with water so as to dilute it was not adopted, especially as the decomposing action of water *per se* must have been observed. Doubtless this would have solved the problem, especially as with this addition a modification of his apparatus answers very well.

The mere dilution of this nitrous sulphuric acid with hot water answers very well. This is done within the chamber. A section of the apparatus employed is shown in Fig. 588. It consists in simply placing within

the chamber, and as near the burner stalk as possible, a round leaden vessel about twelve inches high and eighteen inches diameter. This is placed close to the

Fig. 588.



leaden wall of the chamber. This leaden wall is pierced by three tubes, all terminating within the leaden vessel, and near to its bottom. One of these tubes conveys the nitrous sulphuric acid into the vessel; the second conveys water; and the third is a steam-pipe. The two tubes for the liquids terminate on the outside of the chamber in funnels, while above these funnels are the respective taps, one of which communicates with the nitrous vitriol-store cistern, and the other with the supply of water. The steam-pipe is, of course, in connection with a generator.

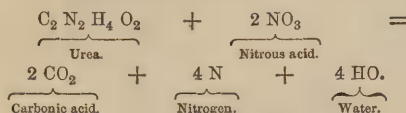
Supposing the chamber to be at work, the mode of operating, with this arrangement, is very simple. The leaden box or vessel is first run full of water—this is by means of the steam jet brought to boiling. The operator or workman then proceeds to run in a slow stream of nitrous vitriol and water from their respective taps. Immediately the nitrous vitriol touches the hot water below, it decomposes into sulphuric acid simply,—which remains in the vessel for a while—and nitrous gas, which flies off, and which is, by the current of gas ascending from the burner, carried off, and enters into the working of the chamber.

Of course, the vessel always remains as near as possible full. The streams of fresh liquid running in immediately displace and drive out a portion of the previous contents, causing it to mix with that already contained in the chamber.

There are at least two advantages which arise from placing this decomposer as near the burner-pipe or gas tubes as possible. In the first place, the gas arising from the decomposition has a better chance of thoroughly mixing with the rest of the gases which form the chamber mixture; and, in the next place, this rapid removal and immediate mixture lessens the risk of local action on the chamber, nitrous gas being rather destructive to lead. In fact, the rapid current of sulphurous acid gas must sweep away every particle of nitrous gas as fast as it is liberated. One of these decomposers has been working in a chamber for nearly three years, and the lead in its immediate neighborhood does not appear to have suffered more than that in any other part of the chamber.

Mr. PETER HART of Manchester has given a method of estimating the value of this nitrous vitriol

by a process of analysis by which one may, in a very simple manner, determine how much nitrate of soda or nitric acid a given volume of this nitrous vitriol represents, or is equal to. The process is founded on the well known reaction which takes place on bringing nitrous acid and urea together, the result of this proceeding being the formation of water, nitrogen, and carbonic acid gases, as shown in the following formulæ—



Mr. HART prefers to employ urea, in the shape of nitrate, on account of the facility with which it can be obtained pure. Of this nitrate of urea he weighs out twenty grains, and dissolves this in about two and a half ounces of water, heating this solution to boiling over a gas lamp. Meanwhile he prepares a test liquid, composed of thin starch water, in which he dissolves a small quantity of iodide of potassium. He spots a white plate with drops of this liquid. He then fills up an ordinary alkalimeter with the nitrous vitriol to be tested. Meanwhile the solution of urea has arrived at boiling, at which point he lowers the gas flame, and proceeds to add the nitrous vitriol from the alkalimeter to the solution in the basin. The reaction goes forward with strong effervescence, and escape of nitrogen and carbonic acid gases. He continues to add the nitrous vitriol drop by drop, not neglecting to stir until a drop, taken out of the basin by means of a glass rod, and added to one of the test spots on the plate, causes the latter to assume a blue color. This indicates the completion of the operation. The number of measures used or added are read off, and this forms the data for the calculation. The rationale of the process is very simple. After the decomposition of all the urea, the nitrous acid, which hitherto has been simultaneously decomposed with the urea, now remains in a free state. Now, it is well known that nitrous acid decomposes hydriodic acid, setting iodine free, which iodine will immediately combine with starch, if any be present. This is one of the tests for nitrous acid; so in this case the formation of the blue coloration indicates free nitrous acid in the basin; and free nitrous acid present indicates the decomposition of all the urea.

The calculation is based on the fact, that to decompose the twenty grains of nitrate of urea employed, there would be required 12·35 grains nitrous acid, NO_3 , which is equivalent to, or represents in chamber effect, 17·56 grains nitric acid, NO_5 , or 27·64 grains nitrate of soda; consequently the number of alkalimeter measures of the nitrous vitriol required in the decomposition represents or contains the equivalent of any of these numbers. All that remains to be done is, to ascertain the relation borne by this quantity to the volume which the cistern is capable of holding, or contains at the time of the experiment; or to put it as Mr. HART gives it—let a represent the number of alkalimeter measures employed of the nitrous vitriol; b the nitrate of soda—if the result is required in nitrate of soda—corresponding to the twenty grains of nitrate of urea, as given above; c the number of alkalimeter measures in a gallon—

seven thousand—and d the number of gallons in the cistern; then—

$$\frac{b \times c}{a} \times d = x$$

x indicating the equivalent in nitrate of soda of the recovered nitrous acid in the entire cistern.

Another method of recovering the nitrous gas has been lately patented in this country. It differs very considerably from the one already described, that is, in principle, although the apparatus bears a great resemblance. It consists essentially in converting the nitrous gases into nitric acid, and combining this acid with lime. The inventor starts out with a column, as in the last process, filled with suitable materials to afford a large surface, down which he runs a stream of thin milk of lime, allowing the waste gases from the chamber to ascend in the opposite direction. In this case it is supposed that, under the influence of the alkaline fluid and excess of atmospheric oxygen, the oxides of nitrogen will be wholly converted into nitric acid, which will immediately combine with the lime, forming nitrate of lime.

It is well known that nitric acid can be reproduced from any of the lower oxides of nitrogen—with the exception of, perhaps, the lowest, nitrous oxide, NO , when in contact with water and free oxygen. This has been dilated upon, and the reaction given when treating of the chamber reaction; and that this is a fact there is no doubt. The only difficulty hitherto appears to have been to obtain nitric acid of a suitable strength. This has scarcely been accomplished, as experiments have shown that the reaction proceeds with less rapidity as the acid gains density. But where lime-water is used this objection is removed, inasmuch as no free acid can exist in the liquid to retard the reaction; each atom of this acid being removed or combined at the moment of its formation, or immediately afterwards. There is no doubt that the presence of an alkali not only obviates this retardation, but actually induces, by its presence, the combination of the lower oxides of nitrogen with oxygen, thus, in fact, acting in a doubly advantageous manner.

The solution of nitrate of lime, formed in the column, is run into a proper cistern placed for its reception and conservation prior to its being converted into a dry or crystalline salt, which the inventor proposes to employ instead of nitrate of soda, as a constituent of the artificial manures now so much in request.

Perhaps the process would have been more perfect had it been more self-containing, and not dependent on outer circumstances for its perfect well-doing; that is, if the vitriol manufacturer, instead of having to depend on the purchase of this nitrate by other parties, could have used it himself. Were it cheaply decomposable, that is to say, were it possible to eliminate the nitric acid cheaply, it would be better; but it can only be decomposed with ease by the addition of some stronger acid, and the only one reasonably available for this purpose is sulphuric acid. By substituting this nitrate of lime for the nitrate of soda or potassa, ordinarily employed, one would certainly most effectually get back the nitric acid; but, unfortunately, sulphate of lime, a body of no value, would be pro-

duced, instead of, as now, producing sulphate of soda or potassa, salts in great and constant demand.

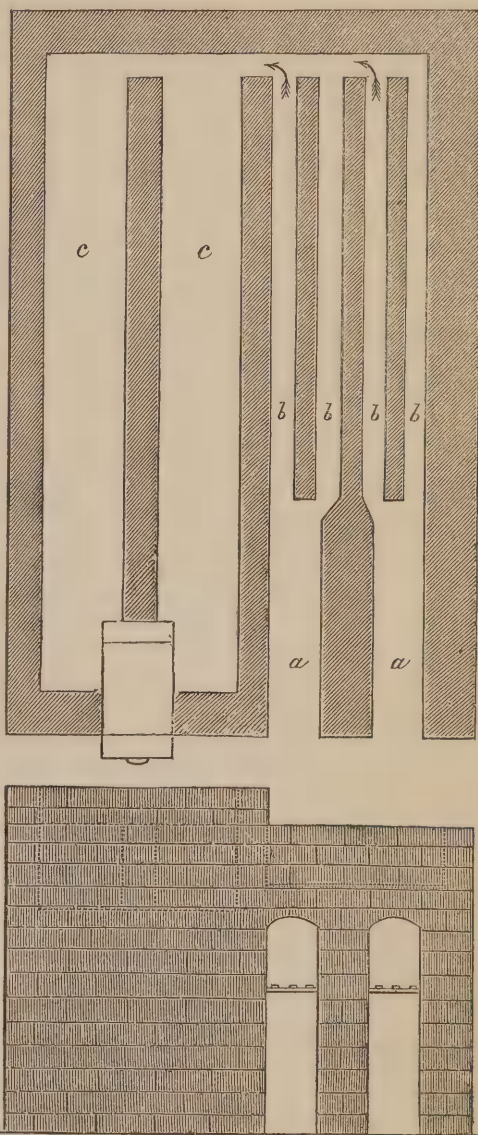
Of the value of processes for the recovery of the nitrous gas little need be said. The benefits they confer are apparent at once, recovering, as they do, the most expensive element in the manufacture, and not only being a saving of the money value of the nitre or its equivalent recovered, but further, when looked at in a politico-economical point of view, another phase presents itself: for were all sulphuric acid manufacturers able to work with half the nitrate they at present use, it would surely tend to reduce the price of this salt; and, if the maxim be correct, that price is regulated by supply and demand, then under the imaginary state of things just mentioned, one-half the quantity now used being thrown on the market, or what is the same thing, not used, must bring down the price of what could be sold, thus lowering a second time the cost of manufacturing sulphuric acid.

Concentration of Sulphuric Acid.—Sulphuric acid, as it exists in the chambers, though strong enough for many purposes, is not sufficiently so for sale, inasmuch as it is the object of the manufacturer to send it out as strong as conveniently may be, in order to avoid the necessity of conveying a quantity of useless water. It is concentrated up to a certain point in leaden pans; that is, until it has attained the density of 1.750; beyond this point it is not considered safe to push the concentration in lead. In order to bring it up to its maximum degree of concentration, or its conversion into what is termed rectified oil of vitriol, the extrication of the further remaining quantity of water must be performed in vessels of glass or platinum.

With respect to its concentration in lead a variety of plans are in use for this purpose. Much difference of opinion exists on this head amongst sulphuric acid manufacturers; their choice probably depending on convenience and situation. One manufacturer, for instance, prefers to concentrate his vitriol by passing the flame and products of combustion of a fire over the surface of his weak acid, the watery vapor being carried away with the smoke, *et cetera*. This plan appears to answer very well where no niceness with respect to the color and purity of the acid is demanded—as when the vitriol manufacturer is also a soda manufacturer, and uses up his own acid; but as the concentrated acid resulting from this mode of working is almost invariably very black and turbid in consequence of particles of coal-dust, *et cetera*, falling into the hot liquid, as well as from contact with the various carbonaceous bodies forming coal smoke, such acid would be scarcely saleable in the ordinary way to calico-printers, bleachers, and other such consumers. In order to avoid this, the manufacturer must employ an apparatus in which the liquid is kept clear from all or any such contaminations. For this purpose a pan in principle, though not in shape, resembling an ordinary pan or boiler, must be employed. This variety of concentrating boiler is in very general use, being, in fact, almost universal amongst those manufacturers who sell their acid; whilst the surface concentrator is as commonly employed amongst the soda manufacturers and others, who make the acid solely for their own use,

The following describes the plan of a manufacturer who makes for sale only. This plan is found to answer very well; it consists of two pans, placed side by side, one being placed higher than the other—so high that its contents can be emptied completely by means of a siphon into the lower pan. No joinings or solderings of any kind are admissible about these pans, the whole must be formed out of one solid sheet of lead,

Fig. 589.



the sides and ends being turned up simply: the lead is half an inch thick, the other dimensions of the sheet being thirty-three feet by seven feet six inches. To form such a pan, the sheet of lead is first spread out on the bed prepared to receive it; the plumber proceeds to mark off eighteen inches from each side of the sheet; this is to form the sides and ends of the pan. To faci-

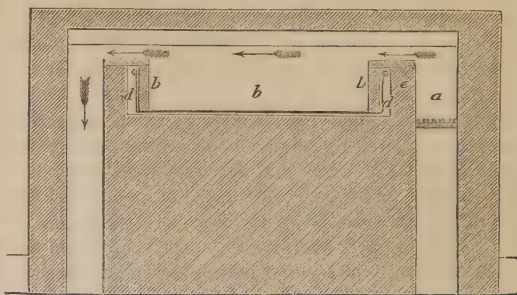
litate the bending, a fire of shavings is made along the line of markings. When the lead has become sufficiently hot along these lines, he proceeds to bend up the sides, and to beat out any inequalities. The brick-work setting of the pans will be understood from the preceding figures, in which Fig. 589 represents the arrangement of the flues, previous to being covered in with the fire-tiles or iron plates on which the bottom of the pan is to be placed; the left hand portion represents the bed of the lower pan, while to the right we have that of the upper one. *a a* are the two fire-places, the flame from which proceeds along the narrow flues or passages, *b b b b*; they turn off at the end in the direction of the arrows, and return beneath the upper pan, along the two wide flues, *c c*, and from thence pass into the wide flue leading to the chimney. Fig. 589 is a vertical section, lengthways, of the fireplace of the lower pan; *c* is the course of thick fire-tiles immediately over the fire, protecting the pan from the too great heat; a little beyond the fire thinner tiles are employed, which thin tiles are continued to the end. The two wide passages, *c c*—Fig. 589—beneath the upper pan are covered with iron plates, half an inch thick, on which the pan is placed. It will be understood from this description, that the tiles, or other supporting medium, diminishes in thickness, but increases in conducting power as the distance from the fire increases. This arrangement is necessary, for were iron plates used the whole distance, they would soon be burned through and destroyed in the immediate neighborhood of the fire; and, on the contrary, were thick tiles used for the whole distance, the latter portion of the arrangement near the end of the pan would offer too much resistance to the passage of the heat, and consequently a considerable portion would pass away without being absorbed.

Two such pans are capable of concentrating the acid produced from eight tons of sulphur per week of six days. There are pans at present in use capable of concentrating forty tons of vitriol weekly. Their mode of working is as follows:—The vitriol in the lower pan being of the proper strength, the workman proceeds to run it off into a vessel called a cooler, where it remains until cold. He runs it empty to within two or three inches; when this is accomplished, he proceeds to set a siphon into the upper pan, running the contents into the lower one, which lower one he fills within two or three inches of the top. When the upper pan is empty he refills it with the weak acid from the chamber; he then proceeds to fire the pan until next day, when he will repeat the operations just described.

The other description of pan, the one spoken of as a surface concentrator, is of the following description: Fig. 590 being a vertical section lengthways, the fireplace is at *a*, the flame, *et cetera*, proceeding in the direction of the arrows over the surface of the dilute acid at *b*, when it descends into the flue, carrying with it the evaporated water. It resembles—with the exception of some particular details, to suit the material to be evaporated—the furnace described under the head ALUM in this work, Fig. 89; but in the case of sulphuric acid, the furnace has to be lined, so to speak, with lead; and this lead being liable to fuse at a comparatively low temperature, much ingenuity is

displayed in the methods adopted to prevent as much as possible such an occurrence. One mode of accomplishing this is shown in Fig. 590, where *d d* is a section of the leaden pan, inclosed in brickwork, to prevent

Fig. 590.



the action of the flame. The side of the pan is brought up to the furnace dam, *e*; then within the pan a close row of firebricks, *b*, are placed on end, but not cemented in any way. Thus the sides of the pan are inclosed between brick walls, it only remains to cover up the space, and this is done by placing firebricks on the top, resting partly on the furnace dam, and partly on the row of bricks just mentioned; the flame is thus completely kept off the lead. This is repeated all round, the pan's sides and ends being equally protected. Some manufacturers employ a slightly different arrangement, although on the same principle. A covering brick, expressly made for the purpose, is employed; these bricks are made of the proper size, with an indentation or channel formed in them; this channel being for the purpose of inclosing the

Fig. 591.



upper edge of the pan, side or end. This arrangement is shown in Fig. 591, where *a* is the pan edge; *b*, the brick or tile, with its channel, *c*, inclosing the edge of the pan.

Though these precautions would appear to be sufficient, yet the manufacturer usually avails himself of another invention, which consists in running a stream of cold water round the pan's edge. This is effected by burning or fusing—by means of the hydrogen apparatus mentioned in another portion of this article—to the edge of the pan a leaden tube of a Π shape, the flat side being next to the pan; a section of this pipe is shown in Figs. 590 and 591. This arrangement has a current of cold water constantly flowing through it.

These vitriol pans are often of immense thickness, in some cases the lead of which they are made is an inch thick; but as the heat does not, as in the previously described pans, penetrate through this, it is immaterial. They are worked rather differently to the other pans, inasmuch as it is necessary to cool them to a much lower temperature before running them off. Before this is done the fire must be slackened, or rather put out; for, were the pan to be emptied while the fire was burning with its usual vigor, the pan sides might get so hot as to become soft, and fall or bend down. The upper portion is an arch of firebrick, through which a hole is pierced over one corner of the pan;

through this hole the siphon is inserted for drawing off the finished vitriol; it is also refilled with dilute acid through this. The workman ascertains the progress of the concentration, or its completion, in all cases by taking out a portion from time to time, and placing the vessel containing this trial sample in water to cool. When cold enough, he ascertains the density by means of the hydrometer. When finished it must, as before stated, be of the density of 1.750, or of the strength of 150° on TWADDELL's hydrometer—the instrument most used in this country—when at a temperature of 60°. When of this density, he draws out the fire and proceeds to run the vitriol into what are called coolers, which, as their name indicates, are for the purpose of holding the acid until sufficiently cool to run off into the glass bottles called carboys, for sale or transport to its destination.

These coolers, which are simply shallow lead vessels almost identical with the first-described pans, are, like the latter, formed out of an entire sheet of lead, sometimes half-inch, often of quarter-inch thick. This is, of course, an indifferent matter. The half-inch will last much longer, nevertheless it is not advisable to make them of less than quarter-inch. These coolers are set on iron plates in the manner described with reference to the upper pan; but the ends of the flues are open to the air, which, circulating through these passages, carries off the heat. The sides and ends are held up by brick walls or other convenient supports.

Very good and efficient coolers are constructed as follows:—The dimensions of an iron vessel, capable of holding the quantity of vitriol likely to be run off from the pan, are calculated—these parts are cast of about half-inch thick iron in such a manner that the whole can be securely bolted together. No care is requisite with respect to the accurate fitting of the various joints, as the whole must be lined with say quarter-inch lead. This lead must be turned over the upper edge and flattened down so as to prevent any infiltration of acid between the iron and the lead. If this is not attended to, the acid which finds its way down will act upon the iron, producing protosulphate of iron in masses. These will continue to grow in size, and in so doing will push the lead from the iron, producing misshapen prominences, which will finally destroy the cooler, or rather necessitate the removal of the lead lining, the cleaning the surface of the iron, and finally relining with lead. Two of these coolers, of six feet square and two feet deep, have been in use for some time; they cool the vitriol very rapidly. They are not set on the floor, but on two low walls of brick, so that almost the whole surface of the iron is exposed to the cooling influence of the atmosphere, and the heat is quickly carried off.

It is possible to construct coolers by simply lining a wooden cistern with lead: such are used for crystallizing various salts; but it is a question whether they can be recommended, inasmuch as the cooling must be very slow, on account of the bad conducting quality of the wood which forms the coating to the lead.

In most vitriol works two coolers are used in connection with the pan or pans. Suppose they are called No. 1 and No. 2, the mode of working resem-

bles that of the pans first described; that is, No. 1 is supposed to be cool enough to bear bottling. When this is done, the contents of the upper cooler, or No. 2, is now run into No. 1, while No. 2 is now ready to receive a fresh quantity from the lower concentrating pan. It will thus be seen that in working a set of concentrating pans and their accompaniments, four stages may be recognized. The upper pan partially concentrates the acid ready for the lower pan, which then completes the concentration. From this lower pan it is run into the upper cooler, where it loses the greater portion of its heat, and finally it is run into the lower cooler, where it remains until quite cold or nearly so.

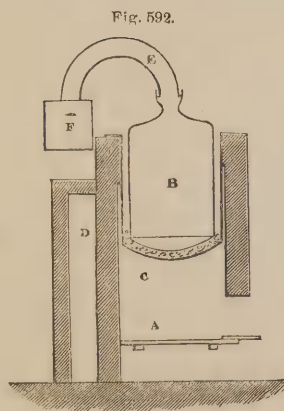
The system just described is in constant use in some works, but is not by any means universal, each manufacturer limiting the extent of his apparatus to his wants. The arrangement most usually seen, especially in small works, is a single boiling-down pan, as it is technically termed; the heat passing beneath it up one flue and returning to the same end down another, after which it passes to the chimney. This pan is accompanied by one cooler. The raw acid from the chamber is run into this single pan, where it is concentrated up to the proper point, after which it is run into the cooler, where it stays until cold; and if the pan is ready to run off again before the vitriol in the cooler is cold enough, there is no help for it, but drawing the fires and letting it stay in the pan until it can be accommodated.

There is no objection to this system except, perhaps, that it is not calculated to do much work; still it answers sufficiently well for small manufacturers.

The manufacture of sulphuric acid has now been traced to the completion of a commercial product, which, in the language of the trade, is called brown oil of vitriol, in order to distinguish it from a product of still higher concentration, to be immediately described. This brown oil of vitriol is used to a large extent by bleachers, calico-printers, dyers, and others; its brown color, from which it derives its name, is due to a certain amount of organic matter which finds its way into it, and which, subjected to the joint action of the acid and heat, becomes carbonized, and colors the whole of a dingy-brown hue. This tint is often augmented from accidental circumstances. Sometimes the workman lets the rag or paper protector, with which he covers his hand while setting the siphon, drop into the pan, at other times fragments of wood-shavings or sawdust find their way into it; when this is the case the vitriol well deserves its name of brown; perhaps, under these circumstances, black would more nearly designate its color. When such an accident occurs, it is usual to destroy this black or brown color by sprinkling a small quantity of some highly oxidizing body into the vitriol while hot in the pan; either nitrate of potassa or soda answers well for this purpose. Finely powdered black oxide of manganese may be used. These bodies yield up sufficient oxygen to the black matter to destroy it, or convert it into some colorless body which does not offend the eye.

Monohydrated Sulphuric Acid—Rectified Oil of Vitriol—English Oil of Vitriol.—Brown oil of vitriol is not sufficiently strong for several purposes; amongst others may be enumerated the manufacture of the dyeing

compound known in commerce as extract of indigo, sometimes called sulphate of indigo. Fuming Nordhausen acid is often directed to be employed in the formation of this body, but in this country it is usual to employ the strongest English sulphuric acid. In order to procure this acid the following methods are adopted:—It has been stated previously that the concentration cannot be safely conducted in lead beyond the density of 1.750, for if driven further, not only would the metal be rather strongly acted upon, but there would be considerable risk of the pan-sides falling in, in consequence of the softening of the lead; so high would the degree of heat become before the last portion of water could be driven off. The further concentration, then, must be performed in vessels made of a material which will withstand the corrosive action of the boiling acid, and which is comparatively infusible. Glass at once suggests itself or some variety of earthenware, such as porcelain, or, amongst the metals, platinum or gold. Of the former two glass offers most advantages, and of the two latter materials platinum is preferable, inasmuch as it resists acids quite as well, and is much cheaper than gold. Glass has been employed in the concentration of vitriol from very early times, perhaps from the period when sulphuric acid began to be understood, and its manufacture attempted on a very small scale, doubtless before the introduction of leaden pans. Platinum, on the other hand, is a comparatively late introduction. The glass vessels employed in the last concentration of sulphuric acid, or, as they are technically known, retorts, resemble very much the bottles or carboys used to transport vitriol from place to place. Their figure is shown in section in Fig. 592, which represents the whole arrangement when at work.



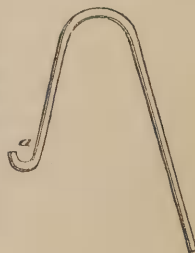
These retorts vary some little in size, manufacturers having lately begun to use much larger ones than were formerly employed. Those in use at the present day are capable of holding more than twenty gallons of liquid, inasmuch as after the rectification or concentration there remains in the retort sufficient vitriol to fill two carboys. This is equal to twenty gallons.

The mode of working can be gathered from the drawing, where A represents the fireplace; the flame, *et cetera*, from the fire plays round the cast-iron pot, C, finally making its exit into the flue, D. On the bottom of the

iron pot just mentioned a quantity of dry sand is laid; and on this the retort, B, is placed, the sand serving as a steady support for it. The retort is not, as is sometimes supposed, surrounded with sand; for, if this were done, it would run some risk of being broken, besides materially retarding the cooling when the rectification was over.

The retort being placed, as in the drawing, it is filled with cold brown vitriol; and when this is done the fire is lighted; the arm, E, is put into its place; the apparatus gradually warms up, and eventually the acid boils; water, with a little sulphuric acid, distils off. This vapor passes off by the stoneware arm, E, into the leaden draught-pipe, F, where a quantity of it condenses; but the greater portion finds its way from thence into the chimney. The contents of the retort are kept boiling for some hours, or until the brown color entirely disappears; for this appears to be the only reaction by which to determine the conclusion of the rectification. It would appear that the organic matter resists the destroying or oxidizing action of the acid, until it has reached its highest point of concentration and temperature. When the clearing has taken place, the fire is withdrawn from beneath the pot; and the whole arrangement is

Fig. 593.



allowed to cool down to a safe temperature, when it is drawn off into carboys. This drawing off is effected by a peculiar siphon, being in fact what is known as MITSCHERLICH'S siphon; but in this case, on a rather large scale, as shown in Fig. 593, it consists of a siphon, with the shorter of its two legs turned back upon itself, as shown at *a*. This turned-up portion should be as short and as close to the siphon leg as possible, in order to be the more easily inserted into the neck of the retort; it is rather exaggerated in the drawing. In order to withdraw the concentrated acid from the retort, the workman first removes the earthenware arm; the siphon is filled with water, the man keeping his thumb firmly closed over the orifice of the longer leg. The shorter leg is inserted into the retort, and gently placed on the bottom; the workman then removes his thumb for a few seconds, until the acid has driven before it the water with which the siphon was charged; when this is done, the end is directed into a carboy which has been placed in readiness by an assistant. When the carboy is full the orifice is again closed by the thumb, while the full carboy is removed and replaced by another empty one. The whole range of retorts are emptied in this manner.

This product is the strongest English sulphuric acid; it is colorless or nearly so, and is of the density 1.850, or 170° on TWADDELL'S hydrometer.

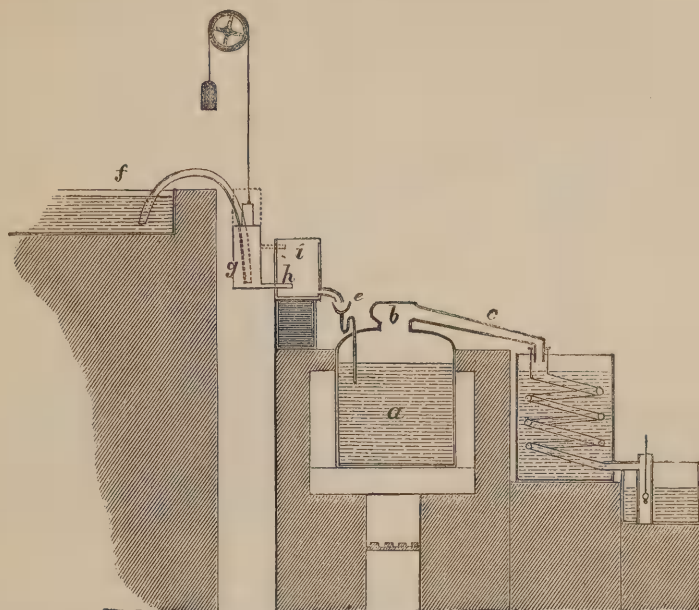
When treating of the commencement of this process, the retort was directed to be filled with cold brown oil of vitriol; it was supposed in this case that the retort was newly starting; but as one charge is now supposed to have been worked off, it will be more or less warm, and the introduction of cold vitriol at this junct-

ture might possibly fracture it. Therefore, it will be necessary to recharge it with warm vitriol, or with vitriol as nearly the same temperature as the retort as possible; and this must be made a rule, if annoyance would be avoided.

It is usual to find in books treating of this matter, the apparatus for rectifying in glass described as con-

sisting of a great number of the retorts, with their accompanying sandpots, *et cetera*, set in a battery, that is, a number of them heated by one fire. Though this may have been the case at one time, it is not the practice or custom to operate in this manner at the present day. Such an arrangement could not have worked as well as the present one, the probabilities being that the

Fig. 594.



retorts which were placed nearest the source of heat, would arrive at their maximum point of concentration some time before those at the end of the arrangement furthest from the fire were finished; in such a case it would have been necessary to have kept on firing until the whole set were done. The result would be that a considerable quantity of sulphuric acid would have distilled off the finished retorts, while those in the rear were being finished. In the present arrangement each retort is by itself, has its own fire, and consequently works totally independent of its neighbors.

The defect of this system of operating is the great fragility of the operating vessel, and the consequent liability to fracture either from a blow or other accident of the kind, or from change of temperature. The room or shed in which a concentrating plant of this description is working, should be closed, and every precaution taken to prevent the access of draughts of cold air or other cooling influence. It is no uncommon occurrence for two or three retorts to be cracked round the top, from the sudden rush of cold wind through an opened door, in such a manner that the whole upper part of the retort could be lifted off; the crack having gone completely round it, and severed the upper portion as completely and as straight along the protecting edge of the sandpot, as though it had been done with a diamond. Mr. JONES of Bristol took out a patent in the year 1845, for a protector to obviate this

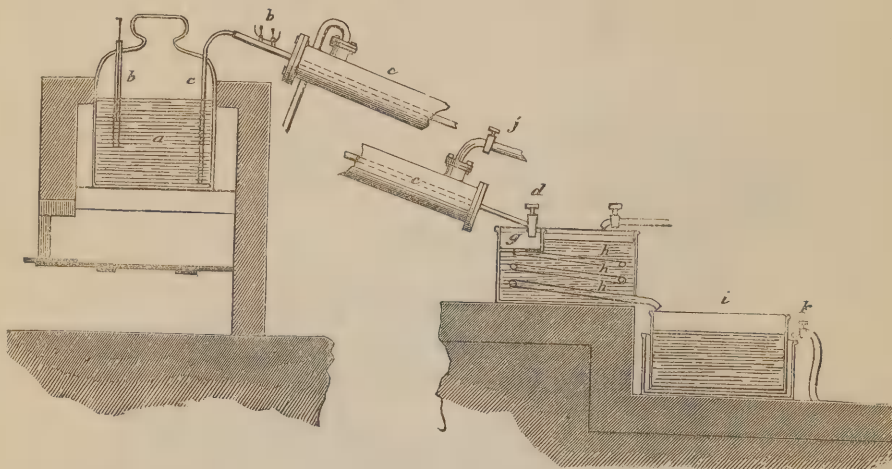
accident. The protector consisted of a sort of sheet-iron bell-jar, if such a term may be used; this bell-jar has a hole cut in the upper portion, so that the whole may be placed over a retort when in work, the neck of the retort protruding through this orifice, while the lower edge of this cover rested on the upper edge of the sand-pot. Such an arrangement effectually protects this part of the retorts from cold draughts, or drops of cold liquid, which, as may be easily imagined, are equally destructive. In fact, any cool or cold body coming in contact with the heated glass is fatal to it, causing much inconvenience; for not only is the retort itself destroyed, but the contents are lost, also creating the greatest annoyance and discomfort, for the vitriol trickles or runs out, and, coming in contact with the red-hot pot, is converted into vapor of a most suffocating kind, filling the whole place. This calamity is without remedy; and even though a remedy were to present itself, it would be impossible to enter the place, and apply it, without running considerable risk of suffocation.

These risks and drawbacks were doubtless the stimulants which brought out the platinum retort, this costly, but efficient substitute being safe from the casualties just described. This retort, with its appendages, is shown in Figs. 594 and 595. The former is a vertical section in front; *a*, is the body of the retort; *b*, the head; *c*, a platinum tube leading from the head to a

lead worm, which worm is kept immersed in water; *e* is a platinum funnel, the tube of which is S-shaped, to prevent the return of any vapor. The brown acid which is kept in the cistern, *f*, under which the waste heat passes, is run into the body of the retort without the aid of any tap or valve by means of the at-first sight rather complicated, but really simple apparatus shown in the figure, where *g* represents a round vessel in which a tube, *h*, is inserted very near to the bottom; *i* is another leaden vessel, which has a slit in the side

from the top nearly to the bottom, along which slit the tube, *h*, slides, when the vessel, *g*, is moved up or down by means of the chain and pulley. A siphon, which is kept constantly set, connects the stock cistern, *f*, with the vessel, *g*. The apparatus, when in the inactive state, as represented by the dotted lines, is as follows:—The siphon is full of vitriol, but the surface of the acid in the cistern being on a level with that in vessel *g*, no flow can take place; when the vessel, *g*, is lowered, the levels become altered; and as the leg of

Fig. 595.



the siphon, which is in vessel *g*, becomes the longer, the acid begins to run into this vessel, and from this into vessel *i*, and thence into the funnel.

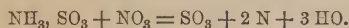
The other portions of the apparatus being at the back, are shown in Fig. 594, which is a side view; *a*, as before, is the body of the retort; *b*, is a platinum tube about three-fourths of an inch in diameter, in which a glass float is placed to indicate the depth of liquid in the still; *c*, is a siphon, also of platinum, of the same diameter as the tube just mentioned. This siphon is inclosed in an iron tube, *d*; between these two tubes a current of water can be passed. The siphon terminates in a platinum tap at *d*. The body of the still rests on a circular tile of refractory clay; the fire being below this tile, the flame rises at the back of the still, circulates round the sides, and finally passes from thence under the stock-pan. The course is shown in Fig. 595.

The mode of working this still is as follows:—The workman fills up his still a few inches above the highest point the flame is likely to reach; the fire is lighted and kept on until the contents are brought to boiling. The concentration then commences; vapor passes off through the head and conducting tube into the worm, where it again resumes the liquid form, running out into a vessel placed to receive it. This liquid is always acid, but at first it is very weak; it eventually reaches a density of 1.2400. When this strength is attained, the workman knows that the highest degree of concentration is arrived at. If the running-off siphon, *c*, is not set, he proceeds to do this by closing the tap, *d*. The two plugs are removed in the funnel, *f*, and the siphon is filled with vitriol; the plugs are replaced. It

now only remains to open the tap, when the contents of the still begins to run off. The tap is allowed to remain open, until from three to four inches of the still contents are drawn. The workman is guided in this by the indications of the glass float before spoken of, which serves as a gauge. The acid falls into the cup, *g*, thence it flows through the serpentine coil of pipe, *h, h, h*, which is immersed in water; and finally it emerges still slightly warm at the end of the coil, and runs into the receiving vessel, *i*, which vessel stands within another one, a stream of cold water from the tap, *k*, circulating between the two. The water tap, *j*, is also turned, when running off, so that a stream of cold water cools the siphon itself. When the operation is over, the workman proceeds to repeat the course of operations just described; he fills up his still to its former level, attends to his fire, heats it up to the proper point, and again allows the acid to run off.

Such an apparatus, the still itself having a capacity of from seventy to eighty gallons, is capable of producing thirty carboys of rectified oil of vitriol in twelve hours, two carboys being all that a glass retort could produce in twenty hours; but this of course is owing to the latter requiring such a length of time to elapse before its contents can be safely drawn off. A retort of the above dimensions, with the siphon and float case, costs about fifteen hundred pounds, the price varying according to the thickness of metal, and consequently weight of platinum, yet it is generally admitted to be a more economical plan of operating than the glass retort system. But it is not free from disadvantages; it is necessary to be careful that the vitriol contains no nitrous

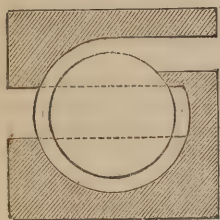
compound, for if this be the case, the platinum is rapidly attacked. To obviate this, it is usual to add a quantity of sulphate of ammonia to the acid, while in the leaden concentrating pan, before it enters the still; the action of this salt is to decompose the nitrous body usually existing in vitriol. It is supposed that the following is the decomposition which takes place, assuming nitrous acid to be the body present:—



This may occur in some cases, but it is not the invariable result. If a *little* sulphate of ammonia be dissolved in a small quantity of the nitrous vitriol of GAY-LUSSAC'S column, and the whole heated in a test tube, either NO_2 or NO_3 is evolved; nitrogen very probably is given off at the same time, but it is not the only body eliminated. When a rather large excess of sulphate of ammonia is employed, sulphide of hydrogen is formed in the still, and can be detected by the smell at the end of the condensing worm; undoubted evidence of its presence has been detected by means of lead paper. The only rule that can be laid down for guidance as to the quantity to be used, is the addition of an increased quantity of the salt each day until nitrous bodies cannot be detected in the finished vitriol; the workman at last obtains a good idea of the quantity to be added.

Sulphuric acid is brought to a saleable condition by the employment of one or other of the methods just described; but although these methods are universally employed, others have been proposed. The patentee who proposed to generate the steam necessary for the chamber by the combustion of the sulphur, also proposed to concentrate vitriol

Fig. 596.



or any other liquid by means of the heat from this source, hitherto, in the inventor's opinion, wasted. The idea is very ingenious, perhaps more so than practical; but it would appear to be doubtful whether it is possible to concentrate vitriol at all by this process. The probability is that the sulphur

would begin to sublime before the vitriol could be brought to the proper strength. The process is not in use in any part of the country, so that one may naturally infer that it is without practical value.

Perhaps the most ingenious proposal for the concentration of vitriol is the one about to be described, the prevailing principle of which is that of carrying over its surface streams of hot air, which, liberating and combining with the water, carries it off. The apparatus consists of two distinct portions, the one devoted to the production of highly heated air, and the other to the concentration. The former portion of the apparatus consists of a series of iron pipes, *a*—Fig. 597—set in brickwork; these tubes are heated externally by the flame of the furnace, *b*, the products of combustion from which pass up the space, *c*; they then descend and circulate round the tubes, finally making their exit into the main flue by means of the openings, *d*. The cold air

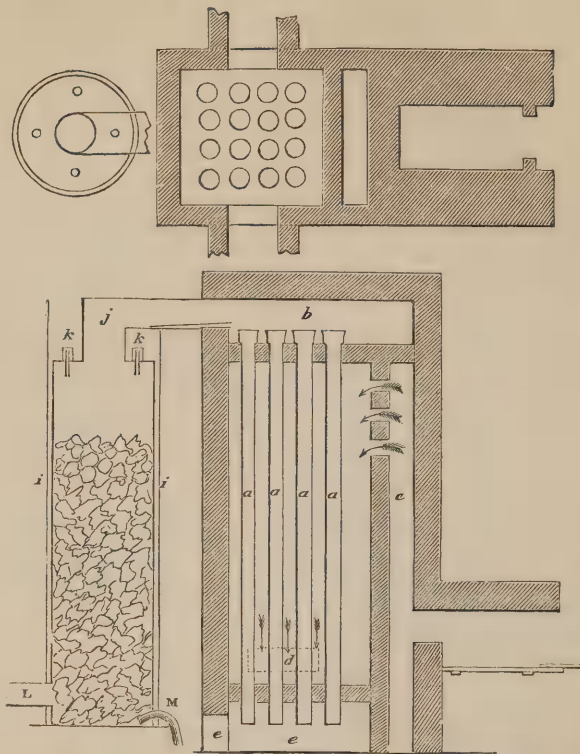
from without enters the lower ends of the tubes which project into the arched recess, *e*, passes up them, and, becoming highly heated during its progress, enters the space, *f*, and passes along the wide iron tube, *g*, and thence into the concentrator. The portion of the apparatus devoted to the concentration is constructed entirely of lead; it consists of two concentric cylinders, *h, h*, made of half-inch lead; *i i*, is a small space, the use of which will be explained hereafter, which exists between them; both cylinders are closed at the bottom by being fused on to one sheet of lead; the inner cylinder is partially closed at the top, space only being left for joining on the leaden tube, *j*, which is a continuation of the iron tube, *g*, spoken of before, and is for the conveyance of the heated air. The inner column or cylinder is filled with coke, or other suitable material, which offers a large surface for the acid to spread itself over, at the same time being unattacked by it. The following is the method of working this apparatus:—The opening into the arched recess from which the cold air is drawn must be closed, or if there be a damper or register beyond the concentrator between it and the chimney, this must be pushed in. The furnace must be heated up until the pipes and the chamber containing them are of a good red heat. This state of preparation having been arrived at, the vitriol to be concentrated must be run on to the top of the inner cylinder; it runs down and fills up the space existing between the two cylinders, rising up to the mouths of and running down the tubes, *k, k*; these tubes are covered with lead caps, the bottom edge of these being immersed in the vitriol from an air-tight joint, which prevents any cold air being drawn in. The vitriol on flowing through these tubes spreads itself over the whole surface of the coke, wetting it thoroughly. When sufficient vitriol has been run in to saturate the whole of the coke, the hot-air current is allowed to enter it, penetrates every space and crevice in the mass, and heating the vitriol up to a high point, carries off its water finally when saturated, making its exit into the chimney by means of the wide tube or pipe, *l*. The vitriol becomes more and more concentrated, the nearer it approaches the lower part of the cylinder. When it has arrived at this point, if the amount of acid and hot air have been proportioned to each other, it will be found to be fully concentrated. It collects in a stratum at the bottom, until the surface rises sufficiently high to flow off into a proper reservoir or cistern through a bent tube, *m*. The use of the double cylinder has two advantages—it heats the sulphuric acid somewhat, previous to its admission into what may be called the concentrator proper; and also keeps the latter cool, or rather lessens the risk of its fusing if too great a heat should be employed.

The apparatus in the form just described, though capable of concentrating vitriol, cannot be said to be a success. The fusion of the lead in the upper portion was the weak point in this invention; in order to work the apparatus with practical efficiency, it was necessary to have the air highly heated, in fact the current of air may be said to have been red hot. Under these circumstances it was almost impossible to avoid the fusion of the lead tube which conveyed the hot air from

the heater. This great difficulty, combined with some minor ones which, however, might be obviated, caused the inventor to relinquish the idea. Although not an

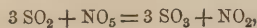
invention or process capable of being carried on in its present shape, yet, in the hands of a patient operator, it might be made to yield better results. It would

Fig. 597.



probably be a work of no little trouble and expense, yet if the anticipated result could be obtained, it would amply repay any trouble or expense that might be expended upon it.

Proposed Improvements in Manufacturing Sulphuric Acid.—The efforts of inventors in connection with sulphuric acid, would appear to have been directed to the substitution of some apparatus of smaller bulk, and less costly in construction, than the leaden chambers ordinarily employed. Perhaps the simplest process embodying the above idea is that of Messrs. M'DOUGALL and RAWSON, who included it in a patent obtained by them in 1848. It consists essentially in passing a stream of sulphurous acid gas through nitric acid by which sulphuric acid and binoxide of nitrogen— NO_2 —are obtained as follows:—



but the great point of the process is the continual conversion and reconversion of this NO_2 into nitric acid, to be again used as before. The inventors say, that the reaction which ensues may be best described by symbols. Thus when 3NO_4 —the NO_2 evolved in the first reaction becoming NO_4 by combining with the excess of oxygen, which as atmospheric air accompanies the sulphurous acid—is passed into water at a temperature of 100° , or upwards, $2 \text{NO}_5 + \text{NO}_2$ results. This NO_5 —or, two atoms of nitric acid—remains in solu-

tion, while the NO_2 , which is an incondensable gas, bubbles through the liquid, and, mixing with the air which is above the liquid, instantly takes two atoms of oxygen from it, and becomes NO_4 ; which, passing again through the liquid, becomes nitric acid and nitrous gas as before: and thus nearly the whole of the nitrous fumes or gas is reconverted into nitric acid. It should be observed that the use of this reaction is claimed in connection with several processes, such as the manufacture of oxalic acid, *et cetera*; but with regard to sulphuric acid, they further say—In our improved method of manufacturing sulphuric acid, we use a series of vessels, similar to that described in the first part of our invention—a modification of Woulfe's bottles, in fact—only that the first vessel of the series is connected with a sulphur burner. The mode of working is to fill the first vessel two-thirds full of nitric acid, and all the others one-third full of water, to charge the burner with sulphur, and then to put in motion the pneumatic apparatus connected with the last vessel of the series. Air is thus drawn over the ignited sulphur, so that sulphurous acid and air pass into a solution of nitric acid in the first vessel, when a portion of the sulphurous acid is converted with sulphuric acid, at the expense of the nitric acid; while the uncondensed sulphurous acid passes into the air, and nitrous gas into the next vessel; and so, as in the first part of the invention, we pass it alternately into water and air, till

the processes of oxidation and condensation are complete. When the working has been continued for some time, we find that the nitric acid has entirely passed from the first vessel, and we have in its place sulphuric acid nearly pure. The same would take place with each of the other vessels of the series, if the nitric acid which has been condensed in the vessels lower in the series, was not again returned to the higher ones, so that when we find the first vessel exhausted of its nitric acid, we remove the sulphuric acid which it contains, and supply it again with nitric acid, obtained from vessels lower in the series. We thus produce sulphuric acid without the loss of nitric acid; as the lower oxides of nitrogen, given off in the oxidation of sulphuric acid, are again converted into the higher oxides, and again used for the conversion of sulphurous acid into sulphuric.

The principle embodied in this process, namely, the perfect recovery of the nitric acid, has been the prevailing idea of many inventors. Some of the other processes to be described are based on the same reaction. About the same time as the date of the above patent, an ingenious modification of their process was being experimented on, of which the following description is an outline:—The apparatus consisted of a burner for the production of sulphurous acid, and an ingenious substitute for the WOLFE'S bottles of the last-described process. The burner, *a*—Fig. 598—consisted of an iron chamber, closed up tight, with the exception of an inlet pipe for the admission of air for combustion, and an exit pipe for the sulphurous acid, proper means being allowed for the introduction of the sulphur. The condensing or the conversion part of the apparatus consisted of two leaden troughs or cisterns; but, as they were exact counterparts of each other, a description of one will suffice. This trough, shown in section in the figure, has, what may not be inappropriately called a false top, *b*, a few inches below the real top, *c*. This false top, which was to all intents a sort of shelf, had borders or edges soldered on to it in such a manner that had it been taken out and laid down with its under side upwards, it would have resembled a large, shallow, square dish. This shelf, as just stated, was fastened inside the cistern, within a few inches of the top, and in an inclined

To work this apparatus the two cisterns were first filled with water or weak vitriol, and the vessel, *d*, was filled with nitric acid; a quantity of sulphur was introduced into the burner, and a coal fire ignited beneath it; a stream of air was then turned on through the tube shown in front of the burner, this stream of air being supplied by a pair of bellows, or other suitable apparatus; when the burner attained a sufficiently high temperature, the sulphur ignited; sulphurous acid became generated; this proceeded along the pipe, *e*, and was discharged beneath the shelf, *b*. At this point it was met by a small stream of nitric acid, which trickled from the vessel, the gases rolled beneath the shelf, and from thence beneath the shelf of the second vessel. The reactions, it is scarcely necessary to observe, must have been precisely the same as those in the last-described process; the gases in this case being kept continually in contact with both air and water, and not alternately, as in the former case.

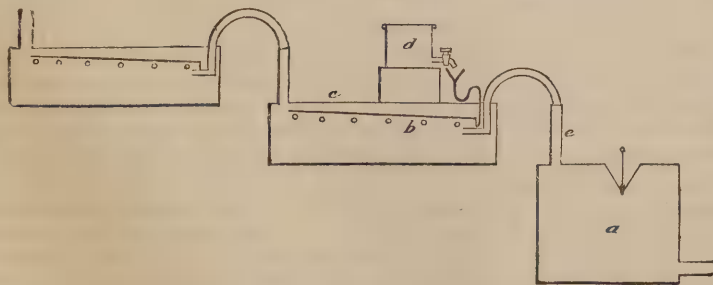
If, in the instances last given, the recovery and *ad infinitum* use of the nitrous gas has been the object, other methods have been invented or discovered by which the use of this body is proposed to be dispensed with altogether. In this latter class of projects, the oxidation of the sulphurous acid has been sought to be effected by the use of some catalytic agent, no cheap chemical body of an oxidizing character having presented itself capable of successfully rivalling the nitrates. The use of spongy platinum, in consequence of its possessing the requisite property in a high degree, naturally was the first suggestion. PARNELL says this was attempted by Mr. PEREGRINE PHILLIPS. His process consisted in simply mixing the sulphurous acid with excess of oxygen in the shape of atmospheric air, and passing this mixture over balls of spongy platinum at a red heat. The combination took place, and the vapor was received and brought to a liquid state by means of a condenser, like those already described, consisting of a column filled with pebbles, kept constantly wet by a stream of water.

Eventually it was discovered that platinum was not the only body adapted to the purpose; other porous materials, it was found, were capable of effecting the desired union of oxygen and sulphurous acid; for SCHNEIDER states that he has succeeded in converting sulphurous acid directly into sulphuric acid by means of a porous body, for instance, pumicestone, and that this process may be employed for manufacturing sulphuric acid of 170° Twaddell, without the necessity of leaden chambers or of platinum retorts. This has the advantage of being an immeasurably cheaper material although it can scarcely be so active.

M. BLONDEAU describes another process of the same

nature as the last. The author has studied the production of sulphuric acid in certain natural conditions. He instances the Rio Vinagre Pasiambo in

Fig. 598.



position, so that one end was rather higher than the other by about two inches, thus giving it a gentle slope—the use of this will be seen when describing its action.

South America, the water of which, he says, according to an estimate of BOUSSINGAULT, supplies something like thirty-four tons of sulphuric acid in twenty-four hours; and also another instance in which three times this quantity was produced. M. BLONDEAU also examined the production of certain natural sulphates, such as those of potassa, soda, alumina, *et cetera*, and the conditions under which they are produced. Reasoning from his observations, he was induced to try whether certain natural conditions, under which sulphuric acid was produced, could not be imitated in the laboratory; he succeeded in the following manner:—A quantity of argillaceous sand was placed in a porcelain tube laid across a furnace, an apparatus for generating sulphurous acid was attached to one end, together with a tube from a gasometer containing air, and a retort for generating steam. A tube was attached to the other end of the retort, which led into a small vessel containing water, for the purpose of condensing any sulphuric acid which might be formed. The tube was heated red hot, and a slow stream of mixed air, steam, and sulphurous acid was passed through it. At the end of the experiment a quantity of sulphuric acid was found in the condensing flask. M. BLONDEAU suggests this as a mode of making sulphuric acid on the large scale.

WÖHLER has given us the results of some interesting experiments on the production of sulphuric acid by the instrumentality of certain metallic oxides, some acting catalytically, others as simple oxides, yielding up a portion of their oxygen, themselves being converted into lower oxides. He passed a mixture of sulphurous acid and oxygen over several metallic oxides placed in a porcelain tube, and kept at a red heat; but he does not say whether he passed water vapor simultaneously with them. He says that oxide of copper, sesquioxide of iron, and oxide of chromium, each separately employed, instantly caused the production of dense white fumes of sulphuric acid. A mixture of oxide of copper and oxide of chromium, prepared by precipitation, had in particular a very energetic action. The same amount of oxide appeared capable of converting an indefinite quantity of the gases into sulphuric acid. He goes on to say that the production of sulphuric acid proceeds so readily that the process will undoubtedly become practically employed. When sulphurous acid alone is passed over oxide of copper or iron, the first is reduced to red oxide— Cu_2O —and the latter to black oxide— Fe_3O_4 —with production of sulphuric acid vapors; but which, however, cease to appear as soon as the reduction is complete. WÖHLER gives the reaction of several other bodies; he also states that sulphurous acid, oxygen, and water vapor, passed through a tube alone, do not give rise to any sulphuric acid.

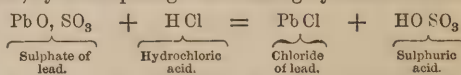
These ideas of WÖHLER appear not to have passed without notice, but on the contrary have been most unceremoniously claimed and patented.

Mr. G. ROBB, in a patent which he obtained, March 26th, 1853, proposes passing sulphurous acid and heated air over the surface of heated sesquioxide of iron—sulphuric acid is the product. He proposes also to take up the sulphuric acid as formed, by passing sulphurous acid mixed with air over a mixture of sesquioxide of iron and common salt—sulphate of soda is formed.

ALFRED TRUEMAN obtained a patent for improvements in the manufacture of sulphuric acid when roasting copper ores, *et cetera*. This invention consists in passing the sulphurous acid resulting from the roasting copper ores, mixed with oxygen, atmospheric air, or other suitable material containing oxygen, in contact with heated *platinum, oxide of iron*, or other substance, having in a heated state the property of causing the combination of sulphurous acid and oxygen. The inventor also claims these bodies when diffused in burnt clay, pumicestone, or other suitable body.

Another process proposed for the manufacture of sulphuric acid is that of M. MARGUERITTE. It is entirely different from any yet described; it consists essentially in the separation of the already formed sulphuric acid from sulphate of lime. It is as follows:—Phosphate of lead is decomposed by hydrochloric acid; the phosphoric acid thus obtained is mixed with sulphate of lime, and the mass is calcined, when phosphate of lime remains and sulphuric acid is expelled. The phosphate of lime is decomposed by boiling with the chloride of lead already obtained, when phosphate of lead is again produced; this is again decomposed by hydrochloric acid, and the phosphoric acid set free again employed in the decomposition of a fresh portion of sulphate of lime. In this process the hydrochloric acid is lost in the form of chloride of calcium. It must consequently always be replaced, but when the sulphuric acid produced is employed in the decomposition of common salt for the production of sulphate of soda, the necessary quantity of hydrochloric acid is always reproduced, with the exception of unavoidable losses. By this process sulphuric acid may be separated from sulphate of baryta and other sulphates. He then proceeds to state that, if necessary, quantities of hydrochloric acid may be obtained from chloride of magnesium by heating it to redness when it is decomposed, especially when mixed with clay. This process is, however, not very likely to come into operation; it would require more hydrochloric acid than the author appears to calculate upon. If the composition of bone earth were CaO PO_3 , there would be a possibility of making vitriol by the reproduced hydrochloric acid.

Sulphate of lead has been patented for the same purpose, by decomposing it with strong hydrochloric acid—

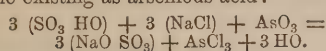


Impurities in Sulphuric Acid.—Sulphuric acid of commerce invariably contains lead. It is not difficult to account for the presence of this body when one reflects how much the acid is in contact with this metal in the chambers, concentrating pans, *et cetera*. Lead always makes its appearance as sulphate when strong acid is diluted with water, the concentrated liquid being able to dissolve a portion of this salt which, when diluted, it is not able to retain. Nitrous compounds are found also, together with traces of hydrochloric acid. Traces of selenium have also been detected. Arsenic is a common impurity, derived usually from the iron pyrites, from which much acid is made. Traces of arsenic have also been detected even in vitriol made from commercial sulphur. Sesquisulphate of iron has also

been found to be present. For the great majority of purposes these impurities are not found inconvenient in the arts; while, on the other hand, for some special uses, a process of purification must be had recourse to.

Purification.—When this is required for analytical or other purposes, distillation must be had recourse to. This, in the case of sulphuric acid, is a disagreeable process, not altogether free from danger, from the violent concussions occurring in the retort. It is usual to put a quantity of strips or fragments of platinum into the acid to obviate this bumping. A very simple condensing arrangement is necessary. The beak of the retort merely requires insertion rather loosely into the neck of a flask or wide tube.

For the purification of sulphuric acid from peroxide of nitrogen, nitric, or arsenious acids, Dr. J. Löwe recommends heating it, in the first place, with oxalic acid. This acid, heated with strong sulphuric acid, becomes first dehydrated, and then, as is well known, decomposes. Carbonic acid and carbonic oxide gases are given off. This carbonic oxide, being in the nascent state, has a strong tendency to deoxidize any highly oxidized body; therefore the peroxide of nitrogen and nitric acid give up a portion of their oxygen, becoming reduced to nitrogen, or nitrous oxide—NO—which bodies are not capable of being retained by the sulphuric acid, and therefore fly off. A temperature of 230° is requisite; at this heat the oxalic acid readily decomposes; it is added to the sulphuric acid, to be purified in small proportions in a dry state, as long as the sulphuric acid continues of a yellow tinge, and until a sample allowed to cool fails to show the presence of nitrous compounds, when heated with protosulphate of iron. The same author proposes eliminating the arsenic from sulphuric acid by converting it into chloride of arsenic, which is very volatile. The vitriol is heated in a flat dish, and small quantities of finely powdered chloride of sodium are added, stirring all the while with a glass rod. The arsenic passes off; the following being the reaction, the arsenic existing as arsenious acid:—



The operation must be conducted under a chimney, or other place where the arsenical fumes will be instantly carried off, so as not to injure the operator.

To avoid the troublesome and dangerous process of distillation, AUGUSTUS A. HAYES proposes to purify sulphuric acid in a very simple manner, namely, by crystallizing it. He first adds a small quantity of saltpetre to the acid while hot, in the leaden pan, and at a density if cold of 1·760. This destroys all organic matter, brownness disappears, and the acid becomes clear. A little sulphate of ammonia is now added, to destroy any excess of nitrate, as well as any nitrous compound already existing in it. The acid is now concentrated to a density of 1·780, and run off into deep vessels of lead, which are allowed to cool to a temperature of 32°; they stand so until clear; they are then run off into shallow lead vessels, so placed that they may become refrigerated to 0°. The acid, which has now nearly the composition $\text{SO}_3 \cdot 2 \text{HO}$, would solidify if allowed to remain long enough; but the vessels must stand only until one half the bulk has

assumed the crystalline state; the mother liquid is then poured off. This mother liquid may be used for any ordinary purposes, such as the decomposition of nitrates, common salt, *et cetera*. The crystals are broken up after being washed with pure acid of a former operation, and are fused in a glass or porcelain vessel, when they form pure sulphuric acid.

Detection and Estimation of Sulphuric Acid.—Sulphuric acid is detected by means of a salt of baryta—this earth being capable of separating it from almost any combination, forming with it sulphate of baryta. In some cases, when testing for sulphuric acid, it is necessary to be very cautious; for instance, when endeavoring to ascertain its presence or otherwise in the nitric or hydrochloric acid of commerce, it is necessary to dilute these acids before adding a salt of baryta. If this is not done the nitrate of baryta, or chloride of barium, will itself be thrown down as a crystalline precipitate, liable to be mistaken for sulphate of baryta; but, if so, the addition of water to the precipitate will cause it to disappear, which will not be the case if the precipitate is sulphate of baryta. This latter salt, being very insoluble in water, furnishes us with a correct method of estimating sulphuric acid; for this purpose a weighed portion of the acid or any of its salts is placed in a beaker glass, and diluted with or dissolved in water. If it is a sulphate, the solution should be made *slightly acid* with nitric or hydrochloric acid, but if it is sulphuric acid alone that is being examined this addition is unnecessary; in either case the liquid is boiled, and, while boiling, a solution of chloride of barium or nitrate of baryta is poured in; the whole is allowed to boil a little longer, when it is removed to cool and settle. A little of the clear liquid above the precipitate is then tested, by the addition of a fresh portion of the baryta salt. If a precipitate is produced, it shows that all the sulphuric acid has not been thrown down, in which case it is necessary to add more of the barytic solution and boil again; if, after settling and further addition of baryta, no precipitate is produced, the whole must be thrown on to a filter, washed carefully with hot water, and dried. It is then ignited in a platinum or porcelain crucible and weighed; 116·6 parts, or one equivalent of sulphate of baryta, are equal to forty-nine parts, or one equivalent of monohydrated sulphuric acid, or forty parts of anhydrous acid. This method would be found too tedious to follow, except on special occasions; ordinarily the manufacturer relies on the indications of his hydrometer—that is, he takes the density for his guide. To enable us to arrive at the real value of the sulphuric acid from the density, several tables have been drawn up, of these. Dr. URE's is commonly used.

AMOUNT OF DRY ACID IN SULPHURIC ACID.

$\text{SO}_3 \text{ HO}$.	Specific gravity.	SO_3 .
100	1·8485	81·54
99	1·8475	80·72
98	1·8460	79·90
97	1·8439	79·09
96	1·8410	78·28
95	1·8376	77·46
94	1·8336	76·65
93	1·8290	75·83
92	1·8233	75·02
91	1·8179	74·02
90	1·8115	73·39

AMOUNT OF DRY ACID IN SULPHURIC ACID—*Continued.*

SO ₃ HO	Specific gravity.	SO ₃
89	1·8043	72·57
88	1·7962	71·75
87	1·7870	70·94
86	1·7774	70·12
85	1·7673	69·31
84	1·7570	68·49
83	1·7465	67·68
82	1·7360	66·86
81	1·7245	66·05
80	1·7120	65·23
79	1·6993	64·42
78	1·6870	63·60
77	1·6750	62·78
76	1·6630	61·97
75	1·6520	61·15
74	1·6415	60·34
73	1·6321	59·52
72	1·6204	58·71
71	1·6090	57·89
70	1·5975	57·08
69	1·5868	56·26
68	1·5760	55·45
67	1·5648	54·63
66	1·5503	53·82
65	1·5390	53·00
64	1·5280	52·18
63	1·5170	51·37
62	1·5066	50·55
61	1·4960	49·74
60	1·4860	48·92
59	1·4760	48·11
58	1·4660	47·29
57	1·4560	46·48
56	1·4460	45·66
55	1·4360	44·85
54	1·4265	44·03
53	1·4170	43·22
52	1·4073	42·40
51	1·3977	41·58
50	1·3884	40·77
49	1·3788	39·95
48	1·3697	39·14
47	1·3612	38·32
46	1·3530	37·51
45	1·3440	36·69
44	1·3345	35·83
43	1·3255	35·06
42	1·3165	34·25
41	1·3080	33·43
40	1·2999	32·61
39	1·2913	31·80
38	1·2826	30·98
37	1·2740	30·17
36	1·2654	29·35
35	1·2572	28·54
34	1·2490	27·72
33	1·2409	26·91
32	1·2334	26·09
31	1·2260	25·28
30	1·2184	24·45
29	1·2108	23·65
28	1·2032	22·83
27	1·1956	22·01
26	1·1876	21·20
25	1·1792	20·38
24	1·1706	19·57
23	1·1626	18·75
22	1·1549	17·94
21	1·1480	17·12
20	1·1410	16·31
19	1·1330	15·49
18	1·1246	14·68
17	1·1165	13·86
16	1·1090	13·05
15	1·1019	12·23
14	1·0953	11·41
13	1·0887	10·60
12	1·0809	9·78
11	1·0743	8·97
10	1·0682	8·15
9	1·0614	7·34
8	1·0544	6·52
7	1·0477	5·71
6	1·0405	4·89

AMOUNT OF DRY ACID IN SULPHURIC ACID—*Continued.*

SO ₃ HO	Specific gravity.	SO ₃
5	1·0336	4·08
4	1·0268	3·26
3	1·0206	2·45
2	1·0140	1·63
1	1·0074	0·82

In this table there is opposite a list of different densities, the quantity of dry acid per cent., either dry or monohydrated. To bring the degrees of TWADDELL'S hydrometer to those of the real specific gravity, it is only necessary to multiply the first by five, and add one thousand; thus, supposing a sample of vitriol to stand 150° on TWADDELL'S hydrometer, multiply this 150° by 5°, and one has 750°; to this add 1000°, and the specific gravity, 1·750° is obtained. Now, to ascertain the amount of real sulphuric acid in this sample, it is only necessary to run through the table and find the density 1·750°, or the nearest approach to it, which in this case is 1·746°. It will be found then that the sample would contain eighty-three per cent. of the monohydrated acid, or 67·68 per cent. of dry acid.

This method of arriving at the value of a sample, though very convenient, is liable to error; for instance, the sample might contain foreign matter dissolved in it; this would augment the density, and cause it to appear of more value than it really is. A slight change of temperature also will alter the density considerably. The following table, the production of Mr. PARKES, shows the gradual lowering of the density as the temperature increases, so that, even though the sample may be free from foreign bodies, error may creep in. From this table it is evident, that the density of all samples of vitriol should be taken, as in the case of Dr. URE'S table, at as near as possible 60°.

PARKE'S TABLE OF VARIATIONS IN DENSITY OF CONCENTRATED SULPHURIC ACID THROUGH CHANGE OF TEMPERATURE.

Temperature Fahrenheit.	Density.
30°	1·8593
32	1·8563
36	1·8546
38	1·8532
40	1·8527
42	1·8520
44	1·8522
46	1·8519
48	1·8517
52	1·8511
56	1·8500
60	1·8468
63	1·8449
68	1·8435
70	1·8430
74	1·8413
80	1·8381
84	1·8343

Again, when the density of a sample is high, it is difficult to estimate it with sufficient accuracy. If one examine Dr. URE'S table, he will find that acid of 1·8439 specific gravity contains ninety-seven per cent. of monohydrated acid, while the density of the monohydrated acid itself is but 1·8485—thus the slight difference of ·0046, or rather less than one degree on the hydrometer, equals three per cent. To obviate this, Dr. DALTON proposed that the boiling point should be taken as the guide, instead of the specific gravity, inasmuch as it permits a range of ten or twelve degrees for one per cent. of real acid. For this purpose he drew up the following table:—

DR. DALTON'S TABLE OF BOILING POINTS OF SULPHURIC ACID AT DIFFERENT STRENGTHS.

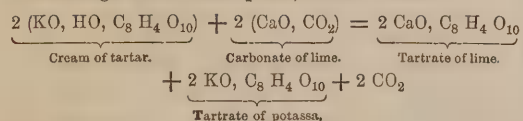
Specific gravity.	Dry acid per cent.	Boiling point.
1.850	81	620°
1.849	80	605
1.848	79	590
1.847	78	575
1.845	77	560
1.842	76	545
1.838	75	530
1.833	74	515
1.827	73	501
1.819	72	487
1.810	71	473
1.801	70	460
1.791	69	447
1.780	68	435
1.769	67	422
1.757	66	410
1.744	65	400
1.730	64	391
1.715	63	382
1.699	62	374
1.684	61	367
1.670	60	360
1.650	58.6	350
1.520	50	290
1.408	40	260
1.300	30	240
1.200	20	224
1.100	10	218

In addition to these methods, there may be mentioned that of testing the value of vitriol by an acidimetric process, with a standard solution of alkali.

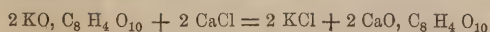
Mr. PETER HART, of Manchester, kindly supplied some valuable information which the Editor has incorporated in this monograph.

TARTARIC ACID— $2\text{HO}, \text{C}_8\text{H}_4\text{O}_{10}$ —*Acide tartarique*, French, *Weinsteinsäure*, German—was first obtained in a separate state by SCHEELÉ in 1770. It is found partly free, partly combined with bases in many plants. It exists most largely in grape-juice, but it is met with also in tamarinds, and the berry of the mountain ash; in madder, potatoes, cucumbers, quassia, squills; in mulberries, pine apples, *et cetera*.

Preparation.—In order to prepare the acid, four parts of crude tartar—*argol*—are suspended in boiling water, and one part of chalk added. As soon as the effervescence entirely ceases, and the liquid no longer reddens litmus, the tartrate of lime is allowed to settle at the bottom, and the clear tartrate of potassa decanted. The change which takes place, is as follows:—

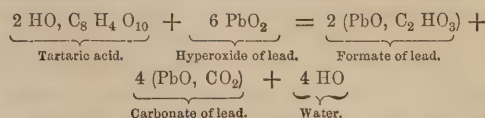


The dissolved tartrate of potash may be further decomposed by chloride of calcium: thus—

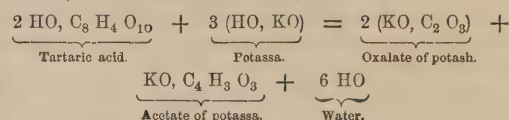


The well-washed precipitates are digested with sulphuric acid diluted with ten parts of water, five parts of the tartar employed requiring three parts of the acid. Sulphate of lime is formed, and tartaric acid set free. On evaporating the filtered solution in leaden vessels to the consistence of sirup, tartaric acid crystallizes in large, transparent, colorless, oblique rhombic prisms of agreeable sour taste, and specific gravity 1.75; is readily soluble in water and alcohol; unalterable in air. When greatly heated, the crystals become strongly electrical.

Boiled with nitric acid, tartaric acid is decomposed into acetic, oxalic, and saccharic acids. Boiled with hyperoxide of lead, it becomes oxidized and changed into formate of lead, water, and carbonate of lead, thus—



If heated with alkalis, a mixed oxalate and acetate results, with evolution of water, thus—



Mixed with spongy platinum and heated in a stream of oxygen, tartaric acid is at 482° completely resolved into carbonic acid and water.

The action of heat upon tartaric is as instructive as it is remarkable.

It melts between 338° and 356° , and without losing weight is changed into a mixture of two acids—metamerie with tartaric acid.

METATARTARIC ACID— $\text{C}_8\text{H}_5\text{O}_{12}$; or $2\text{HO}, \text{C}_8\text{H}_4\text{O}_{10}$ —forms a transparent vitreous mass. It is bibasic, but its salts are more soluble than the corresponding ones of tartaric acid.

ISOTARTARIC ACID— $\text{HO}, \text{C}_8\text{H}_5\text{O}_{11}$ —is monobasic. Its salts are isomeric with the bitartrates, but very much more soluble. Solutions of isotartrates as well as of metatartrates are changed by boiling into tartrates.

If tartaric acid be heated to 374° it fuses: two equivalents lose one equivalent of water and become changed into an acid, called by FRÉMY, **TARTRALIC ACID**— $3\text{HO}, \text{C}_{16}\text{H}_2\text{O}_{20}$.

If the heat be still longer continued tartaric acid loses half its basic water and becomes **TARTRELIC ACID**— $2\text{HO}, \text{C}_{16}\text{H}_8\text{O}_{10}$.

Most probably both tartralic and tartrellic acids are mere combinations of anhydrous tartaric acid with varied proportions of crystallized tartaric acid.

If the heat— 374° —be carefully maintained for yet a longer time, **ANHYDROUS TARTARIC ACID** or **TARTARIC ANHYDRIDE** remains in form of a white, porous mass insoluble in water. Adherent tartrellic acid is removed by washing with water till the wash liquor no longer reddens litmus. By contact with cold water for a few hours anhydrous tartaric acid resumes its basic water.

Small quantities of tartaric acid are completely decomposed in an oil-bath at 512° , leaving only a slight carbonaceous residue.

Tartaric acid is much used by dyers and calico-printers for the removal of certain mordants from portions of the cloth. It is also used in preparing effervescing draughts. In the blood, tartrates are changed into carbonates.

Aqueous solutions of tartaric acid, especially when hot, exercise right-handed rotation upon polarized rays of light—the angle of deviation corresponds to the quantity of acid traversed by the ray.

Tartaric acid is *bibasic*; its salts are tartrates.

BITARTRATE OF POTASSA— KO , HO , $\text{C}_8\text{H}_4\text{O}_{10}$ —is the *cream of tartar* or *argol* of commerce, and is obtained chiefly as an incrustation from the inside of wine casks. It crystallizes in hard, opaque, oblique rhombic prisms, of snowy whiteness when pure, and of sour taste; soluble in one hundred and eighty parts of cold and six of boiling water; in alcohol nearly insoluble. Heated to redness in close vessels, a mixture of carbonate of potassa and charcoal results—much used as *black flux*. Calcined with its own weight of nitre, *white flux*, or carbonate of potassa, is obtained.

NEUTRAL TARTRATE OF POTASSA— 2KO , $\text{C}_8\text{H}_4\text{O}_{10}$ —by slow evaporation in transparent, colorless prisms, somewhat deliquescent, and very soluble.

BITARTRATE OF SODA— NaO , HO , $\text{C}_8\text{H}_4\text{O}_{10}$, 2HO —in transparent, colorless, right rhombic prisms, from a hot solution of the neutral salt, mixed with half its weight of tartaric acid.

NEUTRAL TARTRATE OF SODA— 2NaO , $\text{C}_8\text{H}_4\text{O}_{10}$, 4HO —soluble in five of cold and half their weight of boiling water. In transparent, colorless, right rhombic prisms.

NEUTRAL TARTRATE OF POTASSA AND SODA— KO , NaO , $\text{C}_8\text{H}_4\text{O}_{10}$, 8HO —is *Rochelle salt*, obtained by neutralizing cream of tartar with carbonate of soda. In large, transparent, colorless, right rhombic prisms, soluble in 2.62 parts of water at 42° . The salt is medicinal.

BITARTRATE OF LITHIA— LO , HO , $\text{C}_8\text{H}_4\text{O}_{10}$, 3HO —in small crystals, very soluble in water.

NEUTRAL TARTRATE OF LITHIA— 2LO , $\text{C}_8\text{H}_4\text{O}_{10}$ —white, opaque, deliquescent.

BITARTRATE OF AMMONIA— NH_4O , HO , $\text{C}_8\text{H}_4\text{O}_{10}$ —in delicate needles, but little soluble in water. The crystals are in form of oblique rhombic prisms.

NEUTRAL TARTRATE OF AMMONIA— $2\text{NH}_4\text{O}$, $\text{C}_8\text{H}_4\text{O}_{10}$ —in oblique prisms, readily soluble, and with a taste like that of nitre.

NEUTRAL TARTRATE OF POTASSA AND AMMONIA— KO , NH_4O , $\text{C}_8\text{H}_4\text{O}_{10}$ —in transparent, colorless prisms, isomorphous with neutral tartrate of potash.

NEUTRAL TARTRATE OF BARYTA— 2BaO , $\text{C}_8\text{H}_4\text{O}_{10}$ —a crystalline powder, soluble in eight hundred parts of cold water.

NEUTRAL TARTRATE OF STRONTIA— 2SrO , $\text{C}_8\text{H}_4\text{O}_{10}$, 8HO —soluble in one hundred and forty-seven parts of water at 60° .

BITARTRATE OF LIME— CaO , HO , $\text{C}_8\text{H}_4\text{O}_{10}$ —in the fruit of *Rhus typhinum*, in crystals, sparingly soluble in water.

NEUTRAL TARTRATE OF LIME— 2CaO , $\text{C}_8\text{H}_4\text{O}_{10}$ —occurs in grapes, and mixed with crude tartar; also in senna leaves. Neutral tartrate of potassa forms, with chloride of calcium, a crystalline precipitate—it is the salt obtained in making tartaric acid. Crystals, right rhombic prisms with octahedral summits; soluble in twelve hundred parts of cold water.

BITARTRATE OF LIME— CaO , HO , $\text{C}_8\text{H}_4\text{O}_{10}$ —in the fruit of *Rhus typhinum*. The crystals dissolve in one hundred and forty parts of water and reddens litmus.

NEUTRAL TARTRATE OF MAGNESIA— 2MgO , $\text{C}_8\text{H}_4\text{O}_{10}$, 8HO —obtained by digesting excess of magnesia alba in dilute tartaric acid. Crystalline crusts

soluble in one hundred and twenty-two parts of cold water. Like tartrate of lime, the residue by ignition is pyrophoric.

BITARTRATE OF MAGNESIA— MgO , HO , $\text{C}_8\text{H}_4\text{O}_{10}$ —when excess of acid is employed. Six-sided prisms soluble in fifty-two parts of cold water.

TARTRATE OF ALUMINA occurs in *Lycopodium clavatum*. Very soluble.

TARTRATE OF LEAD— 2PbO , $\text{C}_8\text{H}_4\text{O}_{10}$ —by precipitating neutral acetate of lead with tartaric acid. A white crystalline powder, almost insoluble in water.

PROTOTARTRATE OF IRON is made from iron filings and dilute tartaric acid, with exclusion of air. A white powder requiring four hundred and twenty-six parts of cold water for solution. It is said to contain thirteen per cent. of water.

PERTARTRATE OF IRON, by dissolving the freshly prepared hydrated peroxide of iron in solution of tartaric acid. Its solution is not precipitated by alkalis.

POTASSO-TARTRATE OF IRON— KO , Fe_2O_3 , $\text{C}_8\text{H}_4\text{O}_{10}$ —is an important medicinal salt. It is obtained by digesting the hydrated sesquioxide of iron with water, and bitartrate of potassa at 125° for twenty-four to thirty-six hours, and evaporating the residue on plates. In lustrous scales of dark brown color.

AMMONIO-TARTRATE OF IRON— NH_3 , Fe_2O_3 , $\text{C}_8\text{H}_4\text{O}_{10}$, 4HO . Made like the previous salt, with substitution of bitartrate of ammonia. It is quite stable in composition when its solution is boiled.

TARTRATE OF COPPER— 2CuO , $\text{C}_8\text{H}_4\text{O}_{10}$, 6HO —by precipitation of acetate of copper with tartaric acid. A very light blue powder, soluble in one thousand seven hundred parts of cold water.

POTASSO-TARTRATE OF COPPER— KO , CuO , $\text{C}_8\text{H}_4\text{O}_{10}$ —by boiling oxide of copper in solution of cream of tartar. Crystals dark blue; very soluble.

TARTRATE OF SILVER— 2AgO , $\text{C}_8\text{H}_4\text{O}_{10}$ —by mixing neutral tartrate of potash or Rochelle salt with nitrate of silver. A white, crystalline, lustrous powder; gently heated, spongy silver remains, with evolution of pyrotartaric and carbonic acids.

POTASSO-TARTRATE OF ANTIMONY— KO , SbO_3 , $\text{C}_8\text{H}_4\text{O}_{10}$, HO —is extensively used in medicine under the name of *tartar emetic*. Three parts of oxide of antimony are made into a thin paste with water, and mixed with four parts of bitartrate of potassa. The mixture is digested for several hours, and then boiled with eight parts of water. The boiling-hot solution is filtered and allowed to crystallize. Transparent or opaque, colorless, shining rhombic octahedra, of metallic taste. It is soluble in fifteen parts of cold and two of boiling water. In small doses it is an emetic; in larger doses it is a poison.

Of the heavy metals, iron is the only one which precipitates antimony completely from the aqueous solution of tartar emetic. Hydrochloric, nitric, and sulphuric acids precipitate a basic hydrochlorate, nitrate, and sulphate of the oxide of antimony.

There are several other antimonial tartrates, the place of potassa being supplied by soda, ammonia, lead, oxide, and silver oxide. A compound similar to tartar emetic may be formed with arsenious acid— $(\text{KO}, \text{AsO}_3, \text{C}_8\text{H}_4\text{O}_{10})$.

TIN.—*Etain*, French; *zinn*, German; *stannum*, Latin.—Tin is the *Jupiter* of the alchemists. It is one of the metals which were known to the ancients, and is evidently of high antiquity, although, in all probability, gold, silver, copper, and iron were known much sooner. It is supposed by some that the original Hebrew term *bedil* of Holy Writ indicates this metal; but others infer that a compound or mixture resulting, perhaps, from the purification of gold and silver possessing an inferior value, was meant by it. Under the impression that the word above mentioned denoted tin, the Greek translators of the scriptures rendered it *κασσιτερος*, by which term the classic writers of profane history describe tin, after all doubt had been removed as to its identity. BECKMAN discusses the question whether the *stannum* of the Latins and the *κασσιτερος* of the Greeks was really the metal which forms the subject of the present article; and whilst he leaves the point undecided, advances various arguments to show that a rich alloy of silver and lead was frequently, if not always, the substance indicated by the foregoing titles.

Whatever may have been the nature of such alloys, it is certain, from the writings of DIOSCORIDES, DIODORUS, PLINY, and others, as well as from Celtic records, that tin was known at a very early period. It is recorded that between 1040 and 1030 before the Christian era, the Phœnicians had discovered that part of Britain known at present as Cornwall and Devon, and instituted searches for minerals and metals therein; and the active exportation of the metals—principally tin—led to the adoption of the title *Breotan*—red or burning fires and land—for the mainland, from the circumstance of large fires being kept burning on all the bold heights of the country to serve as beacons for the mariners along the dangerous coast; of which words Britain is but a slight modification. The metal tin was called in the dialect of the people of Phœnicia *stān*, whence the *stannum* of the Romans; from this root likewise has been derived the title *Stanneries*, which is still applied in Cornwall to the districts where tin is produced.

That the quantity of tin extracted from the British mines was considerable, is very evident even from the account of the Greek writers already alluded to; thus DIODORUS, in the second chapter of his fifth book, says—The inhabitants of that part of Breo-tan—Britain—called Bolerion—supposed to be the Land's-end, but actually a corruption of *Bal-erig*, which means the country of the *Erians* or *Iberians*, of which it is an abbreviation—excel in their hospitality; and also, from their converse with merchants, they are more civilized and courteous to strangers. These are the people who make the tin, which, with a great deal of care and labor, they dig out of the ground which is rocky; but it has in its earthy veins, the produce of which is brought down, melted, and purified. Then when they have cast it into the form of cubes, they carry it to an island adjoining to Britain called Iktis. During the recess of the tide the intervening space is left dry, and the tin is carried to the island in carts; and it is something peculiar that happens to the islands in those parts lying between Europe and Britain, for at full tide, the passage being overflowed, they appear islands; but when the

sea returns, a large space is left dry, and they are seen as peninsulæ. From this the tin is transported to Gaul, through which it is conveyed on horseback in about thirty days to the mouth of the river Rhone.—*Diodorus*.

The island above alluded to will be at once recognized as one of the Scillies, and its Greek name was probably derived from its being made a fishing-station by the Phœnicians.

Of the mode of operations by which the tin was extracted, or the mines worked in those days, no record is left; but from the remains which have been discovered, it is conjectured that the methods adopted were of the rudest description. By whatever means the mining and metallurgy of tin were prosecuted in Cornwall and Devon up to the period of the Norman conquest, it is certain that after that event they received a great impetus, so that the chief part of the revenues of the Earls of Cornwall was derived from it. King John gave a charter to the Cornish tin mines in 1201; another was granted them in 1305 by Edward I., and the stannery laws were instituted in his reign. These laws are still extant, and partly in force; but want of space forbids a full account of them here. Previous to the thirteenth century England enjoyed a monopoly of the tin trade; but in that age rich veins of tin ore were discovered in Misnia and Bohemia; and about the year 1250 the English trade was much reduced by the low price at which the Germans were able to sell their tin. At present tin is found in several places, and mines of it are wrought in Bohemia, Saxony, and Austria; in Galicia, on the borders of Portugal; at Piriac, in the *Loire inférieure*; and at Vaulry, in the department Haute Vienne in France; but the mines of French localities are of very little importance. Large quantities of tin ore occur in the Siberian mining district of Nertschinsk, and it is found in Dalecarlia in Sweden; but the richest deposits that have hitherto been found are those in the province of Tenasserim on the east side of the Gulf of Martaban in the Malayan peninsula; these have been worked for many centuries, and considerable quantities are still obtained. In the early part of the last century—1710—large quantities of very pure ore of tin were discovered in the island of Banca, whence as much as three thousand five hundred tons of the metal have some years been abstracted. Minerals of tin exist also in Brazil, in Mexico and Chili, in South America, in the United States, and Australia. The tin mining districts of Cornwall and Devonshire are three in number; namely, that included in the South-west of Cornwall beyond Truro, the neighborhood of St. Austell, and of Tavistock in Devonshire. The chief tin mines in these districts are Wheal Vor, near Helston; Polberrow, near St. Agnes; Polgooth, near St. Austell; Drake Walls, near Tavistock, on the Cornish side of the Tamar; and Birch Tor, also near Tavistock, but on the Eastern side in Devonshire. Ores of tin are found in all the localities mentioned, either in the form of regular lodes or veins disseminated in granite and in felspar—porphyry or elvan—and in alluvial formations on the slopes of hills, or in the valleys. In the former instances, the veins frequently cross one another either horizontally or in their perpendicular descent; occasionally they ramify through the rock in all directions,

producing at the point of intersection masses of ore called by the Germans *stockwerk*, such as the Altenberg mine in Saxony. In the other instance of the occurrence of tin ore, namely, in alluvial deposits, it is usually called *stream tin*, as well from the nature of the deposit, as from the fact that in these cases the workings are generally in the course of rivulets or streams. It is found either in a pulverized sandy state, in separate stones, called *shodes* in Cornwall, or in a continued course of stones, which are sometimes found together in large numbers, and at depths varying from one to fifty feet. The course of these deposits is called a stream; but they have little regularity, varying in their breadth, and are scattered over the entire extent of the moor or valley in which they are found. *Wood tin*, the name given to pebbles of ore having a woody appearance, though now rather scarce, was formerly found in some of the stream-works of Cornwall.

MINERALS OF TIN.—Tin is found almost invariably in the form of binoxide of tin or tin-stone, and in some instances associated with iron and copper pyrites, forming what is called tin pyrites or bell-metal ore, but the quantity so existing is very small.

BINOXIDE OF TIN—*Cassiterite*; *tin-stone*; *zinnstein*.—This ore of tin, from which almost the whole of the metal is smelted, is found, as already mentioned, in different states of aggregation. It is characterized by a high gravity, averaging 6·3 to 7·1, adamantine lustre, and color varying from a brown or black to various shades of red, yellow, grey, and white. In crystalline shape it belongs to the right prismatic system, the crystals being twins, with some of the faces uneven, and others striated parallel to their intersections with each other. The crystals have but a very imperfect cleavage, their fracture is imperfectly conchoidal and their streak grey, and sometimes brown. Heated before the blowpipe, oxide of tin remains infusible *per se*; with soda in the reducing flame it affords small globules of metal. Acids do not exert a solvent action upon it, and therefore it cannot be dissolved till after its fusion with alkalis. In its pure state binoxide of tin contains—

	Atomic weight.	Centesimally.
1 Eq. of tin,	59	78·66
2 Eqs. of oxygen,	16	21·34
	75	100·00

Samples of the ore have been analyzed, and the results are stated thus—

	From Altonon in Cornwall, by Klaproth.	From Schlacken- wald, by Klaproth.	From Finbo, near Fahlun, by Berzelius.
Oxide of tin,	98·93	99·28	93·6
Red oxide of iron,	0·32	0·72	1·4
Silica,	0·75	—	—
Columbic acid,	—	—	2·4
Binoxide of manganese	—	—	0·8
	100·00	100·00	98·2

This ore is found in the various localities already referred to, accompanied with quartz, mica, fluorspar, apatite, topaz, tourmaline, wolfram, heavyspar, mispickel in the lode; and in the alluvial beds of valleys and plains.

TIN PYRITES—*stannin*; *zinnlicies*.—This ore of tin occurs in a few of the Cornish mines, such as those

of Huel Rock in St. Agnes, and some of the granite veins in St. Michael's Mount; also at Zinnwald in Bohemia. Its crystalline form is cubic; the cleavage of the crystals is imperfect, the fracture uneven and conchoidal, the lustre metallic, with a steel-grey, inclining to bronze-yellow color, and a black streak. The specific gravity is 4·3 to 4·51.

Before the blowpipe on charcoal it melts in a strong heat, turns white on the surface, and deposits a fixed sublimate of binoxide of tin round the assay. After roasting, it affords, with the usual fluxes, the peculiar reactions of iron and copper, and a brittle globule of the latter metal on fluxing with soda and borax. Nitric acid decomposes it, dissolving the iron and copper, and leaving a deposit of sulphur and of binoxide of tin. The following analyses indicate the composition of a few samples of this ore; samples A and B from Huel Rock; C from St. Michael's Mount, and D from Zinnwald:—

	Klaproth.		Johnston.	Rammelsberg.
	A	B	C	D
Copper,	30·00	29·69	23·55	26·31
Iron,	12·00	12·57	4·79	6·80
Zinc,	—	1·79	10·11	6·93
Tin,	26·50	25·81	31·62	28·94
Lead,	—	—	—	0·41
Sulphur,	30·50	29·95	29·93	29·89
Loss,	1·00	0·19	—	0·72
	100·00	100·00	100·00	100·00

PREPARATION OF TIN.—The reduction of the ore is effected by roasting and smelting, in a manner similar to that which will be described further on, and the button so obtained is then treated in the following manner, to separate the metal from the arsenic, antimony, bismuth, zinc, lead, iron, and copper, one or more of which it may contain; or ordinary commercial tin may be taken for this purpose.

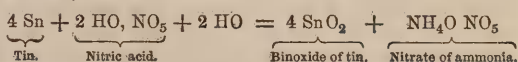
In either case the crude metal is treated with an excess of hydrochloric acid, when the tin, zinc, bismuth, copper, and iron are dissolved, whilst the arsenic and antimony will be separated; the former volatilized in the form of terhydride of arsenic, and the latter partly deposited as a black powder in the liquid, and partly dispelled as antimonide of hydrogen. The solution is filtered, and the liquid concentrated at a boiling temperature, and strong nitric acid in excess added, after which the evaporation is continued to dryness. The tin is thus obtained in the state of binoxide, which should be treated with a little hydrochloric acid, then filtered, washed thoroughly, and dried, mixed with charcoal, and reduced at a white heat in a charcoal-lined crucible.

Properties.—Tin is a white metal, having a metallic lustre, approximating to that of silver; it is softer than gold, but harder than lead, and has a specific gravity of 7·291. It is very malleable, so much so that it can be rolled into sheets of not more than the one-thousandth of an inch in thickness, but wanting ductility and tenacity to any useful degree. A wire of the metal, 0·7 of an inch in diameter, will sustain only thirty-four and a half pounds weight. Tin melts at 442°, and contracts slightly on cooling; at a strong red heat it emits white fumes, but the tension of its vapor is

very feeble, and therefore little loss of metal is sustained. The metal exhibits a great tendency to crystallize when a mass of it is melted in a covered crucible, and allowed to cool very slowly; if before the bulk has solidified the fluid portion be poured off, the hardened part remaining in the vessel will be found crystallized in rhombic plates, according to PAJOT; and in octagonal needles, according to BROOKE. This tendency to crystallize is readily exhibited by dissolving the exterior coating of a plate of the metal by means of moderately dilute aqua-regia, and then washing off the acid with water. The surface will then exhibit a mottled appearance, owing to the irregular reflection of the fern-like crystals which the action of the acid reveals. Various pretty designs are in this way formed on the surface of moderately thick tinned plates; and the French, who practise the process for decorating snuff-boxes, *et cetera*, call it *moiré métallique*. It is to the crystalline arrangement of the particles of the metal that the crackling sound which a bar of it emits on being bent backward and forward is due, the decrepitation being produced by the displacement of the small crystals of which the bar is composed. By repeatedly inducing this friction an amount of caloric is developed, which can be readily detected by a sensible calorimeter.

Tin retains its brilliancy for a considerable time when exposed to the air; when heated in the air to the melting point, however, it is immediately covered with a film of oxide of tin; and if the heat be increased, the oxidation of the metal becomes so rapid as to induce ignition. In both instances binoxide of tin results. The same change takes place when steam is passed over a bath of the metal heated to redness out of contact of air; for the metal abstracts the oxygen of the water, and sets free the hydrogen. Tin combines with most of the metalloids, producing generally two orders of combination, distinguished by the terms proto or stannous, and binary or stannic, compounds of such elements with the metal. The combination with many of these, as with sulphur, bromine, iodine, chlorine, *et cetera*, is so intense that, at a slightly elevated temperature the metal enters into active combustion, whilst the stannic salts of these radicals are produced. Acids have likewise a well-marked action upon it; for instance, hydrochloric acid, at the ordinary temperature, slowly dissolves it, with evolution of hydrogen; at a boiling temperature the action is much more active; in both reactions the stannous chloride is formed. Dilute sulphuric acid, with the aid of heat, converts it slowly into a sulphate of the protoxide, and liberates hydrogen; the concentrated acid has little or no effect upon it in the cold, but if the liquid be heated to the boiling point, it rapidly attacks the metal, sulphurous acid being liberated. Slips of bright tin-foil, immersed in concentrated nitric acid, experience no change, however long they may be

retained in it; but if the acid be diluted with water, the action becomes violent, owing to the rapid conversion of the metal to a binoxide of modified properties, known as metastannic acid, and the evolution of binoxide of nitrogen. If the nitric acid be previously diluted, no nitrous fumes are given off during the oxidation of the metal, but nitrate of ammonia is formed, thus—



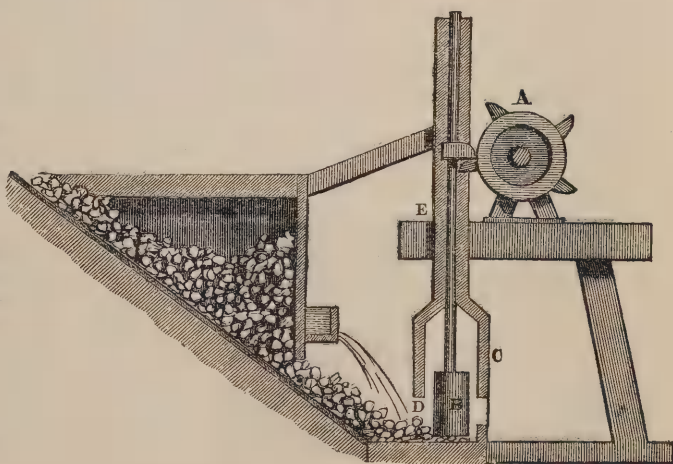
The fixed caustic alkalis dissolve tin, and produce with it a compound in which the combination of this metal takes the character of a salt radical; in this case water is decomposed and its oxygen is assimilated by the tin, whilst the hydrogen is given off.

The symbol for tin is Sn; its equivalent number 59.

METALLURGY OF TIN—Preparation or Dressing of the Ore.—In preparing ore of tin for the smelter, much pains are taken for the separation of all earthy matters and metallic substances that would reduce the percentage yield of the ore, or injure the quality of the tin when smelted. The order in which this dressing is performed is much the same as when copper ores are under treatment—namely, *cleaning* and *sorting* of the ore, *stamping* and *washing*, and, finally, *calcination* and *washing*.

Sorting the Ore.—This operation is commenced on the surface by washing away the clay and light impurities from the ore by a stream of water, and breaking or *spaling* the stones containing the ore, and separating the whole into heaps of different qualities and classes, according to the nature of the gangue, or the other minerals accompanying the tin; thus ores containing copper and iron pyrites are classed differently from such as contain only earthy matters, and such as contain tungsten are set aside by themselves to be submitted to a special treatment. The richest and

Fig. 599.



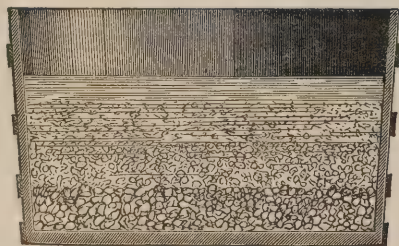
purest lumps are placed together in heaps on the dressing floor, and are called *best work*; the second quality, though less rich than the preceding, are

nevertheless remunerative; and the third division consists of matter that is very poor in, if not wholly without, ore.

The several heaps of ore are further reduced by the stamping mill to a fine powder. This *machine* is shown in section in Fig. 599. It consists of a wooden shaft, connected with a water-wheel or steam-engine, in which are arranged a number of cams that catch upon the lifting arms of a series of pestles heavily shod with iron, and secured in a strong wooden box lined with iron to prevent the dispersion in all directions of the ore by the strokes of the pestles or stamps. In the figure, A indicates the revolving shaft with the cams, B the pestle, and C the box confining them, D the ore to be crushed, and E a sluice which supplies a stream of water that carries off the reduced ore to the tanks along narrow inclined planes. Four stamping heads, averaging two and a half to three and a half hundredweight each, are worked in each box, and in the following order:—The pestle to the left of the spectator, supposed to be standing in front, first; the extreme right second; the right middle one third; and the left middle last—and each pestle is so lifted that the strokes follow in succession. The revolving shaft makes about twenty revolutions per minute, and the ore which enters the box receives from one hundred and sixty strokes to double this number to reduce it. The stream of water, entering the box from E, conveys the reduced ore, aided by the force of the pestles, through gratings at the ends and sides of the box to the inclined plane or cistern already mentioned. Here the ore, in consequence of its gravity varying in the ratio of its contents of metal, arranges itself into three kinds—the heaviest, and therefore the richest, resting on the upper part; a less rich ore in the middle; and the poorest or gangue parts—the tailings—at the lowest part. Very fine portions of the ore are carried off by the water in suspension to the slime pits, where it settles to the bottom, to be occasionally collected. The richest portion of the ore on the inclined plane is removed to the rectangular *buddle*, where it is washed under a regular stream of water, the ore being kept by a brush spread equally over the floor of the buddle. In this way the material is further purified, the richer ore remaining on the upper half of the table, and a poorer product on the lower half.

The richer ore is further purified in the *kieve*, or tos-

Fig. 600.



sing tub—Fig. 600. It consists simply of a stout wooden vat, well bound with iron hoops, having a capacity of a hundred gallons or more. A quantity of the purer

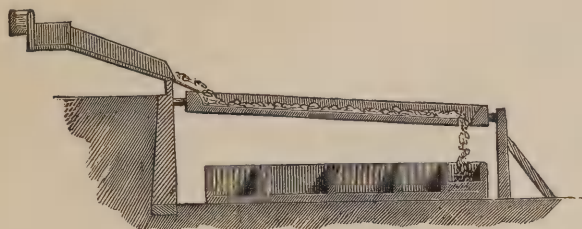
ore, from the buddle in the preceding instance, together with a quantity of water, is thrown into the tub and stirred well up with a shovel for a few minutes, and then allowed to rest, while to expedite the subsidence of the ore, the workman strikes the tub all round with a hammer. Here, again, a further separation of the ore takes place, according to the order of its gravity, the richer kinds being nearer the bottom of the tub, and forming distinct layers, as shown in the figure. The top layer is thrown away as being of little value, or is reserved for further washing in the circular buddle with other portions of poor ore; the second is submitted to another washing; and the lower layer is fit for the smelting furnace or the roaster, if it be pyritous, and is called *tin witts*.

The matter on the middle of the inclined plane or cistern adjoining the stamping mill is delivered into a wooden trough placed over the cistern, and washed by a small stream of water direct into the circular buddle, where the washing of ore is effected in larger quantity, and at less expense than in washing the rich ore as it becomes separated. Several of these circular buddles are required, and the lower layer of the deposit in one is conveyed by a trough to the next, and there washed. In this way the richer parts are removed from the poorer tailings; and when they arrive at the proper standard they are removed, and their cleansing finished on the rectangular buddle and tossing tub, as described. The contents of the slime pits are purified, first, by what is known as the *trunking process*, and secondly, on the *racking table*. The trunking box consists of a long sloping cistern, with a division near its upper end, forming a small quadrangular vessel, in which the ore, slime, and water are delivered. The contents of this small cistern are agitated by the slow movement of a paddle placed in it, and thus portions of slime and water are thrown out into the sloping trunk at each stroke. As it flows down this incline the heavier ore first separates, and continues to deposit, according to its density, towards the end of the trunk, where, however, the matter collected is of little worth. When enough of the mud is thus treated to fill the long cistern, the admission of more of the sludge is prevented, and the higher portion of the deposit is transferred to the *racking tables*, whilst the other portion is again submitted to the preceding trunking process. The racking table, shown in Fig. 601, is a long wooden table, set at an incline of one in sixteen, and having shallow bevilled flanges at the sides and ends to serve as a frame for it, and supported by centre pivots on a wooden framework about three feet high. At the head of the table is fixed the sloping board, hinged to it with leather, and upon this the mixture of ore and water is delivered, and a number of boxes, generally three, are fixed beneath it to receive the different qualities of the washed product.

About twelve or fifteen pounds of the selected stuff from the trunk boxes are placed on the fixed head and washed over the hinge board to the table. It is equally distributed over the board with the aid of a rake or brush, when the water sweeps along the lighter portions, and carries the worthless matter through a

narrow slit at the bottom of the table into a gutter. The selected and rich deposit on the table is washed out into the receptacles beneath it by inclining the latter to one side, and a fresh quantity operated upon

Fig. 601.



as before. The contents of the first, second, and third box are washed again on the rack once, twice, or thrice, as it is deemed necessary, before the product of the first vessel is sent to the tossing tub.

Stream tin is dressed by a similar course of operations as the foregoing, only that the ore is first treated in a large trunking box, where the workmen separate by a rake the larger from the smaller particles of ore. After this, the divisions of ore are submitted to a picking, stamping, and washing operation, mostly like that detailed above. With stream tin these processes serve to produce a very pure ore, devoid of most of its earthy components, and ready for the smelter; but when the tin is found in lodes, associated with copper and iron pyrites, the dressing course with simple washings is insufficient to remove the sulphurous compounds, and with which the ore cannot be smelted.

To remove them, the ore from the tossing tub—the *tin witts*—is conveyed to the burning house, and roasted in reverberatory furnaces, or in a kind of roaster called from its inventor BRUNTON'S calciner. The reverberatories are of the usual form, having a bed about nine feet long, five feet wide in the middle, and four feet at the back part, wherein is situated the working door. The charge, amounting to ten or twelve hundredweight of ore, is let down upon the bed through a hopper in the arch, and when roasted it is drawn out to an arched space beneath the bed by a small aperture inside the working door in the latter. The temperature supplied should not exceed a dull red heat, such as will be capable of dispelling the arsenic and sulphur without fusing the sulphurous compounds. Frequent rabbling of the ore on the bed of the furnace expedites the separation of the sulphur and arsenic; but, under all the attentions given, the time for each charge averages, according to the amount of impurities, from eight to twelve hours. The arsenical and sulphurous vapors pass from the furnace into a wide flue, which is divided into a series of compartments or chambers of varied dimensions, for the purpose of arresting the arsenic, and leading to a low chimney usually erected on some adjoining and commanding eminence.

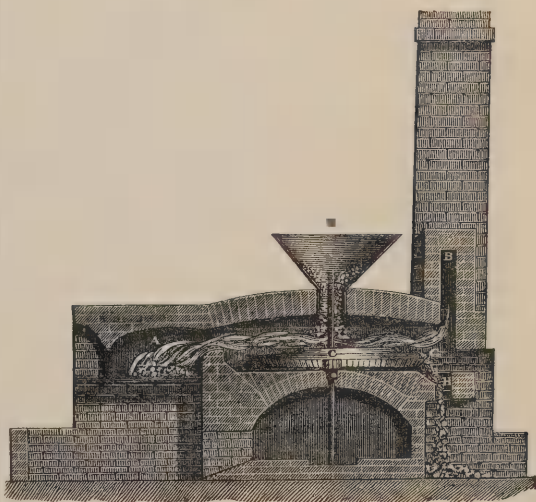
BRUNTON'S calciner is shown in Fig. 602. It is a circular cast-iron table fixed on a stout central shaft,

placed in proper bearings beneath the furnace, so as to permit its turning slowly with the table, C, which is set in motion by a small pinion gearing into a toothed wheel fastened to its under side. This table is fixed beneath the dome of a reverberatory furnace, having a hopper, E, for retaining the ore to be calcined, and in which the upper end of the central shaft turns and distributes the ore on the plate in a continuous stream. The fire is at A, and the products of its combustion pass over the ore to the flue, B, leading to the chimney. Owing to the revolution of the bed of the furnace the ore is kept constantly turned and moved till it travels to the circumference whence it is ejected through the apertures, H, into the receptacle or *wrinkle*, G, in the same ratio that it is supplied from the hopper. Power is communicated to the gearing pinion by a water-wheel or

other means; and the rate at which the ore is to pass over the calciner is regulated by the quick or slow motion of this shaft. Much labor and fuel are said to be economized by the adoption of this system of roasting.

The roasting effects the conversion of the dense metallic sulphides into friable and light oxides, which, being of a less gravity than the tin ore that remains unaltered by the operation, can be readily separated by a proper system of washing. The several kinds of products from the preliminary dressing, such as jigged, fluran, smalls, slime, and roughs, are burned separately,

Fig. 602.



and each subjected afterwards to a particular treatment; thus the jigged parcels are simply jigged again on a copper sieve after the burning; the fluran is passed through the buddle and tie, and the finer divisions are submitted to more complicated processes, consisting of *buddling*, *tossing*, *packing*, and further washing of the residues from these operations on hair sieves, till finally

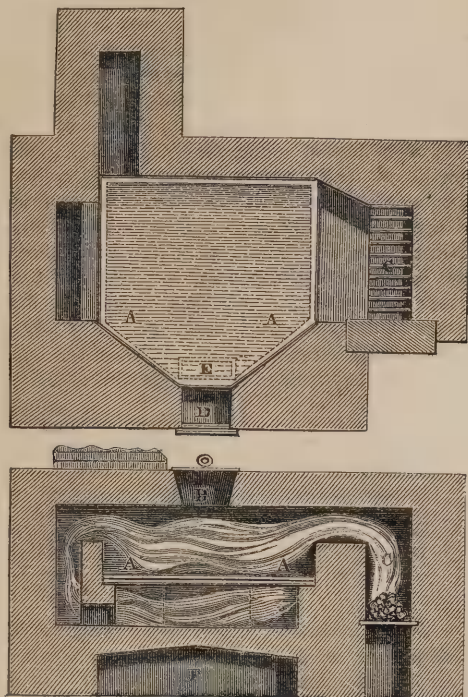
the tin crop remains as pure as possible. Numerous divisions of tin ores are made according to the quantity of the accompanying bodies and their nature, besides those already alluded to; and their dressing gives rise to several refuse matters, the purification of which necessitates a complication of operations, which are varied according to circumstances and the judgment of the superintendent of the mine. The *burned leavings* from the foregoing operations, containing more or less tin, are restamped with some silicious matter and rewashed; the crushing with the sand, *et cetera*, detaches from the particles of tin the earthy matters that were combined with them, and that rendered them specifically lighter in the preceding washings. They may now be readily separated by a stream of water in the trunking box or buddle, and the tin obtained.

Improvements in the Dressing of Tin Ore.—Several improved methods of purifying ores of tin have been suggested and practised during the last quarter of a century. The principal of these consist in the use of acids for the separation of the injurious matters from the tin ore, which remains unacted upon by them. By the use of hydrochloric and sulphuric acids the fragments of metallic iron from the tools of the miners, of oxides of iron, copper, *et cetera*, are dissolved and removed from the tin by simple washing, much more effectively, than could be done by any mechanical operation, however carefully performed. Acids have been in use for the dressing of tin ores since 1842, or earlier; muriatic acid being preferred where the impurity is iron and its oxide, and sulphuric acid for the separation of the copper existing in the roasted ore as oxide, which is afterwards thrown down from its solutions by metallic iron or zinc, and the sulphate of iron, or of zinc recovered. LONGMAID'S patent process of separating the sulphur from pyritic ores by fusing them with common salt, whereby the sulphur is converted into sulphate of soda, and the copper into the form of chloride, could be applied to the purification of tin ores containing the foregoing additional metals. Washing the roasted mass would remove the copper salt, and the sesquioxide of iron would be carried off in mechanical suspension, leaving the oxide of tin in a partially pure state behind. The preceding methods of treatment do not serve to purify ores of tin associated with *wolfram*—the double tungstate of iron and manganese—for this mineral has a density averaging 7.1 to 7.4, and therefore so closely approximating to that of tin that no amount of mechanical washing could part the two satisfactorily. Before the process for its purification was discovered, the tin obtained from this kind of ore was very inferior, and consequently the ores themselves were greatly depressed in value. By OXLAND'S method of removing the tungstic acid from them, however, they are so improved that first quality tin can be smelted from them, and necessarily with such purification their value has been correspondingly enhanced. The principle of OXLAND'S patent is that on fusing ores containing tungstates with alkaline salts, such as carbonates or sulphates of soda or potassa, the tungstic acid combines with the alkaline base, producing an alkaline tungstate, which may be dissolved out, and converted to useful purposes in calico-printing or painting, thus

returning as much if not more than the expense involved in the treatment. The tin ore, as finely dressed as possible, is mixed with as much soda ash or crude soda as will be sufficient to form an alkaline tungstate with the amount of tungstic acid which analysis shows the mineral contains. The mixture is then introduced into the bed of a reverberatory, and heated to low redness, which temperature is sufficient to induce the combination of the alkali and the metallic acid body. When the operation is finished, as observed by the color the mass assumes, and the consistency of a thick paste which it takes, it is raked out by an opening in the bed of the furnace into a receptacle beneath, whence it is taken and cast into vats filled with water, which dissolves out the tungstate of soda, leaving the other constituents of the ore untouched. By a judicious use of the water and a properly-constructed vat, the whole of the tungstate can be extracted with very few changes of water, and without diluting the solution to an inordinate degree. While this operation is progressing, the furnace is being charged with a further quantity of the mixture, which is spread out upon the sole, and left so with the furnace doors closed, till the alkali begins to melt and the mass emits a hissing sound, resulting from the expulsion of carbonic acid from the soda salt by the metallic acid. It is then slightly stirred; and when the preceding noise subsides, and the forementioned indications are observed, the roasted mass is ready for drawing. Latterly, instead of carbonate of soda, or crude soda, sulphate of soda or *salt cake* has been substituted, both on account of its cheapness compared with soda ash, and of its answering all the required purposes, in this respect, as well as the latter salt. Some skill and practical judgment are required, however, on the part of the furnaceman who has the control of the process, to insure success. The charge containing a quantity of sulphate corresponding to the tungsten in the ore, is put into the reverberatory—Fig. 603—through the workable opening, B, in the arch, and spread by the furnaceman upon the iron bed, A A, of the furnace through the working door, D. The bed is composed of two stout cast-iron plates fixed in the sides of the furnace, and supported near the centre by lines of brickwork; the space left by this arrangement between the plate and solid brickwork forming a flue for the smoke and waste gases of the fire to return under the sole, and thus assist in heating it. C is the fire which at the beginning of the operation should produce a highly carbonaceous flame, with the view of reducing the sulphate of soda to the state of protosulphide, to induce the decomposition of the tungsten and the combination of the acid. For the same purpose some small coal or charcoal is mixed with the charge, the more readily and efficiently to decompose the sulphuric acid of the soda salt. A dull red heat is maintained with all the available openings to the interior of the furnace closed, and a strong reducing flame, till the reduction of the sulphate is effected, occasionally stirring the mixture well till the phosphorescent appearance of the mass disappears. At this stage of the operation a bright oxidizing flame should be produced, to induce the further decomposition of the alkaline sulphide and the

formation of the soluble tungstate; after which it is raked out through the hitherto closed aperture, E, to the vault, F. This process has been carried out at the

Fig. 603.



Drake Wall Mine in Cornwall since 1850 with every success.

The solution of tungstate of soda obtained by the exhaustion of the fluxed ore with water, is concentrated in iron pans to the crystallizing point, and drawn off into crystallizing vessels, where it remains. In a few days the tungstate separates in beautiful crystals, and which, after slight washing and draining, are fit for market. On concentrating the mother liquors a further crop is obtained. After the ore is exhausted of its soluble salts it is transferred to the floor of the burning house, and the iron and manganese separated by washing or treatment with acids, according to the methods already detailed.

From a consideration of the several operations which ores of tin pass through from their coming to *grass*, as it is called, till they are ready for the smelter, it is supposed that fully a third or more of the quantity of tin originally in the ore is lost. Distributed as the tin must be in minute grains in the stony gangue, it is evident that the latter cannot be so thoroughly broken off from the tin as to leave it isolated, and thus in a state to separate in the several washings. Further, where the tin ore is to the whole of the matter mined as one to thirty or thirty-five, a good deal of tin must be rejected in the tailings of the first process which it has to undergo, *videlicet*, the *spalling* and picking;

and analysis of the refuse matters shows that they invariably contain quantities of tin, which loss must be entirely owing to the imperfect, or rather inadequate methods, adopted for disintegrating the ore, and the very slight difference in the low gravity of the gangue which the associated grains of tin ore must occasion, so that such ore will be entirely lost to the miner.

Modern researches show that the loss of tin in the dressing of poor ores is much greater than when richer products are operated upon, in which, however, it amounts to about twenty-five per cent. of the whole quantity. This great loss is attributed to the large amount of tailing stuff produced, and the large body of water made use of in the course of the working. Whilst the existing mode of tin dressing is practised, that loss can hardly be avoided, or at best but slightly lessened. To obtain the whole of the two to three per cent. of binoxide of tin in the tin stuff, the dressing must be based upon chemical rather than mechanical principles. Considering that the loss of tin at present sustained in dressing a hundred tons of stuff averages fully fifty to sixty pounds worth of tin, the recovery of this waste would afford a scope for a partial outlay by which to attain better and more profitable returns.

Many mining companies have of late years substituted crushing mills, such as are sometimes employed in the preparation of copper ores, for the stamping mill, and with great effect and benefit; inasmuch as the crushing mill reduces the ore to a finer state of division, and separates more of the gangue from the hard granules of tin than the stamps, and thereby renders it more easily and freely separable by virtue of its gravity, than when this breaking up is defectively performed. A mistaken notion or prejudice seems to occupy the minds of several miners, with regard to the value of crushers in their line of operations, the more especially if the stuff in which the tin ore is disseminated be indurated slate and the like; for in such cases they seem to be impressed with the idea that the crushers could not work it so well as the stampers. The evidence of many very creditable and experienced persons is directly opposed to this view; and a rational examination of the principles of working with regard to each, would undoubtedly tend to the preference of the crushers. At all events, since the tin miner places so much dependence upon the gravity of the ore as a means by which he can cheaply and expeditiously purify it from grosser and injurious matters, the primary consideration with him ought to be the reduction of the ore to the finest possible state of division. The better this is executed the more completely and expeditiously will the *whole* or chief part of the tin separate in virtue of its density, in a properly ordered system of elutriation.

ASSAYING OF TIN ORES.—Although the laws of the Stannery Court do not permit that the product of the tin mines should be sold out of Cornwall before smelting, it happens that the mining proprietors are never the smelters, and so the ores are sold to a few smelters who have the trade in their hands. These buy as cheaply as they can, and according to the declared value of the ore as ascertained by assay. Hence, as in the case of copper, the ores of tin are always submitted to

this test to find their value, and it becomes a matter of some interest to the miner, as well as the smelter, to be able to control the determinations of recognized assayers, for their own satisfaction and often protection. The operation is very simple, since the dressed ores are generally operated upon, and consequently very little of any other ingredient remains in the substance, excepting the binoxide of tin, and the silicious or other gangue matter, separable by fluxes. Still, as binoxide of tin forms permanent compounds with silicic acid at a high temperature, it is necessary to use some precautions as well in the amount of flux allotted to the assay, as in performing the reduction in a black lead crucible, or an earthen one well lined with charcoal, and at the highest temperature of the wind furnace. If sulphurous or other alterable bodies be present in the ore, these should be removed by roasting a quantity of the ore at a low red heat, and using a little ammoniacal carbonate towards the end of the operation, till nothing further is evolved. The ore should in all cases be reduced to the finest powder; and after the roasting, if the quantity of silica and stony matter be deemed in too great excess, the assay may be carefully washed in a mortar or porcelain dish, and a large quantity of the impure matters thus removed. The heavy deposit of tin ore may then be dried and assayed in the following manner. If the ore be highly dressed, two ounces of it are weighed and mixed intimately with one-third to half this weight of powdered charcoal or coke, and half an ounce of ground borax glass; the whole well ground together, and introduced into a black lead pot, or lined clay one, and this placed on the furnace, the heat of which should be maintained at its highest point for fifteen to twenty minutes. At the end of this period, and when the contents of the crucible are in tranquil fusion, the whole is briskly stirred with an iron rod, and then poured out rapidly into an ingot iron mould. When cold, the slag is detached from the button of tin by a few strokes of the hammer, and by the use of the brush; the button is then weighed. Any matters remaining attached to the walls of the crucible are scraped off and ground, then washed, and the particles of metal that may be thus separated, weighed, and the amount added to that of the principal button. Sometimes the flux is composed of equal parts of borax glass and carbonate of soda, and is found to answer very well; so also is the flux compounded of three parts carbonate of soda and one of lime. Of the former thirty to forty per cent. of the ore taken for assay is employed, and of the latter forty per cent. When ores of tin are very poor, so that they necessitate the use of large quantities of flux, very little tin can be reduced from them, on the scale of assay-making, notwithstanding a considerable amount of the metal can be obtained by the treatment of such ores on the large scale. In assaying such ores the better course would be to employ the liquid method of analysis, which will be referred to further on.

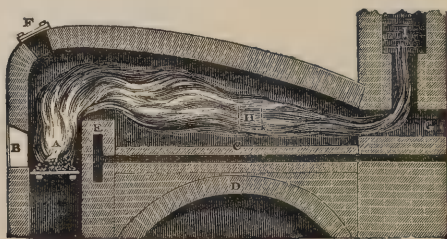
SMELTING THE ORE.—Up to the period of the reign of Charles the First, very little improvements are recorded in the smelting of tin. The remains of ancient workings discovered as existing previous to the above period, appear to indicate that the reduction

was carried on in furnaces or hearths scooped out of the ground, and in which a mixture of black tin and charcoal was placed, the necessary intensity of the heat being kept up doubtless by the blast of rude bellows, and the whole operation being similar to the metallurgic process of the travelling tinkers of a few years ago—and perhaps of the present day in Ireland—whereby cast-iron and other refractory metals were readily melted and cast into shapes, such as smoothing irons, *et cetera*. Remains of such furnaces are of frequent occurrence in Cornwall and Devon, and are called *Jew houses*. One of these smelting forges lately discovered beneath a stratum of bog, twelve feet thick, at Redmoor, contained some tin, peat which had been used as fuel, and furnace scoria, with other remains. An analysis of the scoria from other furnaces in the same locality, and apparently of a more modern date than the preceding, showed the imperfections of the methods of smelting. The following are the results which samples presenting the appearance of thin fragments of bottle glass gave:—

	Centesimally
Silica,.....	40·60
Alumina,.....	19·20
Oxide of tin,.....	22·85
Protoxide of iron,.....	7·31
Sulphide of iron,.....	9·04
Lime,.....	trace
Potassa,.....	1·00
	100·00

From the other remains found in the site of the slags, *et cetera*, from which the above was taken, it would appear that the date of working could not have been later than about the year 1630. Attempts were made in the reign of the first CHARLES to employ pit coal instead of peat and charcoal; but the results were unsatisfactory till the first few years of ANNE's reign, when improved methods of smelting ores of tin in blast furnaces, by means of fossil fuel, were patented by a Mr. LIDDELL. At this period, and when the advantage of fossil fuel above peat and charcoal began to be recognized, the invention of the reverberatory

Fig. 604.

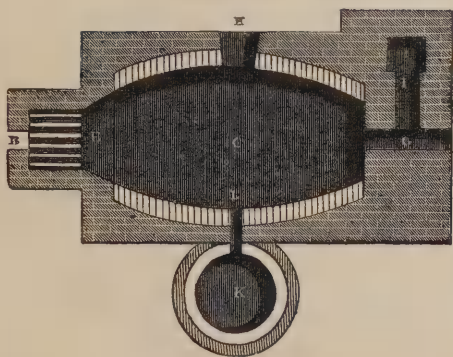


furnace soon followed, in which forms of furnaces tin ores have hitherto, but with slight modifications, been smelted.—*Records of Mining and Metallurgy*.

Figs. 604 and 605 are a plan and section of the smelting furnace at present employed in the smelting of tin ores. In these figures, A is the fire supplied through the door, B; C is the bed of the furnace, constructed of fire-

brick, and supported by the arch, D, having a passage for cold air beneath it, and in the bridge, E, of the furnace, to prevent the overheating of the mass of brickwork in the bed. The charging door is seen at H, and G is the opening through which the charge is worked in the furnace; F is a draught-hole temporarily opened whilst the slags are being skimmed off the metallic bath, and I is the flue leading to the chimney. The ore, which generally averages from sixty to seventy-five per cent. of metal, or, as estimated by the tin assayers and smelters, twelve to fifteen parts, in twenty of ore, is mixed with twelve to eighteen per cent. of powdered anthracite coal, and twenty to twenty-five hundredweight, or a little more, of this mixture, taken for the working charge in the ordinary sized furnace; a small quantity of lime or powdered fluor spar is added in proportion to the amount of silica contained in the material. The whole is shovelled in at the charging door, and spread through this and the working door; after which both doors are closed, and the fire is urged for a period of six to eight hours, gradually increasing in intensity. At the end of this time the ore is well rabbled and mixed by the furnaceman through the hinder door, with the view of bringing the unreduced portions of ore still remaining, within the influence of the heat, and reducing flame from the fire, and the unconsumed carbon of the charge, and likewise of allowing the separated metal to collect into a bath. For a second time the doors are closed, and the interior is allowed to regain its high degree of heat, somewhat reduced during the working of the mass. After a short interval

Fig. 605.



the furnaceman throws some moist slack on the surface of the fused mass in the furnace, and then commences to draw out the top layers of scoria through the working door, to the extent of three-fourths, or thereabouts, of the entire quantity. Whilst this part of the work is being proceeded with, it is customary to open the draught-hole, F, so as to allow the gases to ascend and leave the interior of the furnace partially exposed to the examination of the furnaceman. The above quantity of scoria, if skimmed off with care, contains no metal worth further search, and therefore it is thrown away. The portions which are afterwards drawn out, however, are separated into two classes; the first and largest portion is set aside to be stamped, in order to separate the

globules, or *prills* of metal diffused through it to the amount of five per cent., or nearly so; and the second, or final skimmings from the metal in the furnace, are reserved to be melted with a succeeding charge of metal or refuse products, when not only the particles of metal are recovered, but also the tin in the state of binocide contained in it. When the metallic bath is cleaned in this way, the clay plug hitherto closing the gutter, L, leading to the cast-iron pot, K, is removed, and the tin allowed to flow into the latter. The metal rests here for some time; meanwhile a fresh charge is introduced into the furnace; after which all the apertures are closed as before, and the fire kept up, as already stated. After the metal has remained in the pot sufficiently long to permit the slag and other impurities to rise to the surface, these matters are skimmed off, and the tin is ladled out into cast-iron moulds, each capable of containing about three hundredweight.

The tin so procured always contains a certain amount of impurities, the greater when less care has been exercised in the dressing of the ore. These are generally iron, lead, and some other bodies, according to the nature of the accompanying ore, such as copper, tungsten, arsenic, and cobalt. To separate them, however, it is necessary to submit the crude tin to either of two operations—the one, a process by which the more fusible tin is sweated out at a low temperature, and called *liquation*; the other, a *boiling* or *tossing* of the metal, by which portions of it, by its extended exposure to the air in this operation, are converted into oxide; and being in this state agitated with the body of the metal, the oxygen is transferred to the more oxidizable metals, which are thrown off as a scoria, and can be removed by skimmings.

For the liquation, the smelting reverberatory above described, or one similarly constructed, may be used. The blocks of tin are loosely piled upon the hearth, and a moderate heat is applied; the excess of pure tin melts at the low heat, and flows out by the gutter to the receiver, leaving in the furnace an alloy richer in impurities, and therefore, owing to the more refractory nature of the alloyed metals, requiring a higher temperature for melting it than the purer tin. As the progress of heating crumbles and melts the blocks of tin, fresh ones are supplied till about five or six tons of metal have run out to the cast-iron receiver, wherein the second operation is conducted. This receiver is so arranged as to admit of being heated with the view of aiding in the more ready separation of the contaminating ingredients during the boiling or tossing.

The purification by boiling is analogous in principle to the *poling* practised in refining copper, though differing in detail. In the case of copper, the gases eliminated from the wood—watery vapor principally, and some carbohydrogen—serve to decompose the metallic sulphide left, eliminating the sulphur as sulphurous acid and sulphide of hydrogen; whilst in that of the purification of tin, the metal abstracts oxygen from the steam similarly generated, and the oxide of tin thus partially produced, reacts upon the particles of alloyed metals more oxidizable than itself, and eliminates them as oxide, being itself reconverted to the metallic state.

The method of procedure with tin is to have a bundle of billets of green wood mounted on a crane erected by the furnace, and overhanging the pot containing the melted metal; this bundle is forced into the fluid mass, and the result is a violent seething, caused by the eliminated gases. A scum forms in which oxide of tin is a constituent; this is skimmed off and retained to be remelted with a fresh charge, or with the scoria produced in the first reduction. The action of the wood is renewed, and the scum removed, till by a test applied to the metal it is judged sufficiently purified.

Instead of using wood, the process of *tossing* may be practised with the same effect; that is, the metal is taken up in ladles and allowed to fall from a certain height into the caldron; in this case a scum is formed, and is removed in the same way as stated till the metal is deemed pure. The time occupied in the purification averages about five hours; one hour is devoted to the liquation, three to the boiling or tossing, and one to the subsidence of the metal after it has been thoroughly cleaned by the repeated skimming. During this final hour the metal disposes itself into three qualities of tin: the purer and more fluid metal constitutes the top layer, which is carefully cast or ladled into the moulds, and set aside as grain tin; the middle, which is not so pure, is likewise removed to moulds and retained as common tin; whilst the third portion is returned to the furnace to undergo liquation a second time, to purify it from the greater part of the vitiating ingredients.

The manner of testing the quality of the metal is as follows:—The refiner takes a small ladleful of the melted metal, and having cleaned it by stirring and skimming, casts it into a stone ingot mould, and as it cools, he closely observes its appearance. If it remains bright and clear, full and rounded on the sides, until quite cold, it is sufficiently pure to be classified as grain tin; if the metal, though bright, should not remain so full and rounded at the sides, and if at the moment of solidifying a frosted crystalline appearance shoots from the centre out to the sides, the tin is accounted as second class or common tin; and in the third place, if the metal assumes a slight yellowish appearance, and the crystalline stria appear much sooner, covering the whole of the surface, it is of the third class, and must be repurified by liquation, *et cetera*. The creaking sound emitted by the ingots when bent, is likewise a test which shows the quality of the metal, for this is much greater in proportion to the purity. In tin-smelting works, one day a week is usually devoted to the purification of the crude metal from the reduction of the ore.

The matter remaining in the furnace after the liquation of the tin, is melted at a higher temperature, and run out into another pot, whence it is cast into moulds. This, with the metal washed out from the rich slags after stamping, and the skimmings of scoria, as well as those produced in the refining pot, are resmelted, and the metal which results carried through the same course of operations detailed above. Finally, there remains in the pot a bright brittle alloy, having a crystalline fracture and so surcharged with foreign

metals that it is cast aside as not worth the expense and trouble of purification.

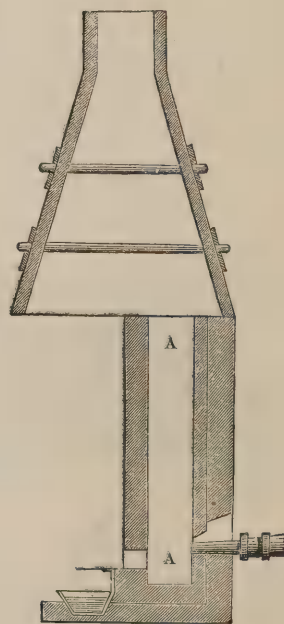
The following is the composition of the three qualities of tin obtained by the preceding operations, according to BERTHIER's analysis:—

	Centesimally.		
	Ordinary Tin.	Common.	Bad.
Tin,.....	99.76	98.64	95.00
Copper,.....	.24	1.16	3.00
Lead,.....	—	.20	1.50
Iron,.....	trace	trace	—
Arsenic,.....	trace	trace	trace
Loss,.....	—	—	.50
	100.00	100.00	100.00

The consumption of fuel for producing one ton of tin is reckoned in the Cornish smelting works at a little more than a ton and a half, sometimes thirty-five hundredweight, and the loss of tin in the process amounts to about five per cent.

German Method.—In the tin-smelting establishments of Altenberg, *et cetera*, instead of the reverberatory, a

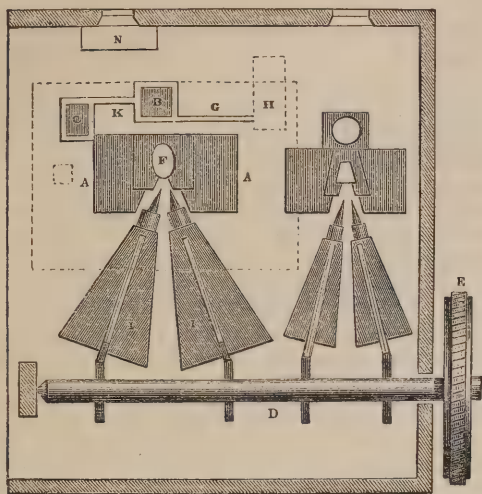
Fig. 606.



small blast furnace is used for the reduction of the ore. Figs. 606 and 607 are a plan and elevated section of this furnace; its height from the hearth to the throat, by which the mixture of ore and fuel is inserted, is fourteen feet. The body, A A, is constructed of large blocks of granite or of coarse-grained porphyritic syenite, and the sole or crucible is formed of a block of the same material hewn to the proper shape, with a fall to the breast of the furnace; but sometimes it is constructed of very refractory fire-bricks, lined with a mixture of charcoal and fire-clay well rammed down. A channel from the furnace leads into a basin, B, from which the slags flow down an incline, G, to the water

cistern, H, where they are cooled, and the tin by another conduit, K, flows into the vessel, C. The blast is supplied by the bellows, I I, through the tuyere opening, O. The furnace is surmounted by a dome which serves to carry off the vapors, and as a depositing

Fig. 607.



chamber for the particles of ore driven out of the furnace by the blast. The shaft, D, is turned by the cog-wheel, E, in connection with a shaft from a water-wheel or steam-engine. The small furnace, the parts of which are similar to the preceding, is employed for resmelting the slags produced from the larger furnace. The furnaces are slowly dried after their construction, and then charged with scoria and fuel, and the blast slowly set to work, so as to fuse the more vitrifiable portion, after which the heat is increased till the temperature is raised to the working intensity. The ore, mixed with the reducing agent, and other flux, when necessary, is now charged portionwise, and the smelting proceeded with. At the end of four hours the metal begins to flow. As the slags collect in the basin at the face of the furnace, they are skimmed into the water cistern, and when the metal accumulates so as to nearly fill the basin, it is allowed to flow into the outer one, C, whence it is cast into moulds of varied dimensions. Much of the same practical knowledge is required in the management of this furnace; as has been pointed out under the smelting of copper ores in the blast furnace; for the length of the nozzle formed of the slags, on the end of the tuyere affects the working, and the charge must be regulated accordingly.

It is affirmed that the tin reduced in the blast furnace is purer than that smelted in the reverberatory; but the loss of metal and the consumption of fuel is much greater; and these disadvantages have led to the abandonment of the blast furnace in England for the reduction of tin. Smelting by the use of the blast involves a loss of metal averaging fifteen per

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cent., and a consumption of fuel amounting to three tons of coal for every ton of metal reduced.

Tin is sent to market as *block tin*, in blocks of three to half a hundredweight, and which are cast, as stated in the foregoing, in strips two feet long, one inch wide, and half an inch thick, being so cast in moulds of white marble; and in the form of *grain tin*; the last being produced by heating large blocks of the metal to nearly its melting point, and while in this state, dropping it upon a hard body from an eminence, or striking it with a heavy hammer—in either case, the mass is shattered into long crystalline fibrous columns.

USES OF TIN.—The principal uses of tin are for the manufacture of various alloys which are largely used in the arts, such as bronze, bell-metal, solder, *et cetera*; for making *tin plates*, or rather iron plates, alloyed with the metal; and for preparing tinfoil, whilst its compounds are employed for pottery, in glazes, and colors; and in cloth-printing, as mordants of great value and importance. The reader will find the account of bronze under COPPER, Vol. I., page 534, and of solder, usually compounded of two parts of lead and one of tin. Tin-foil is manufactured similarly to lead-foil, by passing slabs of it backwards and forwards under a pair of rollers; the temperature of the metal being raised occasionally, or maintained throughout, at 212°. The production of tin plates is one of the principal, if not the principal application of tin, and as such this manufacture will be described more in detail.

MANUFACTURE OF TIN PLATES OR SHEET-TIN.—As the superior quality of tin plates depends almost entirely upon the goodness of the iron which constitutes their basis, and the care taken in its preparation, it will be necessary, from the importance of the subject, to dwell at some length upon this part of the process.

The pig-iron selected for the manufacture is generally that known as *red short*; but other varieties may be used, the iron being converted during the purification into plates, the essential qualities of which are great tenacity and toughness at ordinary temperatures. Iron from hematitic ores mixed with other pure ores of the coal measures, answers all the required ends. It has an average composition corresponding with the following samples, containing centesimally:—

	I.	II.	III.	IV.	V.	VI.	VII.
Carbon.....	3.47	3.70	2.37	3.42	4.23	3.27	—
Silicium....	1.40	1.33	0.81	1.63	0.49	1.03	1.55
Sulphur....	0.10	0.02	0.54	0.15	0.37	0.04	0.05
Phosphorus	0.60	0.12	0.26	trace.	0.36	0.38	0.18
Iron.....	94.43	94.93	96.02	94.80	94.55	95.28	—
	100.00	100.00	100.00	100.00	100.00	100.00	—

Tin plates are divided into two classes, and known by the terms *charcoal* and *coke* plates, owing, in the first place, to the nature of the fuel used in the preparation of the plates before tinning; but, more particularly at present, these names serve to distinguish the goods manufactured by entirely different methods. Charcoal tin plates were the first that were made, and they have been accounted the best. The iron for these plates is rendered tenacious and workable by the aid of a charcoal refinery through which the pig-iron, is passed; and that for the *coke* tin plates is prepared by the

G T

ordinary method of puddling and rolling, as described under the article IRON. It will, therefore, be unnecessary to revert to the latter; and so far as the mere coating of the prepared plates is concerned, the description to be given will answer for both. To convert the iron into charcoal tin plates, it is necessary to refine it in a shallow furnace called a *refinery*, the sides and bottom of which are formed of hollow, but very massive blocks of iron, through which a stream of water is kept continually flowing, to protect them from the intense heat of the melted charge. This furnace is of a rectangular shape being four feet long, two and a half wide, and one and a half deep. On one side are three tuyeres for the admission of blast; and these are sometimes round, sometimes oval, the transverse diameters of each in the latter case being 1·15 inch, and its conjugate one inch; they are placed about a foot from the bottom of, and project considerably into the furnace, inclining downwards at a sharp angle. These, like the block forming the furnace, being subjected to a powerful heat, are protected by a coil of iron pipe, twisted round them, through which pipe a stream of cold water is kept always passing. Occasionally, refiners are constructed of larger dimensions than that described, having tuyeres at both sides; these are usually called *double refiners*. A coke fire is made in the space between the *water-blocks* or hearth, and the blast turned on till the whole is thoroughly ignited; a fresh supply of fuel sufficient to fill the space to the height of three feet above the tuyeres, is then heaped on; and, after a few minutes' blowing to increase the heat, a charge of pig iron, varying according to the size of the furnace, and generally reduced for the first time, is put on; the coke is soon ignited, and the metal attains a red heat quickly, after which, the heat being still kept up with fresh supplies of fuel, the metal gradually sinks, and as it comes into contact with the blast, it melts and drops to the bottom of the hearth. The downward direction of the tuyeres causes the stream of air to impinge on the highly-heated liquid iron, and thereby renders the temperature of the latter intense, owing to a portion of the metal being oxidized, as well as the silicium, sulphur, *et cetera*. All these products of oxidation are thrown up to the surface, and form a considerable amount of scoria or cinder that considerably aids in the depuration of the metal. Generally, in an hour and a half after charging, the furnace is fit for tapping; the metal is run out into iron moulds prepared for it, and which are protected against melting by a stream of cold water that flows beneath them. These moulds are sometimes flat, in which case the metal is called *plate metal*. In South Wales, however, it is more usual to run the liquid iron into moulds, consisting of three longitudinal grooves or channels,

having raised dams or *stops* at the distance of every five feet, to facilitate the breaking of the metal. As it runs out of the refinery, it is covered by minute, intensely brilliant, and very numerous coruscations arising from the combustion of a portion of the fluid; these coruscations are accompanied by a brown smoke—a phenomenon also of the BESSEMER process. As the metal runs out, the slag or cinder, which is likewise highly heated, flows after it, forming a layer on the surface of the moulds, and thus prevents further combustion of the iron. Cold water is now thrown on the whole, when the cinder at once froths up and solidifies on the surface, causing it to assume a spongy appearance that distinguishes it from all other kinds of slag formed in the several processes for refining iron. The first charge worked in the refiner is less than the following ones; but the normal weight, about twenty-two hundred-weight, is attained after the third. The number of charges worked every twenty-four hours is eleven or twelve; and the weight of refined metal produced in a week of six days and five nights averages sixty tons, for which about seventy-two tons of pig are required. The produce varies, however, according to the skill of the refiner, the quality of the material used, and the nature of the required product.

Good refined metal has a bright silvery-white fracture, and a radiated structure, the rays springing and diverging from the lower side; it emits a clear metallic sound when struck, is very brittle, with its upper surface indented into a kind of honey-combed structure, the depth of the indentations being dependent on the length of time that the iron has been subjected to the blast. About half an inch deep of honey-comb is considered to indicate the state of refinement best suited for the making of tin plates. It is somewhat curious that, as the refined metal graduates into steel, the honey-comb leaves the face or upper side, and tends to the centre of the horizontally-cast ingot.

The effect of the refining, as before stated, is the removal of the silicium, and of a portion of the sulphur and phosphorus contained in the crude material. The silicium is converted by oxidation into silicic acid, which combines with a portion of the iron oxidized, and forms a fusible slag or cinder on the surface of the metallic bath. The sulphur is converted into sulphurous acid gas, and passes off as such, and the phosphorus into phosphoric acid, which is retained in combination with the oxide of iron in the slag. Very little of the carbon, contrary though it be to the preconceived opinion of iron-masters, is removed during the preceding course of refining, as is sufficiently proved by analysis, and will be evident from an examination of the annexed table showing the composition of different specimens of refined iron:—

	I.	II.	III.	IV.	V.
Carbon.....	3·070	3·250	2·000	3·200	—
Silicium.....	·630	·500	·540	·550	0·32
Sulphur.....	·157	·575	1·250	0·870	0·18
Phosphorus.....	·734	·835	·985	·920	·09
Manganese.....	trace	—	·056	trace	·24
Insoluble residue.....	·530	·050	—	—	—
Iron.....	95·140	96·300	94·255	95·000	—
	100·261	101·510	99·046	100·540	—

Although the above samples were not made from the cast-irons, the analyses of which have been previously given, yet they serve to prove what has been just stated regarding the chemical changes that take place in the fire. By comparing the results of the two series of analyses, it will be found that only one-seventh of the carbon is separated at the same time that one-half of the silicium is removed. On the other hand the sulphur and phosphorus are in larger quantities in the samples of refined than in the crude metal, showing at least that very little if any of these elements are separated, or else that the crude material submitted to the process was of very bad quality. It appears, however, that fully one-third of the content of phosphorus and somewhat more than this amount of the sulphur, with nearly the entire silicium in the pig, are thrown off, the carbon suffering only a slight diminution.

The following analysis shows the nature of the refining cinder thrown off during the operation:—

Silica	23.76
Protoxide of iron	61.28
Oxide of manganese	3.58
Alumina	7.30
Lime	2.41
Magnesia	0.76
Sulphur	0.46
Loss	0.45
	<hr/> 100.00

Besides the foregoing method of refining, two others, long followed to some extent, are known—the first is a modification of BESSEMER'S process, and the second is one patented by Mr. PARRY of the Ebbe Vale Iron Works. In the first, the action of the blast is stopped when the melted iron has passed to the state of refined metal; but as the iron prepared in this way has never been used in the manufacture of tin plates, it will be needless to prolong the description. The metal purified from common Welsh pig contains centesimally—

Sulphur	1.040
Phosphorus	1.128
Silicium	trace

PARRY'S process differs considerably from those referred to. According to it the melted pig-iron is run at once from the blast into a reverberatory furnace very similar to that used in puddling. On each side of this are three or four small tuyeres pointing downwards to the hearth, through which superheated steam is forced at high pressure; they are so arranged that the current will cause a gyration of the surface of the metal, and thereby expose fresh surfaces of it continually to the blast. The action produced is similar to that effected in the ordinary refinery—the oxygen of the steam, together with that passing over the grate, causes the necessary oxidation, and, therefore, the formation of cinder as before. It should be observed that in this process a considerable quantity of rich cinder, such as hammer slags, mill-scales, *et cetera*, is added to the melted metal in the refinery, and the result of the union is that much of the iron in those cinders is reduced and converted into refined metal, so that in most cases the product equals the amount of metal introduced from the melting furnace. This

result is brought about by the carbon in the molten mass acting upon the rich slag, and reducing the iron in it to the metallic state simultaneously with its own consequent conversion into carbonic oxide, in which form it escapes; hence the cinder produced, though abundant, contains less iron than that formed under ordinary circumstances, namely, only thirty per cent. The hydrogen, likewise, has an important effect; it acts upon the sulphur and phosphorus of the metal, and converts these into sulphide and phosphide of hydrogen, which, like the carbonic oxide just mentioned, escape. The metal is thus rendered much purer, and well adapted for the manufacture of tin plates.

The next operation is the refining in the charcoal fire, in a furnace similar to the old blooming fire used in this country previous to the introduction of the puddling process. It consists of a shallow hearth eighteen inches deep, twenty-eight by thirty-two inches at the upper part, and twenty by twenty-one inches at the lower. On one side is placed a Δ -shaped tuyere protected, like the others spoken of, seven or eight inches from the bottom. The tuyere side and that opposite to it are occasionally constructed of *water blocks*, but generally of dry iron plates. Charcoal is the fuel used, and, in recently-constructed works, the products of combustion pass through a chamber at the back of the fire, and there raise the charge of metal to a red heat previous to its introduction into the fire. The refined metal being thus heated, it is drawn down into the fire, the whole of the hearth of which has been previously filled with charcoal, so as to completely cover the tuyere; more fuel is then added, and the blast turned on. In twelve to fifteen minutes the metal begins to melt, and at the end of forty-five minutes it is completely molten and lies on the bottom just under the blast. The workman now proceeds with a bar to break it up and raise it into more immediate contact with the blast, exposing it by this operation on all sides. A small quantity of cinder is thus formed, after which it is tapped off and another charge of heated metal let down and treated in the same way till the whole coheres into one mass. This occurs about an hour after charging. At this period it is usual in most tin works to add a bundle of shavings, cut from the edges of the *black plate* presently to be described. This new addition is very quickly blended with the previously formed *loops* of iron; so that in about ten minutes after adding it, the whole will be in one mass at the bottom of, and nearly filling, the hearth. During this part of the work very little fuel is required, merely sufficient to cover the iron. It is now taken out of the fire and freed from scurf and cinder as much as possible, all the pieces thus separated and the scales from the *helve* being taken back to the fire for the next charge. The loop is first hammered into a roughly cylindrical bloom and then into a flat irregular shape of about two inches thick. In this plate are cut deep grooves parallel with one another, and six inches apart. It is then thrown into cold water to cool, and broken into the rectangular pieces previously roughly indicated by the parallel grooves or notches. The charge of refined metal taken in this operation is about two hundred and seventy pounds, and the loss is such that to make one ton of

charcoal-refined, or stamped iron, as it is sometimes called, requires twenty-two hundreds of refined metal and about eight bags—equal to one hundred and twenty cubic feet—of charcoal. The number of charges worked off in the twenty-four hours averages eighteen.

The effect of this process is to continue, and, in a

great measure to complete, the purification begun in the previously described process, the result being, in fact, crude wrought-iron. The fresh fracture presents very large, bright, and flattish crystals, of a silvery color; and its fitness for the subsequent processes is mainly judged of by its appearance, and by the manner

Fig. 608.

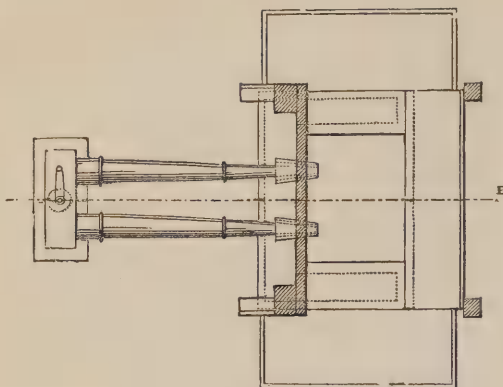
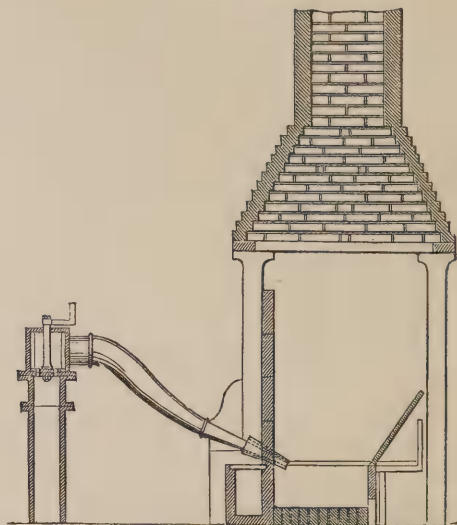


Fig. 609



in which it breaks under the hammer. In fact this is almost the most important operation in the whole series which constitute in the aggregate the manufacture of tin plates; and if it be not properly conducted all subsequent treatment results in loss and vexation. The chemical reactions that are effected are a continuation of the carbon in the iron, and the separation of the sulphur and phosphorus, with other impurities, by the same agency. The similarity between the two methods now treated of and the BESSEMER process must be apparent to every one; the only difference being the presence of carbon in both, the plans described, to prevent the excessive oxidation and loss resulting from the patented method of BESSEMER.

In some works it is usual to run the fluid metal direct to the charcoal fire, and this practice certainly economizes fuel, as all the caloric absorbed in raising the refined metal from its cold state to the melting point must be saved. When this is the case, the refinery is made very much smaller than that before mentioned, and is charged with only six hundredweight of pig, which, when refined, supplies two charcoal fires. This kind of furnace is often called a *running out* or *dandy fire*—Figs. 608 and 609, the former a plan and the latter a vertical section on the line A B of the plan—and is now very generally used. Instead of using charcoal in these fires, it is customary in some localities to use a very light, spongy coke, and this difference gave rise to the terms *coke* and *charcoal* plates, though at present the former name is applied to puddled iron. Coke of this nature has received great attention recently; and there can scarcely be a

doubt of the fact that if this fuel is carefully manufactured from a proper and pure coal, and finished by the action of steam while hot, according to a process lately patented by Mr. R. S. ROPER, it forms as good a fuel as charcoal; and that tin plates made in this way are not to be distinguished in appearance or quality from the charcoal plates.

The charcoal iron next undergoes a reheating and welding process. One of the rough irregularly oblong pieces, weighing about thirty pounds, is laid on a flat plate of iron with a long handle, called the *portal* or *staff*, and placed in the *hollow fire*—shown in elevation in Figs. 610 and 611—where it is raised to a soft welding heat previous to reducing it to blooms. Fine sand is thrown on the surface of the metal from time to time, to remove the oxide or *scale* formed on it by the action of the heat and the free oxygen entering the fire, which scale, if left on it, would interfere with the proper welding. Afterwards it is carried to the hammer and beaten into a bloom, as stated above, and welded to the portal; this is again returned to the hollow fire, three other pieces of the charcoal iron being previously placed upon it, and after its temperature is raised as before, again worked into a bloom six inches wide and two thick under the hammer. This is cut nearly in the middle, and the parts doubled up on one another—reheated—rehammered into a bloom six inches by four—then taken to the hollow fire to be reheated—cut off from the portal—and finally passed several times through a series of grooves in a pair of rollers till it is reduced to a bar or slab six inches wide and half an inch thick. These dimensions,

however, vary slightly particularly the thickness, according to the size and gauge of the plates afterwards to be rolled from them.

The *hollow fire* alluded to is one of the earliest applications of the gas flame to metallurgical purposes, having been in use upwards of seventy years, previous to which an earlier form, was used, and is still employed in the charcoal forges of North Lancashire; in this early form the iron was surrounded by a dome

Fig. 610.

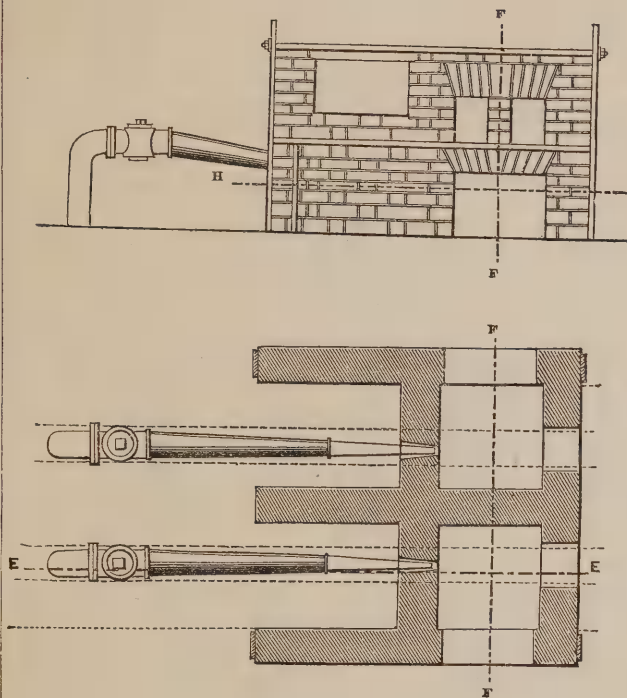


Fig 611.

of ignited fuel, the flame from the combustion of which produced the necessary heat. In the present modification, the furnace is of bricks, and in three divisions—at one end is a space containing ignited coke, into which a continued blast of air is blown by two tuyeres; the flame thus produced passes into the middle position, where the iron to be heated is placed; and the third or middle-end division is intended for the partial heating of said iron by the waste heat, preparatory to its being introduced to the middle division.

The operation just described is a most wasteful one, involving a loss of three or four hundredweight of iron per ton of bars made; and this is the more striking as the material operated on is wrought-iron. It is owing chiefly to the numerous heatings to which the metal is submitted, and the large volumes of oxygen that enter the furnace through its numerous openings, and possibly also the excess of blast blown into the coke. The latter cause of loss might be avoided by care on the part of the workmen; but it is to be feared that the waste can be but slightly diminished while so many

apertures for the entrance of air are allowed to exist. To remedy the evil many experiments have been made to avoid this process altogether, but hitherto without leading to the adoption of any advantageous plan. Mr. WILLIAM DANIEL patented a mode of dispensing with the operation, but it is only partially carried out, though it was in a great measure successful. He directs to put the lump from the charcoal refinery under the hammer, where it is *nobbed* or hammered into a roughly cylindrical bloom, then passed through the rolls and reduced to a bar six inches square and about two feet and a half long. This bar is then either cut or sawn into pieces six inches long, and rolled endwise to give a bar six inches wide, two and a half thick, and twelve long; afterwards this billet is heated in a small balling furnace, and rolled down to a bar a quarter of an inch thick, eleven wide, and about six feet long. This is at once taken to the tin plate mill and made into plates.

It is necessary to revert here to the *coke tin plates*, which name, as already stated, was originally applied to them in consequence of the kind of fuel used in the second refining operation. At present it means those produced from puddled iron rolled into bars similar to those described in the preceding, and called *tin-plate bars* or *tin bars*. In all the subsequent processes the same *modus operandi* is followed, whether the tin bars be made from the puddled or from the hollow fire iron—charcoal tin bars; therefore the following description of the process to which the bars are subjected, previous to, and up to their conversion into tin plates, applies equally to both kinds.

The bars are taken to the shears, where they are cut to proper lengths in accordance with the size of plates to be made—thus for No. 1 c plate, which is $13\frac{1}{2} \times 18$

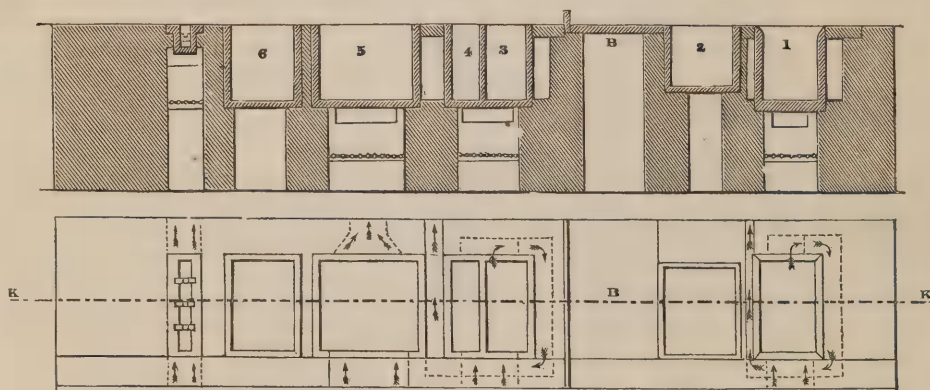
—see table, page 1071, the length of piece will be fifteen inches, the exact dimensions of it being $15 \times 6 \times \frac{3}{8}$ inches. These short pieces are then placed in packs in a reheating furnace, having a very slow draught, and there raised to a dull red heat; they are next passed singly breadthwise several times through a pair of narrow flat rolls; reheated, and then drawn out across the original fibre to a length of five feet and a half. Such plates are then doubled down, and the ragged ends produced in the rolling shaved off. After this they are returned to the furnace and heated to redness, passed through a pair of rollers similar to the last, but more carefully turned to give them a very smooth surface, and there rolled till each is drawn out to five feet—this virtually being two plates five feet long united at one end. The combined plates are again doubled, the waste end sheared off, returned to the fire, and when heated repressed under the rolls till they are extended to about forty-three inches, the entire forming four plates. The operation of doubling, heating, and rolling, is continued sometimes till the original plate is reduced to eight and even sixteen

plates, all passing under the rollers as one. It is to be observed, that great care is required to prevent the plates from being welded either by a too high heat, or from a neglect of partially separating them from time to time, by the rollers. In this way the original piece of bar is rolled into four sheets, each forty-three inches long by fifteen wide. The plate of four, eight, sixteen, or thirty-two thicknesses, or sheets, is then taken, unopened, to a pair of shears, which cut off the two ragged longitudinal edges at one stroke, and at such distances as to determine the length of the tin plates; they are then cut across by the same machine at distances equal to the intended breadth of the same; and thus are obtained four, eight, sixteen, or thirty-two plates in each division of the proper dimensions, still so closely pressed as apparently to be but one. They are next separated, and all the defective ones picked out; such, for instance, as contain streaks of dirt pressed into them, those welded together, and the like, and the choice ones, called in this state *black* plates, are taken to the *pickling* room. Here they are immersed in a bath of warm dilute oil of vitriol during fifteen or twenty minutes, to remove the scale of oxide

on them. The acid leaves them with a clean dullish-grey metallic surface; and to assist the action of the acid in this respect the plates are rubbed with sand and water, and afterwards washed, when they are ready to be sent to the *annealing* house.

It will be readily understood that, after the repeated rollings and the immense strain the plates have been subjected to, they are at this stage very brittle; and therefore, if turned in this state, they would not bear to be hammered into the multitudinous and complex shapes required in commerce. To remove this defect, the process of annealing is had recourse to, and the work is conducted thus:—The plates are placed to the number of about eighteen hundred—for common sizes—in piles, within a cast-iron box about two feet square, the lid carefully luted on to prevent air entering, and then placed with several similarly filled ones in a stove constructed very much in the shape of a reverberatory furnace, but considerably larger, and having its bed on a level with the ground. The fire-bridge being tolerably high, the flame from the grate rolls slowly over the boxes, and raises them gradually to a cherry-red heat, at which temperature they are main-

Fig. 612.



tained during twelve hours, and then withdrawn. When quite cold, the covers are taken off, the plates taken out, carefully examined, and sorted. If the heat has been too high, some of the plates will be found adhering to one another; if too mild, they will not be much improved by the operation, and if air should have entered, they will be either partially or completely converted into scale or oxide of iron. After being subjected to this process, the plates will have a deep plum-color bloom on their surfaces, due to a very thin film or coating of oxide that has formed upon them. They are now passed three times through a pair of rolls similar in form to those previously described, but with which great pains have been taken, to make their surface hard, smooth, and brilliantly polished. Then rolls are placed in close proximity, so that the plates passing between them are subjected to a very great pressure, but not sufficient to enlarge them. After having been thus *cold rolled*, as it is termed, the plates are extremely smooth, and possessed of a lustrous and dappled appearance, still owing to

the thin oxidation. One effect of this rolling is to make the plates brittle once more, and therefore to necessitate a second annealing, which is performed in the same way as the preceding; but the heat is milder, and the time reduced to five or six hours. Another sorting follows, when the good plates are sent to the *tin house*, and the defective ones returned with the shearings of the *black* plates to the *charcoal fire*.

In the tin house the plates are again *pickled* in a warm but more dilute bath of oil of vitriol than that already used, during ten minutes, then removed and well rubbed with sand and water, to detach all dirt and scale. They should now have a smooth, perfectly clean, greyish metallic surface, in which state they can be kept in cold water without injury for some time, and are ready for the *tinning*.

TINNING.—The apparatus or *stow*—Fig. 612—for this process consists of a series of baths set side by side, for the convenience of the workmen, each bath having a fire beneath it, to keep the materials they severally contain in a fluid state. These baths

or pots are six in number—namely, 1, the tinman's pot; 2, the tin-pot; 3, the washing or dipping pot; 4, the grease-pot; 5, the cold-pot; and 6, the list-pot. The tinman's pot is full of melted grease, and into this the plates are immersed and left till all moisture upon them is evaporated, and they become completely covered with the grease. It is about two feet long, fifteen inches wide, and twenty inches deep. From the tinman's pot the plates are removed to the tin-pot, and plunged into the bath of melted tin, protected with a layer of grease which it contains, and remain in it for about twenty minutes. This pot has a capacity of $22 \times 18 \times 16$ inches. In the first dipping the alloy is imperfect, and the surface not uniformly coated, consequently the plates are removed to the dipping or wash pot, which is divided into two compartments. The first immersion takes place in the larger division, which contains molten tin covered with grease like the last, and here the plate is left sufficiently long to make the alloy complete, and to separate any superfluous tin which might have adhered to the surface. The workman then takes out each plate separately to a table between the wash-pot and the grease-pot, and wipes it on each side with a brush of hemp to remove any excess of tin; to obliterate the marks of the brush, he dips it quickly into the second compartment of the wash-pot, and then at once into the grease-pot. This second compartment of the wash-pot always contains the purest tin; and as it becomes alloyed with iron, it is removed to the first compartment of the same, and thence to the tin-pot. The grease-pot is filled with melted grease; and great care is necessary to maintain it at the proper temperature. Its purposes are to allow any superfluous tin to run off, and especially to prevent the alloy on the surface of the plate cooling more rapidly than the iron. If this were neglected, its surface would be cracked. After ten minutes' immersion in the grease-pot the plate is removed to the cold-pot, which is filled with tallow heated to a comparatively low temperature. The pots 4 and 5 serve the purpose of annealing the plates, and of cooling them down

to a low temperature. The last one in the series is the list-pot, and is a small cast-iron bath kept at a sufficiently high temperature, its bottom covered with tin to the depth of a quarter of an inch. In this the edges of the plates are dipped and left in till the wire of tin, which usually forms on them in the course of the foregoing processes, melts, and is removed by a quick blow on the plate with a stick.

The articles are now tin plates; but before they are sent to market, they undergo some further treatment. Firstly, they are carefully rubbed with bran to clean them from grease and dirt; secondly, they receive another rubbing with a pad of sheep-skin, retaining its wool; and thirdly, they are sent to the sorter, whose duty it is to pick out defective plates, and to arrange the good ones in piles according to their size and quality. They are finally packed in boxes, which are branded on the outside with the marks indicating the size and quality of the plates, and sent to market.

Quality of Tin Plates.—The tests for tin plates are ductility, strength, and color; and to possess these, the iron used must be of the best quality, and all the process be conducted with care and skill. The following conditions are inserted in some specifications, and will serve to indicate the strength and ductility of first-class tin plates:—

1st, They must bear cutting into strips of a width equal to ten times the thickness of the plate, both with and across the fibre, without splitting; the strips must bear, while hot, being bent upon a mould to a sweep equal to four times the width of the strip.

2nd, While cold, the plates must bear bending in a heading machine, in such a manner as to form a cylinder, the diameter of which shall at most be equal to sixty times the thickness of the plate. In these tests, the plate must show neither flaw nor crack of any kind.

The following table exhibits the usual brands and their value in dimensions of plate, number, and weight per box, and may be found useful for reference:—

TABLE OF MARKS, WEIGHTS, AND DIMENSIONS OF TIN PLATES.

Name.	Size. Inches. inches.	Number in box.	Weight of box.			Mark or brand.
			wt.	qr.	lbs.	
Common, No. 1,.....	$13\frac{3}{4} \times 10$	225	1	0	0	I C
" No. 2,.....	$13\frac{1}{4} \times 9\frac{1}{2}$	"	0	3	21	II C
" No. 3,.....	$12\frac{3}{4} \times 9\frac{1}{2}$	"	0	3	16	III C
No. 1, cross,.....	$13\frac{3}{4} \times 10$	"	1	1	0	I X
No. 1, 2 ".....	"	"	1	1	21	I X X
No. 1, 3 ".....	"	"	1	2	14	I X X X
No. 1, 4 ".....	"	"	1	3	7	I X X X X
Common doubles,.....	$16\frac{3}{4} \times 12\frac{1}{2}$	100	0	3	21	C D
Cross doubles,.....	"	"	1	0	14	X D
2 cross doubles,.....	"	"	1	1	7	X X D
3 ".....	"	"	1	2	0	X X X D
4 ".....	"	"	1	2	21	X X X X D
Common small doubles,.....	15×11	200	1	2	0	C S D
Cross ".....	"	"	1	2	21	X S D
2 cross ".....	"	"	1	3	14	X X S D
3 ".....	"	"	2	0	7	X X X S D
4 ".....	"	"	2	1	0	X X X X S D
Wasters, common No. 1,.....	$13\frac{3}{4} \times 10$	225	1	0	0	I C W
" cross No. 1,.....	"	"	1	1	0	I X W
" common small doubles,.....	15×11	200	1	2	0	C S D W
" common doubles,.....	$16\frac{3}{4} \times 12\frac{1}{2}$	100	0	3	21	C II W
" cross doubles,.....	"	"	1	0	14	X II W

The Editor thankfully acknowledges his obligations to his late talented pupil, Mr. R. S. ROPER, for his assistance in preparing the preceding remarks on tin plates.

ULTRAMARINE.—*Outremer*, French; *Lazurstein*, German.—This is one of the most beautiful pigments known, and its artificial production is justly viewed as belonging to the greatest triumphs of modern chemistry. It is obtained by isolating the coloring matter of lapis-lazuli, outremer, or lazurstein, mostly brought from China, Thibet, and the shores of Lake Baikal. It is a mineral of indeterminate composition, as will be seen from the annexed analyses—

	Gmelin.		Dann.
Silicic acid,	49·00	....	45·50
Sulphuric acid,	2·00	....	5·90
Alumina,	11·00	....	31·80
Soda,	8·00	....	9·10
Lime,	16·00	....	3·50
Magnesia,	2·00	....	—
Sesquioxide of iron,	4·00	....	0·80
Sulphur,	trace	....	—
Water,	trace	....	—
Chlorine, .....	—	....	0·40
Loss,	8·00	....	2·00
	100·00	....	100·00

Lazulite often contains scales of mica and iron pyrites. It is found in masses, more or less pure, generally in small volume, fragile, but capable of scratching glass, of granular texture, imperfectly laminated, and almost transparent at its edges. It crystallizes in dodecahedrons, with rhombic faces, but the crystals are rare—specific gravity, 2·50 to 2·96. The hue, which occurs in isolated places, merges from celestial to pure blue and indigo purple. It is usually disseminated in a rock, which contains many other laminated substances, among which is a fine white lazulite. In the *Musée Mineralogique* at Paris are two fine specimens of lazulite, in which is seen the transition from the azure to the white. TOMLINSON remarks that the iron pyrites sometimes propagated in lazulite, is of a bright yellow hue, helping to relieve the lustre of the blue, and they have often been mistaken for pellets of gold; in fact, the cause of its intense blue color was long a matter of controversy. No traces could be detected of cobalt, copper, or any other element or compound known to impart an azure tint. The existence of an unknown protoxide of aluminium— AlO —was even assumed as a means of solving the difficulty; and not until ultramarine had been prepared artificially, and the synthetic proof had thus been superadded to the analytical, was it admitted that a blue tint could be produced by the union of three colorless bodies—*alumina, sulphur, and soda*.

CLÉMENT and DÉSORMES published an analysis of this substance in 1806; they admit, of course, the great difficulty experienced in analyzing ultramarine. They regarded it to have the following composition, which is in many respects similar to the results obtained by WILKENS, and subsequently given—

	Centesimally.
Silica,	35·80
Alumina,	34·80
Soda,	43·20
Sulphur,	3·10
Carbonate of lime,	3·10
	100·00

The great cost of ultramarine, and the unparalleled effects which it produces in painting, rendered it most

desirable to produce this compound artificially. Chemists were for some time baffled by the discordant results each obtained, and were thereby unable to distinguish which of the ingredients of ultramarine were essential, and which accidental or superfluous.

The first step, says TOMLINSON, towards the production of this pigment artificially was in 1814. VAUQUELIN, in visiting the plate-glass works at St. Gobain, was informed by the director of the sulphuric acid and soda department of the establishment, that, in taking down the soda furnaces a blue mass was found when *grés*—gritstone—was employed in the formation of the sole, but there was no such deposit when the sole was of brick. The Editor has often remarked in black-ash furnaces the production of ultramarine; in fact, all recent analyses of this substance give about one per cent. of this blue pigment. VAUQUELIN took some of the compound, reduced it to powder, and, washing it, found it was decolored by the mineral acids, with the disengagement of sulphide of hydrogen; that it was not attacked by boiling alkaline solutions, nor destroyed at a red heat. This chemist further states, that though the composition of this artificial product is unlike that of lapis-lazuli, yet he is not without a hope that the circumstance may lead to the production of ultramarine artificially. This observation, and the suggestion founded upon it, appears to have been forgotten for nearly fourteen years. To GMELIN of Tübingen the honor of the discovery of artificial ultramarine is generally said to be due; but, as TOMLINSON remarks, if the question of priority were raised, then it must be claimed by the *Société d'Encouragement* of Paris, who offered a prize of six thousand francs for the manufacture of ultramarine. GUIMET obtained the prize in 1828, on which occasion he communicated his recipe confidentially to GAY-LUSSAC.

To prepare the pigment lapis-lazuli, freed from all mechanical impurities, is gently ignited, slaked in water, and reduced to an extremely fine powder. This is now incorporated with a melted paste called *pastelle*, consisting of linseed oil, wax, and resin, and kneaded under cold water. Ultramarine gradually deposits in the vessel as a dark-blue powder, which grows brighter by degrees, whilst the impurities remain entangled in the *pastelle*.

The color thus obtained is of necessity very expensive, from the rarity of the material, and from the tedious and wasteful mode of producing it.

The preparation of artificial ultramarine has undergone many modifications since the experiments of GMELIN. BRUNNER mixes seventy parts of silica, two hundred and forty of burnt alum, forty-eight of charcoal powder, one hundred and forty-four of flowers of sulphur, and two hundred and forty of anhydrous carbonate of soda, all reduced to an impalpable powder; puts the mixture in a Hessian crucible, and lutes down the cover. The crucible is heated to moderate redness, and kept steadily at that temperature for an hour and a half, and then suffered to cool. If the operation has succeeded, the mass has a loose, half-fused appearance, and a greenish or reddish-yellow hue. If solid, fused, and brownish, the heat has been too high. The mass is taken out of the crucible, and washed till the liquid has no longer a sulphurous taste. The residue, a dark

greenish-blue powder, is filtered, dried, mixed with its own weight of sulphur, and one and a half times its weight of anhydrous carbonate of soda, and heated as before. The residue is boiled with water for some time, filtered, and washed till the liquid no longer blackens carbonate of lead. The dried powder is sifted, and submitted to the following final process:—A plate of cast-iron is covered to about the depth of a line with pure sulphur, upon which the compound is sifted to about an equal depth. The plate is then cautiously heated till the sulphur takes fire. The residue is removed from the plate, again pulverized, and resubmitted to the same treatment with sulphur, until the color is found satisfactory.

PRUCKNER adopts a somewhat modified process. Sulphide of sodium is prepared by igniting sulphate of soda with charcoal powder. This is dissolved in water, some free sulphur is added, the liquid is concentrated, mixed with one half per cent. of sulphate of iron and twenty-five per cent. of a well-tempered clay—the purer and whiter the better—the mixture evaporated to dryness, the residue powdered, and ignited for an hour in a cupelling furnace; when cold, it is extracted with water, the residue dried, powdered, and once more heated in a muffle, when the required tint appears.

A still further simplification is to ignite sulphate of soda with charcoal powder and clay in a crucible, with slight access of air.

TREMON's recipe for this pigment is the following:—One thousand and seventy-five parts of crystallized carbonate of soda are fused in their own water of crystallization, and the fused mass mixed by stirring, first with five parts of red sulphide of arsenic, then with a quantity of hydrate of alumina, prepared from alum by precipitation with carbonate of soda, and containing seven parts of anhydrous alumina, and lastly, with a mixture of one hundred parts of sifted clay, and two hundred and twenty-one parts of flowers of sulphur. The mass, after being intimately mixed and evaporated to dryness, is introduced into a crucible provided with a good cover, and gently heated at first, in order to expel the remaining traces of moisture, the temperature being afterwards raised to full redness. The mass should cake together without fusing. If the materials have not been properly mixed, the whole will exhibit white spots; and if it has been fused, it is studded with brown ones. After cooling it is roasted, in order to expel the greater portion of the sulphur, then reduced to powder, and washed slightly on a filter with cold water. The bluish-green powder thus obtained is again roasted for an hour or two, with occasional stirring, in covered basins, at a temperature never exceeding low redness. According to ELSNER, a very small quantity of iron, such as is usually contained in the ingredients, is *essential to the production of the hue*, but excess is injurious. A mixture of one part of clay, perfectly free from iron, with one part of sulphur and two parts of anhydrous carbonate of soda, yields a yellowish mass when ignited; but if a trace of sulphate of iron is added to the mixture, a mass is obtained which is black, green, or blue, according to the degree of heat to which it has been subjected. When potassa is used instead of soda, GMELIN states the blue tint is not obtained.

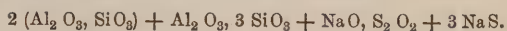
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Before the analysis by MARGRAF, the color of ultramarine had been attributed to the presence of copper, but this chemist only found sulphuric acid, lime, and iron; others suspected, naturally enough, the presence of cobalt; others again, hydrofluoric acid. KLAPROTH's results indicated the following:—

Carbonate of lime,	28.00
Sulphate of lime,	6.50
Alumina,	14.50
Silica,	46.00
Sesquioxide of iron,	3.00
Water,	2.00
	100.00

GUYTON thought that the coloring matter was a blue sulphide of iron.

Pure ultramarine, according to WILKENS, has the composition—



It should contain, therefore, theoretically—

	Per cent.
Silica,	38.75
Alumina,	26.37
Sulphur,	13.68
Soda,	21.20
	100.00

an assumption which agrees pretty closely with the actual analysis of the purest samples. A variety of substances, such as iron, lime, potassa, magnesia, sulphuric acid, and chlorine, may be present as impurities, and were, in part at least, purposely added by the earlier manufacturers; but they are found to be perfectly unnecessary. The coloring matter appears to consist of hyposulphite of soda and sulphide of sodium. If the firing be conducted in porous crucibles, the coloration of the mass is generally unequal.

GREEN ULTRAMARINE.—Ordinary ultramarine, on ignition with saltpetre, assumes a green color. Green portions, more or less in quantity, are frequently formed in the crucibles, especially on the first ignition. On repeated heating it passes into a blue tint. Artificial ultramarine is, however, very rarely entirely freed from all traces of the green modification, and hence it is, for the most part, less beautiful than the natural variety.

Ultramarine is readily decomposed by acids, with evolution of sulphide of hydrogen, and total destruction of the color. At a high temperature this effect is even produced by silica, whence the unfitness of ultramarine for painting on glass and porcelain. Solutions of potassa and soda have no decomposing action, even at a boiling temperature. By a prolonged red heat ultramarine is rendered perfectly white, and then no longer evolves sulphide of hydrogen on the addition of an acid.

Tests.—Purchasers frequently judge of the comparative value of samples of ultramarine by mere inspection—a most fallacious method. The eye may indeed decide on the purity of the blue, but it can give very little notion of its depth. In other words, it is impossible to determine, by mere inspection, how far a sample has been let down with some colorless substance. It is better to take equal weights of the respective samples under examination, and to grind up each with

6 U

ten to twenty times its weight of gypsum. When thus let down, a difference in the depth of color becomes perceptible.

BERNHEIM prepares a normal solution by mixing one ounce of concentrated sulphuric acid with twenty grains of water; equal weights—fifty to one hundred grains—if the various samples to be examined are next taken, and each placed in a separate glass. The normal liquor is now added from a graduated burette until the blue color is converted into a reddish one, and no blue particles are perceptible. The quantity of sulphuric acid consumed in each case shows the relative value of the sample. If cobalt is present, the blue color of the sample cannot be completely destroyed by the acid.

Uses.—Ultramarine is employed as a pigment by artists and decorators. Under certain circumstances, however, it gradually loses its color if ground with oil. It is also used in printing cotton and woollen goods, being fixed to the fibre either by solutions of albumen and casein, or by shell-lac varnishes. It is abundantly employed as a *powder-blue*, in getting up white cotton and linen goods. For this purpose it is ground up with soda-ash, chalk, gypsum, or any other cheap white matter, and sold sometimes under its own name, but more frequently as superfine Saxon smalts. This fraud is much in vogue in a sea-port town on the Eastern coast of England notorious for its manufacture of inferior and spurious colors. The detection is not difficult, since hydrochloric acid at once destroys the color of ultramarine, whilst it is without action upon genuine smalts.

VARNISH.—*Vernis*, French; *Firniss*, German.—In the commonest acceptation of the term, a varnish consists of a resin of some description dissolved in a fluid more or less volatile, which, on evaporation, leaves the resin in the form of a lustrous film. It is generally applied by means of a brush in successive coats, and is laid on in the direction of the fibres of the wood. The most desirable feature of a good varnish is durability, dependent upon the quality of the resin and its solvent.

The principal substances employed in making varnishes are the following:—

SOLVENTS.

Oil of nuts—alcohol.
Oil of linseed—ether.
Oil of turpentine—wood-spirit, pyroxilic alcohol, or hydrated oxide of methyle.
Oil of rosemary—methylated spirit.

SOLIDS.

Amber,	Colophony,	Elemi,
Anime,	Copal,	Lac,
Benzoin,	Damara,	Mastic,
	Sandarac.	

COLORS.

Aloes,	Dragon's blood,	Red saunders,
Anatto,	Gamboge,	Saffron,
Cochineal,	Indigo,	Turmeric.

The spirituous varnishes dry most rapidly; this advantage is, however, partly counterbalanced by their aptitude to crack and to peel off. This defect is partially remedied in the turpentine varnishes which dry more slowly. But in those called *oil-varnishes*, this defect is alone entirely obviated: in these a small quan-

tity of a drying oil is added to the solution of the resin in rectified spirit of turpentine; and although they take a longer time to dry, they are all the more durable.

Before treating of the various varnishes, a description will be given of the chief resins before mentioned, as being employed in the manufacture:—

Amber is most distinguished for durability. It is usually of some shade of yellow, transparent, hard, and moderately tough. Heated in air it fuses at about 549°; it burns with a clear flame, emitting a pleasant odor. When pounded, absolute alcohol extracts succinic acid and resin; the latter to the extent of about one-eighth of the weight of the amber. In fact, amber is a mixture of several resins. It resists the action of solvents so greatly, that it requires to be fused and kept in a state of fusion—for oxidation—at a somewhat high temperature before it is fitted for making amber-varnish. The costliness of amber, as well as the length of time it takes to dry, are the chief objections to it.

Anime is imported from the East Indies. The large, transparent, pale-yellow pieces, with vitreous fracture, are best suited for varnish. Inferior qualities are employed for manufacturing gold-size or japan-black. Although superior to amber in its capacity for drying, and equal in hardness, varnish made from anime deepens in color on exposure to air, and is very liable to crack. It is, however, much used for mixing with copal varnish.

Benzoin is a gum-resin but little used in varnishes on account of its costliness. The finer sorts are brittle, pulverulent, with conchoidal fracture; they fuse at a gentle heat.

Colophony is synonymous with arcanson and rosin. When the resinous juice of *Pinus sylvestris* and other varieties is distilled, colophony remains in the retort. Its dark color is due to the action of the fire. Dissolved in linseed oil or in turpentine by the aid of heat, colophony forms a brilliant, hard, but brittle varnish.

Copal is a gum-resin of immense importance to the varnish-maker. It consists of several minor resins of different degrees of solubility. In durability it is only second to amber; when made into varnish, the better sorts become lighter in color by exposure to air.

Copal is generally imported in large lumps about the size of potatoes. The clearest and palest are selected for what is called *body-gum*; the second best forms *carriage-gum*; whilst the residue, freed from the many impurities with which it is associated, constitutes *worst quality*, fitted only for japan-black or gold-size.

Copal is tasteless and inodorous; transparent and of conchoidal fracture. Heat softens it without rendering it viscid. In alcohol it is but little soluble; but it is said to become more so by reducing it to a fine powder, and exposing it to atmospheric influences for twelve months. Boiling alcohol or spirit of turpentine, when poured upon *fused* copal, accomplishes its complete solution, provided the solvent be not added in too large proportions at a time. The addition of camphor also promotes the solubility of copal; so likewise does oil of rosemary.

Dammara is a tasteless, inodorous, whitish resin, easily soluble in oils. It is not so hard as mastic, with which it forms a good admixture.

Elemi is a resin of a yellow color, semi-transparent,

and of faint fragrance. Of the two resins which it contains, one is crystallizable and soluble in cold alcohol.

Lac constitutes the basis of spirit-varnish. The resin is soluble in strong alcohol aided by heat. Its solution in ammonia may be used as a varnish, when the articles coated with it are not exposed more than an hour or two at a time to water.

Mastic is a soft resin of considerable lustre. The two sorts in commerce are, *in tears* and the *common mastic*; the former is the purer of the two. It consists of two resins—one of which is soluble in dilute alcohol. With oil of turpentine it forms a very pale varnish of great lustre, which flows readily and works easily. Moreover, it can be readily removed by friction with the hand; hence its use for delicate work of every description.

Sandarac is a pale odorous resin, less hard than lac with which it is often associated as a spirit-varnish. It consists of three resins differing as to solubility in alcohol, ether, and turpentine. It forms a good pale varnish for light-colored woods; when required to be polished, Venice turpentine is added to give it body.

Of the solvents of these various resins little need be said. In the manufacture of varnishes great care, as well as cleanliness, are required. The resins should be washed in hot water, to free them from particles of dust and dirt; they should be dried and assorted according to their color, reserving the lightest shades for the best kinds of varnish.

The *linseed-oil* should be as pale-colored, and as well clarified as possible. New oil always contains mucilage, and more or less of foreign matters; as these prevent the regular absorption of oxygen, the oil requires preliminary treatment. The common plan is to boil it with litharge; but such *oil varnish* is inferior to that prepared with sulphate of lead.

The best method is to rub up linseed-oil with dry sulphate of lead in sufficient quantity to form a milky mixture. After a week's exposure to the light and frequent shaking, the mucos deposits with the sulphate of lead, and leaves the oil perfectly clear. The precipitated slime forms a compact membrane over the lead, hardening to such an extent that the clarified oil may be readily poured off.

Turpentine is of very extensive use. The older it is, the more ozonized, the better it is. Turpentine varnishes dry much more readily than oil varnishes, are of a lighter color, more flexible and cheap. They are, however, neither so tough nor so durable.

Alcohol is employed as the solvent of sandarac and of lac. The stronger, *ceteris paribus*, the better.

Naphtha and *methylated spirit of wine* are used for the cheaper varnishes. Their smell is disagreeable. The former is, however, a better solvent of resins than alcohol.

SPIRIT VARNISHES.—Mix—

Alcohol	500 parts.
Ether.....	60 "

Heat in a flask, and suspend therein from a bag, one hundred and twenty parts of finely-divided well oxidized copal. Continue the heat until complete solution takes place.

Such a varnish combines brilliancy and transparency with considerable hardness and solidity. As color is easily generated over the fire, the materials are best digested in a water bath. Such a varnish is, however, only suitable for fancy articles, and is, after all, not equal to a mixture of resins.

A VARNISH FOR PAPER, MAPS, ET CETERA.

	Parts
Spirit of wine,	32
Mastic,	6
Sandarac,	3
Venice turpentine,	3
Pounded glass,	4

Mix the pounded mastic, sandarac, and glass thoroughly together, and place them in a tinned copper digester. Add the alcohol, stir well and frequently with a wooden spatula, and heat for several hours in a water bath. When the solution is complete, add the turpentine, stir frequently, continuing the heat for an hour, and strain when cold through a cloth.

This method is applicable to all spirit varnishes.

A WHITE SPIRIT VARNISH FOR VIOLINS.

Spirit of wine,	One gallon.
Mastic,	Two pounds.
Turpentine varnish,	One pint.

A VARNISH FOR WHITE WOODS.

Bleached shellac,	Three pounds.
Spirit of wine,	Two and a half gallons.

The shellac should be first dissolved in a gallon of the spirit, and the rest added after straining.

ANOTHER VARNISH FOR MUSICAL INSTRUMENTS.

	Parts.
Spirit of wine,	32
Sandarac,	4
Pounded glass,	4
Seedlac,	2
Mastic in tears,	2
Venice turpentine,	2
Elemi,	1

These varnishes may be readily colored—*red*, by dragon's blood; *yellow*, by gamboge. If a colored varnish is required, clearly no account need be taken of the color of the resins. Lac varnish may be bleached by Mr. LEMMING's process:—Dissolve five ounces of shellac in a quart of spirit of wine; boil for a few minutes with ten ounces of well-burnt and recently-heated animal charcoal, when a small quantity of the solution should be drawn off and filtered: if not colorless, a little more charcoal should be added. When all tinge is removed, press the liquor through silk, as linen absorbs more varnish; and afterwards filter it through fine blotting-paper. Dr. HARE proceeds as follows:—Dissolve in an iron kettle about one part of pearlash in about eight parts of water, add one part of shell or seed lac, and heat the whole to ebullition. When the lac is dissolved, cool the solution, and impregnate it with chlorine gas till the lac is all precipitated. The precipitate is white, but the color deepens by washing and consolidation. Dissolved in alcohol, lac bleached by this process yields a varnish which is as free from color as any copal varnish.

One word in conclusion with reference to all spirit varnishes. A damp atmosphere is sufficient to occasion a milky deposit of resin, owing to the diluted spirit

depositing a portion : in such case the varnish is said to be *chilled*.

ESSENCE VARNISHES.—They do not differ essentially in their manufacture from spirit varnishes. The polish produced by them is more durable, although they take a longer time to dry.

Table Varnish may be made as follows :—

Damma resin,	1 pound
Spirits of turpentine,	2 pounds
Camphor,	200 grains

Digest the mixture for twenty-four hours. The decanted portion is fit for immediate use.

COMMON TABLE VARNISH.

Oil of turpentine,	1 pound
Bees' wax,	2 ounces
Colophony,	1 drachm

COPAL VARNISH FOR INSIDE WORK.

Pounded and oxidized copal,	24 parts
Spirit of turpentine,	40 "
Camphor,	1 "

FLEXIBLE COPAL VARNISH.

Copal in powder,	16 parts
Camphor,	2 "
Oil of lavender,	90 "

Dissolve the camphor in the oil, heat the latter, and stir in the copal in successive portions until complete solution takes place. Thin with sufficient turpentine to make it of proper consistence.

OIL VARNISHES.—These, the most durable and lustrous of varnishes, are composed of a mixture of resin, oil, and spirit of turpentine. The oils most frequently employed are linseed and walnut ; the resins chiefly copal and amber, but also the others already recorded.

The drying power of the oil having been increased by litharge, red-lead, or by sulphate of lead, and a judicious selection of copal having been made, it is necessary, according to BOOTH, to bear in mind the following precautions before proceeding to the manufacture of varnish :—1. That oil varnish is not a solution, but an intimate mixture of resin in boiled oil and spirit of turpentine. 2. That the resin must be completely fused previous to the addition of the boiled or prepared oil. 3. That the oil must be heated from 250° to 300°. 4. That the spirit of turpentine must be added gradually and in a thin stream, while the mixture of oil and resin is still hot. 5. That the varnish be made in dry weather, otherwise moisture is absorbed, and its transparency and drying quality impaired.

The heating vessel must be of copper, with a rivetted and not a soldered bottom. To promote the admixture of the copal with the *hot* oil, the copal—carefully selected and of nearly uniform fusibility—is *separately* heated with continuous stirring over a charcoal fire. Good management is required to prevent the copal from burning or becoming even high colored. When completely fused, the heated oil should be gradually poured in with constant stirring. The *exact* amount of oil required must be determined by experiment. If a drop upon a plate, on cooling, assumes such a consistency as to be penetrated by the nail without crack-

ing, the mixture is complete ; but if it cracks, more oil must be added.

The spirit of turpentine *previously heated* is added in a thin stream to the former mixture, care being taken to keep up the heat of all the parts. With proper attention to these directions, the following prescriptions from DUMAS, TOMLINSON, BOOTH, and others, will be found of use :—

COPAL VARNISH FOR FINE PAINTINGS.

Gum copal, fused,	8 pounds
Linseed oil, heated to 250°,	2 gallons

Boil for about a quarter of an hour, until the mixture strings strongly, and then add spirit of turpentine, hot, three gallons. Although much loss of turpentine ensues, the varnish will be so much the more transparent, durable, and drying.

CABINET VARNISH.

Copal, fused,	14 pounds
Linseed oil, hot,	1 gallon
Turpentine, hot,	3 gallons

Properly boiled, such a varnish will dry in ten minutes.

BEST BODY COPAL VARNISH.

Copal, fused,	8 pounds
Linseed oil,	2 gallons
Turpentine, hot,	3½ "

The mixture must be slowly boiled for five hours until quite stringy, and subsequently mixed with the heated turpentine. This varnish is well suited for all objects intended for polishing.

In preparing *artists' copal varnish* it is advisable to separate the particles of copal by means of pounded glass, to prevent the gum from adhering, so that a moderate fire will suffice. The older the turpentine the more drying the varnish. Take—

Finest picked copal,	3 pounds
Pounded glass,	2 "
Linseed oil,	3 quarts
Spirit of turpentine,	5 "

All the before-mentioned varnishes are recommended to be made with clarified, but not otherwise prepared oils. Consequently they take long to dry, and cannot be polished for months. Anime is often introduced to hasten the hardening of the varnish, in the proportion of one part to two of copal. But such varnish is less durable. A yet inferior copal varnish contains anime in the proportion of two parts to one of the former.

WAINSCOT VARNISH FOR HOUSE PAINTING AND JAPANING.

Anime,	8 pounds
Clarified linseed oil,	3 gallons
Litharge,	½ pound
Acetate of lead,	½ pound
Sulphate of copper,	¼ pound

All these materials must be carefully but thoroughly boiled together until the mixture becomes quite stringy, and then five and a half gallons of heated turpentine stirred in.

Such a varnish is, of course, every way inferior to one made with a carefully prepared drying oil, as above prepared by the aid of sulphate of lead. But it exsiccates very rapidly, and is well suited to the common purposes

for which it is intended. It can be easily deepened in color by the addition of a little gold-size.

The varnish used in India for palanquins is made by melting a kind of sandarac, and mixing it with boiling and drying linseed oil. Mr. RHODE, in *Balfour's Cyclopædia*, knows of no better or more durable polish for teak and chittagong wood particularly, than may be prepared by melting three or four bits of sandarac, of the size of a walnut or small egg, and pouring upon it a bottle of boiling linseed oil previously rendered drying by boiling litharge or other dryer, and after boiling them together gently for an hour, adding while cooling a teaspoonful of venice turpentine. If too thick, it may be thinned with spirit of turpentine. It should be rubbed on the furniture, and after a little time—during which it may be exposed to the sun—rubbed off. The friction should be continued daily, and the polish should not be again applied for eight or ten days; after which it may be slightly applied every one or two months. Water does not injure this polish, and any stain or scratch may be rubbed over, which cannot be done with French polish. To give the appearance of gold to silver leaf used by the Condapilly Moochies, for ornamenting boxes, palanquins, *et cetera*, a little aloes is dissolved in the varnish, which is laid over it. A very good varnish is prepared by Moochies with shell-lac and wood oil, heated in small quantities.

French polish is employed upon flat surfaces, and consists simply of a solution of resin in spirit of wine. The simplest sort of French polish may be made by dissolving one and a half parts of shell-lac in eight parts of spirit of wine. Such a polish is very durable, but many other gum-resins are employed. A good dark-colored polish is prepared from one pound of shell-lac, half a pound of gum-benzoin, and one gallon of spirit of wine. Others recommend twelve ounces of shell-lac, three ounces of copal, six ounces of gum-arabic, to one gallon of spirit.

The *lacker* used for wood work or brass is also a varnish. For brass the proportions are half a pound of pale shell-lac to one gallon of spirit of wine. It is better prepared without the aid of heat, by simple and repeated agitation. It should then be left to clear itself, and separated from the thicker portions and from all impurities by decantation. As it darkens on exposure to light, the latter should be excluded. A pale yellow lacker may be made by mixing one ounce of gamboge, and two ounces of Cape aloes, with one pound of shell-lac. For a bright yellow half a pound of turmeric and two ounces of gamboge are required; for a red lacker, half a pound of dragon's blood and one pound of annatto. It need scarcely be said that the color will also be modified by that of the lac employed.

WATER.—*Eau*, French; *Wasser*, German; *Aqua*, Latin.—The poet SOUTHEY thus appositely writes of this all-important fluid:—

Most blessed water! neither tongue can tell
The blessedness thereof; no heart can think,
Save only those to whom it has been given
To taste of that divinest gift of heaven.

In the very first record of that fiat of the Creator, which called forth by omnipotent volition the innu-

merable planetary bodies distributed in infinite space, the primary matter especially mentioned is water: *And the Spirit of God moved upon the face of the waters.* Whether the circumstances of the creation, as related in Genesis, differ from the order observed in giving form to, and producing diversity of, objects upon the earth by the *great First Cause*, is a question which does not affect one way or another, the subject of the present article; although the study of the disposition of the principal objects within the limited range of man's sphere of inquiry, geographically and geologically considered, demonstrates most conclusively, that water has fulfilled functions in the formation of mineralized and other strata in the solid crust of the earth, of undeniable importance. It is not previous to the generation of vegetal and animal life, however, that the importance of water, as an abundant and primary constituent of the globe, can be properly estimated; for it is only in the fulfilment of the higher designs of Providence, such, for instance, as the production and sustenance of vegetal and animal life and organization, that any approach to an adequate notion of the great ends which water serves, can be formed. Without water no organized structure, whether of vegetal or animal, could, in the human estimation of things, preserve its functions and reproduce itself in obedience to the great generic law of Nature. Independently of its essential importance in this respect, water serves another purpose only secondary to it—namely, that of distributing a medium temperature over the whole surface of the earth, conformably to certain physical laws which will be subsequently alluded to, thereby insuring a genial warmth which is absolutely necessary for the development of plants and animals. It may be assumed, that for some such or other similar all-wise dispensations, the extent and quantity of water on the globe greatly surpasses that of the land. It is well known that water is capable of combining with caloric to a great degree; and, owing to the superficies of the globe being to the extent of two-thirds, water, it is evident the chief portion of the heat derived from the sun is stored in this liquid, for the purpose merely of being eliminated gradually to compensate the earth for that which, owing to its superior radiating power, it gives off so freely as to chill it to a degree prejudicial to organized life, unless supplied by winds or air-currents, passing over the surface of large tracts of waters. This capacity of storing caloric possessed by water is subservient in other respects, not only for equalizing the heat of the habitable portions of the globe, but for the distribution of the liquid itself over the arid parts of the earth. For instance, the warm rays of the sun would be unendurable in the torrid zone, were it not that in these regions large quantities of water are evaporated, and that every unit of it thus converted into vapor renders latent or insensible above one thousand units of heat, thus beautifully neutralizing the violent effect of the sun's intense rays. Again, the aeriform moisture ascends obedient to its expansive force, and diverges laterally to colder regions, where the water having parted with a great portion of its acquired temperature, condenses into clouds, and finally falls as rain, hail, or snow, to refresh and nourish life in its multifarious varieties;

whilst a current of air from colder regions loaded with water rushes to the locality whence it was driven, to compensate the loss of moisture, and maintain the equilibrium of temperature. Thus is a beautiful provision for the preservation of organic life and the maintenance of a genial warmth sustained, a provision which, from its regularity and precision, is called a physical law, though in reality a divine and beneficent dispensation.

Water is therefore of primary importance as well in the physiology as in the economy of life, and quite as indispensable as the air breathed from the dawn to the close of man's existence; without them all other provisions of nature would, under existing circumstances, be inadequate to sustain vitality.

HISTORY.—In considering water scientifically, it offers a wide and an interesting field of inquiry to the aspiring student. For a long time many earnest minds were misled regarding its nature, nor was it till almost within the span of the present age—namely, in 1781—that its true composition was revealed. Formerly, philosophers, universally following the footsteps of the ancients, regarded it as one of their elements, though, in later times, some among them were found who considered it transmutable into an earth by repeated distillations, in consequence, as LAVOISIER subsequently proved, of the glass vessels in which the operations were performed, undergoing slight disintegration on the surface, and giving rise to a crust of silicious and other matters contained in the glass. Its real nature lay hidden and subject to conflicting hypotheses till, by the superior powers of deduction, aided by a deep and patient penetration into the secrets of phenomena, according to the principles of chemistry as then understood, CAVENDISH, by most conclusive and beautiful researches, as well synthetically as analytically, revealed its true nature as a compound body. Like all other inventions and discoveries of great importance, there were others ready to claim the honor, such as WATT and LAVOISIER; but evidently the principles which they enunciated appear to have originated with CAVENDISH, and had been communicated through PRIESTLEY and others to the forementioned philosophers, previous to the publication of the account of CAVENDISH'S researches on the subject. The light thus shed upon the knowledge of chemical phenomena, might appropriately be placed in juxtaposition with the brilliant lustre emanating from the discovery of oxygen by a PRIESTLEY, or from that of the atomic theory by a HIGGINS and a DALTON. The phenomena attending the combustion or explosion of hydrogen gas in common air, and the endeavors of WARLTIRE to deduce from the experiment whether or not caloric was ponderable, seem to be the primary facts that led subsequently to the discovery of the composition of water. PRIESTLEY, WARLTIRE, and doubtless others, too, repeated the experiment frequently; and although water was a product in every instance, yet no one before CAVENDISH seems to have given the necessary attention to the question of how this water was formed. After numerous trials regarding the proportions of air and hydrogen that were required to produce this important liquid, CAVENDISH found these to be two volumes of hydrogen and five

of air. Subsequently the research in this direction recommended itself to other philosophers, among whom GAY-LUSSAC fixed the respective quantities of the component gases necessary to produce water at one volume of oxygen and two of hydrogen.

PREPARATION.—When two volumes of hydrogen and one of oxygen gas are mixed in a confined vessel and ignited by means of the electric spark, a slight flash of light and loud explosion follow their combination, and water remains in the vessel to the extent of the weight of the combined gases. In like manner, when hydrogen issuing from a small jet is ignited, and a deep cylindrical glass is inverted on the flame, water is produced; and, owing to it being condensed on the cold surface of the glass, appears first as a slight coating of dew, and subsequently in the form of small drops which trickle down the walls of the vessel. Many other means are now known, whereby pure water from its elements is produced, such, for instance, as transmitting pure hydrogen gas over several metallic oxides inclosed in tubes, and heated to redness. The most conclusive experiment for demonstrating the composition of water is that performed by the aid of the galvanic battery. In this experiment, the constituent gases are evolved at the respective poles of the battery in the ratio of two volumes of hydrogen and one of oxygen; and by mixing these gases in a eudiometer or other tube, and transmitting the electric spark through them, water is again reproduced. It would be tedious to specify the numerous ways in which water can be formed from the combustion of hydrogen. It may be instanced, however, that finely-divided platinum—platinum black—possesses the power of causing the combination of the gaseous constituents of water in a remarkable manner. The principle of DOBEREINER'S instantaneous light is founded on this same property.

The arrangement by which the decomposition of water may be illustrated, consists simply of a glass globe with stopper openings at the sides and at the top, filled with water. Small platinum wires pass through the corks at the sides, and up through the apertures at the top, terminating in flat plates of the same metal. Two graduated tubes filled with water are inverted over these plates, and the zinc and copper poles of a voltaic battery connected with the protruding wires at the side, thus converting the two tubes into ordinary decomposing cells. On setting the battery in action, the water in the tubes will undergo decomposition in part, oxygen being formed on the side of the copper or positive pole, and hydrogen on that of the zinc or negative pole; both gases, as they accumulate, ascend to the closed ends of the tubes, forcing out the water. By reading the index on the tubes, it will be found that the quantity of hydrogen in the tube inverted on the zinc pole will be strictly double the volume of the oxygen in the other; in other words, the elements are evolved in the exact ratio of their existence in water, as may be proved experimentally by exploding the mixture of both gases in a cylinder over mercury.

PROPERTIES OF WATER.—Water, like gases and elastic bodies generally, possesses very varied properties both of a physical and a chemical nature. The knowledge of the former constitutes the chief division

of two correlative branches of the physical sciences, namely, hydrostatics and hydrodynamics; the former relating to the equilibrium, or the statical momentum of this fluid, and the latter, to the order of its motion under unequal forces. As the knowledge of these is more particularly connected with the science of mechanics or engineering, they need not be specially dwelt upon here.

Pure water has neither taste nor smell; it is colorless in small bulk, but of a greenish hue when seen in large masses. Water is solid at temperatures below 32°, liquid between 32° and 212°, and gaseous at a higher heat. By a careful method of reducing the temperature of water, and guarding against any agitation of the liquid or contact with any angular body, the point of solidification descends as low as 8°, or even 5°; that is, 24° and 27° below the point at which it freezes when it is agitated. In like manner, if the ordinary pressure under which it boils at 212°, namely, thirty inches of mercury, be reduced, the phenomenon of ebullition succeeds at considerably lower degrees of heat. Thus it is that on the summit of high mountains, where, in consequence of the elevation, the normal pressure of the atmosphere is lessened, water is observed to boil at a lower thermometric degree than at the base. In the act of solidification water resolves itself into numerous forms, one of which is a rhomboid, closely resembling Iceland spar. Under ordinary circumstances, when its particles are in equilibrium, water is elastic and compressible. This property had long since been proved by OERSTED, and modernly has been established by PERKINS. The results are, however, variously stated: thus, PERKINS found that by a pressure of three hundred and twenty-six atmospheres, the compression amounted to .035 of the bulk, or a value of one hundred and eight millionths for every atmosphere; whereas, when the strain was raised to two thousand atmospheres, the reduction was less than one-half of the above for each atmosphere, namely, forty-one millionths. OERSTED found the average reduction per degree to be forty-five millionths of its bulk; he likewise observed that the contraction increases in direct proportion to the power exercised in compressing it, up to seventy atmospheres. Water is likewise subject to compression and extension when under the influence of another power, namely, that of heat, but with greater irregularity than is observed when acted upon by mechanical force. Generally speaking, the abstraction of heat from bodies serves to bring their particles closer together, and therefore contract them, and *vice versa*; but the axiom is true with regard to water only within certain limits. For instance, when ice is melted by causing it to combine with caloric, instead of expanding with each increment, its bulk suffers a diminution till the temperature of the mass rises to 39·2°, at which degree it has been found to possess its greatest density; on continuing the addition of heat, however, it begins to expand till the boiling point is attained, the acquired bulk in this range being, according to the researches of HALSTROM, one part in twenty-four. The experiment can be easily illustrated by a glass vessel fitted with a narrow tube; the contraction and expansion of the water in the flask being indicated by its descent or rise in the capillary

tube inserted into its mouth. The peculiarity attending a change of temperature in water, between the limits of 32° and 48° may be shown to vary from the expected effects resulting under ordinary circumstances from the addition or abstraction of caloric; thus, the expansion which is observed to take place in the liquid from its point of greatest density, 39·2°, when heated through a range corresponding to that between this and the freezing point, equals exactly that which a reduction of temperature from 39·2° towards the freezing effects, so that the volume at 48° and 32° is exactly the same.

The following table of the contraction and expansion of water between the three points, 32°, 39·2°, and 212°, gives the results arrived at by KOPF:—

Temperature.	Volume.	Temperature.	Volume.
32·0	1·000000	69·8	1·001776
33·8	·999947	71·6	1·001995
36·5	·999908	73·4	1·002225
37·4	·999885	75·2	1·002465
39·2	·999877	77·0	1·002715
41·0	·999883	86·0	1·004064
42·8	·999903	95·0	1·005697
44·6	·999938	104·0	1·007531
46·4	·999986	113·0	1·009541
48·2	1·000048	122·0	1·011766
50·0	1·000124	131·0	1·014100
51·8	1·000213	140·0	1·016590
53·6	1·000314	149·0	1·019302
55·4	1·000429	158·0	1·022246
57·2	1·000556	167·0	1·025440
59·0	1·000695	176·0	1·028581
60·8	1·000846	185·0	1·031894
62·6	1·001010	194·0	1·035397
64·4	1·001184	203·0	1·039094
66·2	1·001370	212·0	1·042986
68·0	1·001567		

This peculiar behavior of water is not only interesting as a curious deviation of a natural law, but because it serves purposes of the highest importance in the economy of Nature. The hardest rocks are split asunder by the freezing and expansion of the water which penetrates their fissures, soils are disintegrated, and their hidden elements of nutrition presented in a state fit for absorption by the roots of plants.

When the great body of water of the globe is cooled on the surface, the exposed portion, owing to its density being slightly increased, sinks, causing the warmer substratum to rise, to manifest the same behavior when its temperature is lowered in like manner. Did this circulation continue till the entire mass acquired a freezing temperature, it is evident that the whole body of water would enter nearly at once into the solid state of ice, to the destruction of all living creatures inhabiting it, to the destruction of oceanic commerce, and of the communion of peoples separated by large tracts of oceans and seas. Further, were such the order of the laws governing Nature, not only would the living inhabitants of waters inevitably perish, but those on the land would also be destroyed, in consequence of the insupportable cold that would be produced in the atmosphere, owing to another property which water, whether in the liquid or solid state possesses, of combining with heat, and rendering it latent or insensible. The warmest seasons would be of little avail to counteract such dire effects, and the genial climate of temperate zones would be changed to a far worse condition than

the frigid regions of the North pole! Providentially, however, the progress of the cooling and consequent circulation induced in water by cold is arrested when the whole mass reaches a temperature of about 40° , that is, 8° above the freezing point; for at this limit, instead of contracting and sinking it becomes specifically lighter by expansion, and therefore remains floating on the subjacent mass. By a continued reduction of its temperature the surface will ultimately freeze, and the crust of ice may go on thickening; but it is inconceivable what cold could thus convert the entire mass into the solid form in this way. Hence, even in the perpetually frozen regions of the North, the water beneath the ice retains a heat of 40° —a temperature much higher than is experienced in this climate often during Winter—and suited not only to marine animals, but calculated, under the least favorable change, to aid in bringing about the normal state of things best suited to the wants of the great family of God's creatures.

From the preceding remarks, the cause of ice—solidified or crystallized water—floating in water will be readily understood. It has been shown that at the point of solidification the liquid has the same, if not a lesser density than at 40° ; but, in passing to the solid state, the gravity is much further reduced, as well by the arrangement which its particles assume, as by the expulsion of the gases dissolved in the water, and which, before they can escape, are enveloped and compressed within the solid crystal. From both, and perhaps other conjoint causes, the density of ice at a temperature of 32° is less than that of water at 212° , and hence the former floats in the latter. At the normal degree at which chemists are accustomed to compare the densities of bodies, namely 60° , and a barometric pressure of the atmosphere of thirty inches, pure water is taken as the standard of comparison, and is expressed by unity, or 1000—compared to this ice has a density of 0.916.

Another circumstance which prevents the freezing of the waters of the oceans is the quantity of saline matters which they hold. DESPREZ found that all such saline solutions have a point of maximum density, which is so far below 39.2° as the solution is richer in salt, and this point of maximum density is even below the freezing point of these solutions when agitated, although in a quiescent state they may be cooled below it without assuming the solid form. The following are the results of his researches on this subject, with solutions of 3.759 parts of the undermentioned compounds in one hundred of water:—

	Maximum density.	Freezing point.
Potassa,.....	21.80	28.22
Carbonate of potassa,.....	24.89	26.22
Sulphate of potassa,.....	27.90	28.24
Carbonate of soda,.....	19.38	26.87
Sulphate of soda,.....	24.21	27.84
Chloride of sodium,.....	24.45	27.02
Chloride of calcium,.....	26.95	26.95
Dry sulphate of copper,....	30.89	29.63

In considering the effects of heat upon water, a further insight into the beautiful provisions of Nature may be obtained. It has been stated in the preceding that water is the medium by which the great heat of warm climates is assuaged. Here it may be well to explain a little more fully how this is effected. Water, of all

known substances, has the greatest capacity for heat—that is, its power of combining with this imponderable, and exhibiting in a less degree its effects in point of warmth than any other body. This property is possessed by it in its several forms of solid, liquid, and vapor or steam. If a given weight of ice, indicating a temperature of 32° be added to an equal bulk of water at 135° , and the mixture be left at rest till the former is melted, the temperature of the mixture on being essayed will not be the mean of the two degrees of heat— 83.5° —as might be anticipated, but it will be found at the same standard as that of the ice itself before its introduction to the hot water. Hence it is evident that ice, or water, in passing from the solid to the liquid state, renders latent as much sensible heat as would bring it to about half the temperature of boiling water, were it in the liquid state at 32° ; or within 52° of boiling water, were it at the normal temperature of 60° . REGNAULT's results on this subject are 142.6° , as the amount of heat rendered latent by water in passing from the solid to the liquid state. All this latent heat is evolved from the water in passing to the solid state of ice; and thus does it beautifully serve to soften the rigor of the cold necessarily felt by those in polar climes. In its liquid state, between 32° and 212° , water manifests the same power of uniting with heat, and showing less of its effects sensibly than any other body. For instance, when a pound weight of water at 100° is mixed with the same weight of itself, of olive oil, and of mercury respectively, at 40° , it will be found that the temperatures of the resulting mixtures will not be the same; the mixture of the waters will show the exact mean of their respective heats before mixing, that is 70° ; but that of the water and oil will be 80° , and of the mercury and water will be 98° . Hence it will be seen that the same quantity of heat which in the last instance produced an effect of 2° on water, raised the same weight of mercury 58° ; and that of 20° in the case of the mixture, water and oil, equalled an effect of 40° on the oil alone. The consequences of this capacity for heat are most important in retaining the temperature of bodies at a medium point, and its value to the human frame in hot climates is almost incalculable; for when taken into the system, or evaporated from the parched and inflamed skin of the inhabitants of dry and arid countries, it reduces the heat of the system more than the same weight of any given substance.

When water is evaporated, the caloric which is thus carried off, and with as little sensible effect as that absorbed by the ice during its transition from solid to a liquid, is very great. Water may be boiled in a vessel, and although heat is transmitted to it, during the period of its evaporation, in a continuous stream, yet the heat of the liquid does not rise beyond 212° , nor does the vapor exceed the same; necessarily, therefore, the whole of the caloric absorbed must be rendered latent in the vapor formed. This may be proved to be the case by transmitting a given weight of the vapor of water—steam—at 212° into a measured bulk or weight of water at any degree, such for instance as 32° or 60° , and noting the effect. In this way it has been found by DULONG to contain as much as 977.4° of latent heat, which, added to its sensible

caloric, 180° —the difference between 32° and 212° —gives a total of 1157 degrees, or units of heat, possessed by every unit of water in the form of steam at 212° . Without dwelling upon the importance in an industrial point of view of this property which water possesses of combining with heat on assuming the gaseous form, and parting with the same wherever this vapor is transmitted to and condensed, or on the power which an accumulation of the vapor at its normal temperature, or at a higher heat, exercises in the thousands of varied forms in which steam is employed in connection with mechanism and industrial works of arts and manufactures—it will be well to cite this property in further proof of the profound beauty of the conception which, as stated in the introduction, has ordained this to be the medium of modifying the rigor of seasons and the influence of the geographical position of lands. Thus the water which is evaporated within the tropics, and which takes up with it an amount of heat corresponding to 1100° , conveys this heat towards the frigid zones, where, on being condensed either into rain, hail, or snow, it is given out to the air and surrounding objects, and thereby greatly contributes to the mildness and habitableness of those parts. Water evaporates not only at 212° , but at all intermediate temperatures between this and its freezing point; and even when in the state of ice, it has been ascertained that it gives off a very rarefied steam. In all these cases the quantity of heat which it renders latent increases with the degree of rarefaction, so that the same weight of steam, or watery vapor, produced at 60° , contains much more insensible heat than when generated at the boiling point of water.

The chemical relations of water are likewise of the utmost importance. In solvent power, that is, its power of overcoming the cohesion of particles of matter, it has no equal; and this force is exercised in reference to gases and liquids, as well as solid bodies; only that in the case of gases, instead of overcoming the cohesive force of the substance, the reverse is the effect, for it is the repulsive force or their expansion that is, so to speak, neutralized. To this phenomenon of destroying the repulsive force of the particles of gases, and the cohesive in solids or liquids, the term *solution* is applied; and, as is well known, it can in some cases be effected by heat, although in these the change is properly designated *fusion*. Water does not manifest the same behavior, however, with all solids, liquids, and gases, so that it appears the particles of the body capable of being affected in this way, must have a peculiar state of molecular aggregation which holds them together with a force inferior to that which water exerts upon them. There are therefore a numerous class of substances that are not affected at all under ordinary circumstances, and others to a very unequal degree, by water in this respect. For instance, a piece of rock crystal, calcareous spar, or glass, will remain in water a length of time without undergoing any change; but a crystal of sugar-candy, alum, or carbonate of soda, will be found to disintegrate readily, and disappear in the liquid. The former are said to be *insoluble*, and the latter *soluble* substances, in reference to water. Of those which are soluble in water, the quantity of them

which the liquid is capable of combining with, till the equilibrium of the cohesion of the substance dissolved is attained—in other words, the point of saturation of the liquid with such a compound, is very variable, though almost in all cases more or less increased by heat. This may be readily proved by adding to equal weights of water, sugar, salt, or chloride of sodium and gypsum, exposing as great an extent of these as possible to the water by stirring the mixture, and then permitting to rest a while. If the solutions, say one pound of each, be evaporated, and the dry residue weighed, it will be found that the saccharine matter will weigh about twelve ounces, the saline residue about five and a quarter ounces, and the calcareous not more than fourteen or fifteen grains. Again, difference of temperature affects the solvent power of water, increasing it—except in few instances, such as when common salt and gypsum are the subjects, and which are nearly equally soluble in cold and hot water—with each additional degree of heat communicated to the liquid up to 212° ; thus nitrate of potassa is dissolved in water at 57° to the extent of one-fourth, at 92° to that of one half, at 131° to an equal weight, and at 212° to the extent of twice the weight of the water employed. When the solutions made at the higher temperatures, however, are allowed to cool, the particles of the solids, over and above what is taken up at the normal degree, regain their cohesive force, and separate in the form of crystalline bodies. These reactions are of particular importance in a chemical point of view, as they offer a simple and ready means of separation and purification of many substances in various branches of manufacturing industry, the principles of which are governed by chemical laws. Another phenomenon connected with the solution of solids in water is, that in several instances a reduction of temperature takes place; while in other cases heat is evolved. GAY-LUSSAC has explained this anomaly. He found that when simple solution was effected of a salt, whether in a hydrated or anhydrous state, cold, or a reduction of the temperature of the liquid, resulted; but when chemical combination took place between the substance and the solvent, as, for instance, in the production of a definite hydrate, a rise of temperature is experienced. In the former case the salt, in passing from the solid to the liquid form, renders a quantity of heat greater or less according to its capacity for this imponderable, latent, and which is abstracted from the sensible temperature of the water; whilst in the latter the chemical force exerted in the act of combination develops an amount of caloric which is greater than that of the latent heat of the body, and hence the rise of temperature. The simple experiment of dissolving nitrate of potassa or chloride of ammonium in water will, with the aid of an ordinary thermometer, illustrate the truth laid down to the reader as regards the cold produced; and of hydrate or caustic potassa or sulphuric acid in reference to the heat developed. This reaction affords a ready means of distinguishing between chemical combinations with, and simple solution of a substance in water. In all these cases, however, with the exception of simple combination, water effects no change in the substance, so that by evaporation of the liquid, the solid

matter may be again obtained, possessing the properties peculiar to it before solution. There are a few instances, however, in which water does not retain this neutral character; for with some of the salts of bismuth, antimony, and tin, its addition produces a decomposition, causing a liberation of the radical or acid of such, while itself in part undergoes decomposition. The reader will find these examples of decomposition illustrated under the respective metallic salts referred to.

To enter into the behavior of water with the alcohols, ethers, oils, resins, and other matters, would prolong the subject beyond prescribed limits; suffice it to say, that when alcohols partake of the nature of oils, they are not at all soluble in it; neither are ethers and oils, in the ordinary acceptation, dissolved by water; nor are the resins. Alcohol—that resulting from the fermentation of saccharine matters—is soluble in it in all proportions, although ether, the derivative of this body, and differing from it only by the elements of one equivalent of water, is almost insoluble in the liquid.

Behavior of Water with Gases.—Not only has water the property of liquefying a great number of solid bodies, but it exercises the same function with respect to many gases; a property that is of very great importance in the economy of nature in many instances.

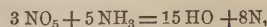
To convey an adequate conception of the solvent power of water for gases, it may be stated that one hundred cubic feet, or six hundred and twenty-five gallons of water, at 60° and a barometric pressure of thirty inches, will dissolve of—

Hydrochloric acid gas,	50000·0	cubic feet.
Ammonia,	67000·0	"
Sulphurous acid,	5000·0	"
Sulphuride of hydrogen,	300·0	"
Chlorine,	200·0	"
Carbonic acid,	100·0	"
Carbonic oxide,	6·6	"
Binoxide of nitrogen,	5·0	"
Oxygen,	4·6	"
Nitrogen,	2·5	"

Water which has been much exposed to the air, such as rain water, absorbs two and a half parts of that compound; and what is so curious regarding it is, that the amount of oxygen in such, instead of being only twenty-one per cent., as in the atmosphere, was found to be so high as 34·8 per cent. by GAY-LUSSAC and HUMBOLDT. BOUSSINGAULT found that at an elevation of six to eight thousand feet, water absorbs not more than one third of the volume of air which it liquefies on the plain; which behavior has been cited as the cause of fishes not being found in the Alpine lakes situated at comparatively high altitudes; the small amount of oxygen in the soluble state in the water being thought insufficient to support the respiration of these cetaceous animals.

Many natural waters contain considerable quantities of nitrogen. PLAYFAIR estimated that the famous Buxton water, as it issues from the spring, is in combination with nearly three-fourths of its volume of nitrogen—as will be hereafter more discussed under its analysis. With so unnatural a phenomenon, the question, Whence does it come? at once intrudes itself. That it is assimilated from the air is impossible; and it is hardly conceivable that the water in passing through

the calcareous strata of the district should meet with or take up such quantities of nitric acid and ammonia as would, by their mutual decomposition in some such manner as the following—



give rise to the forementioned volume of gas.

Before entering upon the consideration of natural waters with respect to their hygienic qualities, *et cetera*, it may be stated that pure water at 62° and thirty inches barometric pressure, is taken for the standard to which the relative density of all other solids and liquids is compared; just as air is adopted as the standard for measuring the gravity of gases, both being assumed unity, or 1000. At the above degree of heat and pressure, one hundred cubic inches of it weigh 252·45 grains; consequently the imperial gallon weighs 70·000 grains, or ten pounds avoirdupois. It is eight hundred and fifteen times heavier than air, and one thousand three hundred and four times the weight of an equal bulk of its densest vapor, steam, generated at 212°. Its composition is represented as being one equivalent of hydrogen and one of oxygen—HO—and it has been found to contain—

	At. weight.	Centesimally.
1 Eq. hydrogen,	1	11·1
1 Eq. oxygen,	8	88·7
	9	100·0

NATURAL WATER.—By this term is understood the ordinary liquid which serves the purposes of every-day life, whether its source be the rain, hail, or snow, which falls from the atmosphere; the drainings of the surface of the country, accumulated in lakes or rivers; well, or natural springs, through which the liquid permeating the porous strata of the earth at one place, finds an outlet or lower hydrostatic level at another; and sea or salt water. For the sake of clearness in the details which the Editor intends to lay before the reader on this subject, its consideration will be made in the following order, namely, rain, surface—including lakes and rivers—and spring or well waters, all embraced under the class Fresh Water; and Sea Water, or such waters as contain an abnormal quantity of foreign ingredients, and are therefore unfit for the more general uses to which this liquid is applied.

FRESH WATERS.—*Rain and other Waters immediately derived from the Atmosphere.*—As already stated, there is a continual evaporation of water taking place from the surface of the land and sea, which is greater in warm latitudes, and lesser in the parallels approaching the frigid zones and the poles of the earth. This evaporation is dependent, in the first instance, on that curious property of gases, discovered by DALTON, by which a space filled with one kind of vapor or gas, offers as little obstruction to the diffusion of another vapor or gas, in the same space, as if it were already a vacuum; and in the second, upon the temperature. Some other conditions likewise affect the evaporation of water spontaneously, such as the quantity of moisture already contained in the atmosphere, the force and direction of the winds, *et cetera*, which need not be followed. Whilst the heat at which it

was converted into an elastic vapor remains the same, watery vapor is quite as invisible as the air; but on sudden changes of temperature, occasioned by being brought into contact with a colder body of air, or any cooling surface, then the moisture is first condensed into very minute drops, forming clouds, and these drops continue to aggregate among themselves till their gravity becomes greater than the air, and they fall to the earth as refreshing rain. The theory of HUTTON, with respect to rain being produced by the mixing of opposite currents of air at different temperatures, though true to some extent, appears to be inadequate to produce the amount of rain which the numerous meteorological observations so generally made during late years have registered; and it is therefore supposed that more rain is formed in close proximity to the earth, than in the higher regions of the air. The experiments of Professor J. PHILLIPS corroborate this in an extraordinary manner. He found that the fall of rain on the—

Top of York Minster, 242 feet high, was 15·910 inches.		
Roof of Museum, 73 "	20·461 "	
Surface of ground, 0 "	24·401 "	

That all the rain of these latitudes could not be produced on Dr. HUTTON's principle, may be readily conceived by considering the circumstances a little in detail. The tension of the vapor of water at 59° equals 0·5000 of an inch of mercury, and at 41° 0·2573; now, if equal bulks of air at these temperatures, saturated with water, commingle, the mean temperature of 50° will be attained, at which the tension of the aqueous vapor is 0·3608, the difference between which and 0·3786, the mean of the tensions above indicated, that is, 0·0178, represents the tension of the amount of water that would be condensed from the state of vapor. This quantity is very inconsiderable compared with that resulting from atmospheric changes which take place on or near the earth, as may be seen from the following example, quoted from GRAHAM. The mean temperature of January in this country is about 34°, but with a South-west wind the thermometer may be observed to rise gradually in the course of forty-eight hours to 54°; now, supposing such wind to be saturated with aqueous vapor, and that in traversing over the surface of the land it is cooled to 34°, the amount of moisture which it must deposit will be very considerable, as appears by the following—

Tension of vapor at 54° equal to 0·429 inches mercury.	
Do. do. 34° "	0·214 "

Difference condensed as rain,	215 "
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Invariably there is the greatest average fall of rain near the equator; it diminishes towards the poles, as the latitude is higher. The average annual fall of rain at—

New Granada, 12° 0' N.....	is 126 inches.
Calcutta, 19° 46' N.....	81 "
Rome,.....	39 "
England, average.....	31 "
London,.....	23 "
St. Petersburg,.....	16 "
Uleaborg,.....	13½ "

Snow and hail is a form of rain, in which the water is frozen before it reaches the earth; the former results from the formation of clouds at temperatures below 32°, wherein the minute drops are crystallized into an infinity of spiculæ, which arrange themselves into regular lines and figures, diverging from one another at angles of 60° and 120°. They are all referable, however, to the hexagonal and prism shape, though the details differ in almost every storm.

Hail is supposed to be formed in warm weather, when the sun is above the horizon, and under different circumstances to those calculated to produce snow. It is supposed to be produced in the ascending current of greatly rarefied air, by the cold consequent on such rarefaction, the force of the upward current being such as to carry with it the minute solid globule, till, by uniting with others, it attains a density that causes it to descend. Generally, this phenomenon of the production of hail is associated with a peculiar electrical state of the atmosphere, to which it must be principally attributed.

Rain, as it descends from the clouds, is contaminated with various gases and vapors which it dissolves from the air. The atmosphere, normally composed of oxygen and nitrogen, contains vast quantities of ammonia, carbonic, nitrous, and nitric acids, besides other gases and vapors which arise from the number of chemical phenomena which are ever taking place on the surface of the earth. The principal of the *abnormal* gases is *carbonic acid*—a gas which escapes in enormous quantities from volcanic districts, and which results also from respiration, from the combustion of fuel, and decay of organic matter and vegetal growth generally, on the surface of the earth. Though analysis detects only about one thousandth of this gas in the air, still when the total bulk of the latter is taken into consideration, the entire weight of carbonic acid disseminated in it is enormous, averaging more than *five billions of tons*! The air likewise contains much *ammonia* and vapors of the oxides of nitrogen, besides other unknown gases and vapors, which escape from decomposing animal and vegetal matter.

All the gases which have been detected in atmospheric air are exceedingly soluble in water; hence it follows, that rain-water, as it descends through the lower strata of the air, must become to a great extent impregnated with these gases. LIEBIG has shown that even snow contains much ammonia, and recently in some rain-water, collected on Brighton Downs, MEDLOCK detected this gas, and also traces of the acids of nitrogen, which had probably resulted from the oxidation of a portion of the volatile alkali. It is, therefore, evident that water as it falls from the clouds, whether in the form of snow or rain, is not absolutely pure, but contains much carbonic acid and ammonia. Probably traces of other gases, which have hitherto eluded detection, are likewise present. Not only is ammonia present in snow and in rain, but HOKSFORD even detected it in large quantities in the ice from the Glacier de Boisson, at a height of twelve thousand feet above the level of the sea; and MEDLOCK has found marked quantities of this volatile alkali in the purest and most transparent masses of ice from the Wenham Lake in

America. The presence of ammonia in rain-water has not long been known; and it is one of the main causes of the fresh and invigorating influence of it upon the vegetal creation.

SURFACE WATER.—Rain-water is a very powerful solvent of certain ingredients of the soil, such as sulphate of lime, chloride of sodium, and magnesian salts; but when saturated with carbonic acid, as is ordinarily the case, its solvent properties are remarkably increased. For example, ordinary water, free from carbonic acid, will not dissolve more than a grain of chalk per gallon; but when saturated with that gas, the same quantity will dissolve upwards of two hundred grains. In like manner it is found that carbonate of magnesia, which is almost entirely insoluble in ordinary water, will dissolve in water impregnated with carbonic acid in very considerable quantity. Hence, in addition to the alkaline chlorides and sulphates, and sulphate of lime, nearly all spring-waters are found to contain carbonates of lime and magnesia, which are held in solution as bicarbonates by the carbonic acid derived from the soil and atmosphere. Certain of the mineral constituents impart to water its *hardness*. These are the salts of lime and magnesia. By the hardness of a water is understood the power it possesses of decomposing soap; and according to the quantity of soap decomposed by a given quantity of water before the remaining soap becomes available as a detergent, so is its relative hardness. The sulphates, chlorides, and nitrates of lime and magnesia give to the water the so-called *permanent* hardness, while the carbonates, which are held in solution by excess of carbonic acid, impart to it its *temporary* hardness, or that which it loses by boiling.

The waters of rivers, from which the greater number of English cities and towns obtain their supplies, contain the above-named mineral constituents in quantities varying according to the composition of the soil over which they flow. In the water of streams which have their sources in the primitive rock formations, as, for instance, the rivers Dee and Don, there is found only from two to eight grains of mineral constituents per gallon. The water of the Trent, which flows through a *selenitic* district, contains about sixty grains of sulphate of lime; while in the water of the Thames, which is derived from, and flows over a chalk formation, there are only about three grains of sulphate, and from eight to ten grains of carbonate of lime per gallon. For the sake of comparison, and in illustration of the above statement, the analyses of the Thames, Trent, Dee, and Don are given:—

	Thames water.	Trent water.	Dee water.	Don water.
Carbonate of lime,	10.80	0.32	0.85	2.23
Sulphate of lime,	3.00	21.55	0.12	0.13
Nitrate of lime,	0.17	—	—	—
Carbonate of magnesia, . .	1.25	5.66	0.36	1.07
Chloride of sodium, . . .	1.80	17.63	0.72	1.26
Silica,	0.56	0.72	0.14	0.52
Iron, alumina,	0.27	0.50	0.06	0.27
Phosphate of lime,	trace	trace	trace	trace
Organic matter,	2.36	3.68	1.64	3.06
	20.21	50.06	3.89	8.54
Hardness,	14.00	26.50	1.50	3.00

From the preceding analyses it is evident that the proportions of mineral constituents are, in a great measure, dependent upon the nature of the soil over which the water flows. Although the opinions of chemists differ widely regarding the hygienic effects of an access of the mineral constituents in water, the Editor is inclined to believe—and this opinion almost universally prevails—that so long as the proportion does not exceed thirty grains per gallon, they are decidedly more beneficial than injurious. The sense of taste is perhaps the best guide; and so long as preference is given to a water containing mineral matter to such as are almost entirely free therefrom, it may be assumed that such waters are the best for general purposes.

These remarks apply equally to the waters derived from wells. Indeed, in all the water supplied for man's use there are found the above-mentioned mineral constituents. Are they there for no purpose? Would Nature contaminate water with constituents injurious to health? It has been already mentioned that such waters as contain a certain proportion of mineral constituents, are much more refreshing and agreeable to the taste than those in which they are absent. The remarkable investigations of modern chemists have shown incontestably that a certain proportion of mineral elements in food is absolutely necessary for the due performance of the vital functions. In milk, man's natural food, there are all the elements necessary for the formation of the body—phosphate of lime for the formation of bone; salts of soda to aid in the formation of the gastric juice, and to give fluidity to the blood; casein to form the flesh; and butter to produce fat. In all the cereal grains and in the vegetables which constitute the chief food of graminivorous animals and of man, there are found the *same* mineral constituents which occur in water—*man's natural drink*. Who, then, can deny the value of mineral constituents in the water of wells and rivers? When in very large excess, as in the *shallow* well-waters of London—an exception to the rule—they may, perhaps, tend in some measure to derange the digestive organs of delicate persons, especially of those who have been accustomed to the use of softer water—that is, such as contains less earthy salts—for dietetic purposes; but in most cases in which hard waters are found to disagree, the objectionable effects may, in all probability, be ascribed with greater truth to *organic* impurities than to the actual *mineral* constituents. Having thus briefly alluded to the physiological effects of the mineral constituents of water, it becomes necessary to enter more fully into the nature of the more abnormal *organic* contaminations to which the water of wells and rivers is exposed, since on these is essentially dependent the hygienic character of the water—its fitness for domestic purposes.

NATURE OF THE ORGANIC MATTER CONTAINED IN WATER.—All river and well waters contain more or less of organic matter, which is acknowledged to be a predisposing cause of disease. The separation of these impurities from water is a problem of high scientific interest, and one that has engaged the attention of all the eminent chemists of the day.

The great importance of this subject in a sanitary

point of view renders it necessary to enter into detail regarding it :—

1. The source of organic matter.
2. The nature of the decomposition it undergoes.
3. The means of destroying the organic matter and rendering the water pure and wholesome.

1. *The Source of Organic Matter.*—A river is the natural drain of the country and towns through which it flows, and the organic matter the water contains must necessarily be derived from the three following principal sources :—

From the sewage of towns ; from the surface drainage of manured and cultivated lands ; and from the decay of the aquatic plants and animals which inhabit the streams.

The sewage of towns consists mainly of the urine and fæces of man and animals, the refuse of gas-works and numerous manufactories, which are diluted with the refuse water which has been used for domestic and manufacturing purposes. The Thames, which may be taken as a type of other rivers, before it reaches London drains an area of four thousand square miles, and receives in its course the sewage of towns containing upwards of seven hundred thousand inhabitants. It flows, moreover, through a richly cultivated country, from which it derives vast quantities of organic matter. It is further contaminated with the products resulting from the decomposition of aquatic plants and animals. Hence it is obvious that the water of the Thames, even before it reaches Teddington lock, must be most seriously contaminated with putrefactive organic matter. That much of the organic matter which enters the river is spontaneously decomposed is undoubted, otherwise the river would be little better than a filthy sewer ; but that a vast quantity remains in solution in the water as now supplied to the inhabitants of London, is equally a demonstrable fact, as will be seen by the analyses and experiments detailed in the following pages.

Most, and indeed all the companies who take their supply from the Thames, filter the water through sand and shingle previously to pumping it into the mains. By this means most of what exists in it in the form of undissolved or *mechanically suspended particles* is removed, and the water is consequently to some extent improved in appearance. But the greater part of the organic matter is *dissolved* in the water, and is not separated by mere filtration. That much organic matter exists in the present supply is evident from the decided color which the water possesses. This is also the case with the Pike water at present supplied to Liverpool.

If a tall tumbler be filled with any of the water now supplied to London, Liverpool, Manchester, and other towns, and placed on a sheet of white paper, the water will be seen to possess a yellowish or brownish tinge, occasioned by *the organic matter which is held in solution*. The removal of this organic matter, which is doubtless a fertile source of disease in those who daily drink it, is a problem of the highest interest to solve, and one to which MEDLOCK has devoted several years in the hope of its elucidation. Accident in some measure led him to follow out an inquiry into this subject,

which promised to lead to most important results, and the Editor deems the circumstances which suggested this investigation worthy of being recorded ; especially as the results arrived at by accurately conducted experiments are not only of high scientific interest in themselves, but, practically applied, are of great hygienic and national importance.

In September, 1856, he was requested by the directors of the Amsterdam Water Company to analyse several samples of water from the city of Amsterdam. Complaints had been made of the water by several of the inhabitants. It possessed a peculiar *fish-like* smell ; and although perfectly transparent and colorless, and free from the slightest chalybeate taste, it was found, after standing some time, to deposit a reddish-brown sediment, which coated every vessel in which the water was placed.

The service-pipes being of iron, the deposit was assumed to consist of the sesquioxide, resulting either from the decomposition of a protosalt of iron in solution, or from the attrition of the iron pipes through which the water was conveyed.

It may be observed that Amsterdam is supplied with water from the *Dunes*—sand-hills—in the neighborhood of Haarlem. Trenches, five miles in length, have been dug on the sides of the hills, to intercept the rainfall. The water is conveyed to a large reservoir, whence it flows to the filterbeds at the works, and is there filtered through four feet of filtering medium, consisting of pebbles, shells, and fine sand. After filtration it is pumped up an iron standpipe one hundred and fifty feet high, and conveyed thence by iron mains to Amsterdam, a distance of eighteen miles.

Five samples of the water were sent for analysis—one from the works *before the water came in contact with iron* ; the other four from various standpipes in the city.

In the water from the works, before it came into contact with iron, the quantity of iron oxide, alumina, and phosphates amounted to 0.95 grain per gallon. In the analysis of the four other samples, *after passing* through eighteen miles of iron pipes, the quantities were reduced in the several determinations to 0.09, 0.07, and 0.07 grain, and in the fourth sample to an unweighable trace. Thus, instead of taking up an additional quantity of iron oxide from the mains and service-pipes, the water was found actually to have lost nearly the whole of the iron which it previously held in solution ; but, notwithstanding the almost entire precipitation of the iron actually in solution in the water which had passed through iron pipes, it formed the objectionable red deposit on standing, while the water from the works, holding in solution nearly half a grain of iron oxide per gallon, formed no such deposit : therefore it was, *à priori*, to be assumed that the red deposit could not consist of oxide of iron, and consequently it appeared necessary to examine this deposit very carefully both chemically and microscopically. The precipitate from ten gallons of water was collected in a porcelain capsule, evaporated to dryness on a water-bath, and heated subsequently in an air-bath to 248° Fahr., until it ceased to lose weight. On ignition, the precipitate *charred* and

was almost entirely consumed, leaving only a minute quantity of ash, consisting of silica, alumina, iron oxide, and carbonates of lime and magnesia.

The small quantity of this deposit at command did not admit of a quantitative analysis. The deposit having been found to consist almost entirely of organic matter, a portion of it, which had been separated from one gallon of water, was examined under the microscope, and was seen to consist of the filaments of dead and decaying algæ, *confervæ*, and other microscopic plants in various stages of decay, and varying in color, like autumnal leaves, from green through pale-yellow, orange, red, brown, dark-brown to black. Many of the fibres retained a perfectly organized structure, and in some the spores, by which these plants are propagated, were distinctly visible. Amongst these plant remains were numerous silicious tubes, which had probably invested the delicate filaments of the algæ while living.

It appeared highly important to determine the *cause* of the precipitation of the organic matter from the water which had been in contact with the iron pipes; and in the hope of elucidating this interesting question MEDLOCK proceeded to Amsterdam to inspect the source of supply and the works. As anticipated, the Dune canals were found to be actually choked up with aquatic plants, and at the sides and wherever the current was sluggish were large masses of dead algæ floating on the surface. The sand at the bottom, originally very white and pure, was blackened to some depth by decaying vegetal matter, and, when disturbed, numerous bubbles of fetid marsh gas escaped.

The water had the peculiar fish-like smell of the masses of *flab—ulva intestinalis*—floating on the surface. The stones on the sides of the canals, the hurdles placed to keep up the banks, floating pieces of stick, and indeed every *solid* body with which the water came in contact, were coated with a reddish-brown deposit, similar to that which was found to separate from the filtered water in Amsterdam. *This deposit was observed to be particularly abundant near the iron sluice gates.* A pipe from one of the mains in the city was examined at the same time, and found to be coated on the inside with a thick slimy deposit of vegetal remains, which presented under the microscope an appearance exactly similar to that of the deposits above alluded to.

Remembering the important fact established by SCHÖNBEIN, that copper and platinum in a finely divided state have the property of converting ammonia into nitrous acid; and MEDLOCK having demonstrated that *lead* in any form possesses a similar power—it occurred to him that if the same property were possessed by iron, it would throw some light on the separation of the organic matters from waters which are placed in contact with that metal. SCHÖNBEIN, however, states that iron, before it produces a similar oxidizing effect on the ammonia, requires to be heated to redness. But in the course of an extensive series of experiments, it has been found that iron pyrophorus *instantly* transforms ammonia into nitrous acid; and in pursuing the inquiry further, it was found that strips of sheet iron placed in water containing ammonia or

organic matter capable of yielding it, act almost as energetically as the metal in a finely-divided state.

Having proved that metals possess this remarkable power of oxidizing ammonia, and converting it into nitrous acid, and, bearing in mind the extraordinary oxidizing power of this acid, even when present in minute quantities, it appeared to MEDLOCK that he had arrived at a simple and effectual means of depriving water of all organic impurities by thus accelerating a natural process of decay. The facts just mentioned appeared to merit a thorough investigation, and the results arrived at will sufficiently prove that he did not, in the first instance, attach too much importance to them. In order to study the action of iron upon the Amsterdam water, he submitted to analysis a quantity of this water which *had never been in contact with iron*, and at the same time he immersed several coils of iron wire in two gallons of the same water. The water in which the iron wire was placed was perfectly bright and free from color, and had nothing visible in mechanical suspension except a few of the siliceous tubes already alluded to. The experiment was made in four open glass bottles. A series of remarkable phenomena were observed. In five minutes a faint white cloud was seen radiating from the coil of wire, and descending in the form of a parachute. In half an hour the cloud had increased in density, and the water became opalescent. In six hours the cloud assumed a brownish color, and there was a brown deposit at the bottom of each of the bottles. The cloud continuing to increase during forty-eight hours, assumed more and more a flocculent character, and a reddish color, exactly like the deposit from the water which had flowed through the iron pipes. The water was now filtered through fine Swedish filter-paper and submitted to analysis, and a portion of the deposit examined under the microscope. The latter consisted of the remains of algæ, each separate flock having a siliceous tube as a nucleus. The remainder of the deposit was burned, and the ash found to consist of oxide of iron, silica, and the carbonate of lime and magnesia.

The following are the analyses of the water before and after being in contact with iron:—

	I. Water from the Dune canals. Grs. per gal.	II. Same water, having been in contact with iron forty-eight hours. Grs. per gal.
Sulphate of lime,.....	3.70	3.68
Chloride of sodium,.....	4.10	4.01
Carbonate of lime,.....	5.60	3.20
Carbonate of magnesia,.....	3.97	1.30
Silica,.....	0.16	trace
Iron, alumina, and phosphates,	0.95	trace
Matter, volatile on ignition—so called organic matter,.....	2.10	trace
	20.58	12.19

By these analyses it is seen that the 2.10 grains of organic matter contained in the water *were decomposed or thrown down by contact with iron.* The water, thus purified, no longer had the unpleasant fish-like taste and smell which had marked its previous contamination.

A portion of the water which had been in contact with the iron wire was rendered slightly alkaline by

pure alcoholic potassa, evaporated to dryness, and the residue tested for nitrous acid. The paper became instantly blue from the liberation of a trace of the nitrous acid formed by the oxidation of ammonia, and which had been instrumental in destroying the organic matter.

In the residue of the water which had *not* been in contact with iron and still containing its organic matter, no indication of nitrous acid could be obtained.

The Amsterdam water, the water of the Thames, and indeed that of nearly all other rivers, contain much organic matter, which may be divided into two classes—*nitrogenous* and *non-nitrogenous*. The latter, consisting of carbon, oxygen, and hydrogen, may be represented by the general formula— $n(\text{CHO})$; and, when no longer under the mysterious influence of the vital force, are rapidly resolved into carbonic acid and water. The nitrogenous class being chiefly of animal origin, and composed, in addition to the above-mentioned elements, of nitrogen, sulphur, and phosphorus, may be represented by the general formula— $n(\text{CHONSP})$. Now, when animal matter decays, and when dissolved in water, decomposition proceeds very rapidly; beside carbonic acid and water other and very offensive products are eliminated. As a general rule, the carbon unites with oxygen to form carbonic acid; and with hydrogen, to form marsh gas or carbide of hydrogen; hydrogen and oxygen unite to form water; nitrogen and oxygen with hydrogen to form ammonia; sulphur with hydrogen to form sulphide of hydrogen; phosphorus with hydrogen to form phosphide of hydrogen.

The latter two are exceedingly offensive to the sense of smell, and are, moreover, highly poisonous. Thus in the spontaneous decomposition of the organic matter contained in water there are produced carbonic acid, carbide of hydrogen, ammonia, sulphide of hydrogen, and phosphide of hydrogen. These are the *recognized* compounds; but when it is borne in mind that the gaseous emanations of decomposing animal matters are infinitely more offensive to the sense of smell and injurious to health than any of the gases above mentioned, or of any combination of them, it can only be concluded that the effluvia of decaying organic matter contain other constituents, of which the true character has not yet been determined. Thames water, if allowed to stand in an open vessel for a few days in warm weather, acquires a very offensive odor, arising from the decomposition of the animal and vegetal matter which it holds in solution.

This water, notwithstanding, is considered by maritime authorities to be the very best for the use of ships' companies. On board ship the water is stored in wooden casks, which are placed low down in the hold. During the first week or fortnight, according to the temperature of the atmosphere, the water ferments, evolves a quantity of gas of offensive odor, and deposits a copious brown sediment. The water gradually ceases to smell badly, becomes bright and sparkling, and will then keep fresh and sweet for an indefinite length of time. In other words, it loses by a natural process of decay, the whole of its *putrescent impurities*. In vessels of war, and in most of the large steamers, tanks of iron have been substituted for casks of wood for storing

the water necessary for the use of the passengers and ship's company. In iron tanks Thames water evolves *no offensive gases*, but becomes much purer than when stored in wood, and deposits a more copious brown sediment, which turns red on exposure to the air. The gases produced in the wooden casks are said to be slightly luminous in the dark, and to explode when a lighted candle is incautiously placed near the bung-hole, when the plug is removed. The luminosity is due to phosphide of hydrogen, and the explosive character of the gases to carbide of hydrogen.

As the organic matter was found to be so effectually removed by iron from the Amsterdam water, MEDLOCK instituted a series of experiments upon the water of the Thames. The water operated upon was that supplied to his laboratory by the Grand Junction Company. On placing some of this in contact with iron in glass bottles, precisely similar phenomena were observed as in the case of the Amsterdam water, but the deposit was *black*, and was formed more quickly. The next step in the investigation was to test the water before and after contact with iron for the great destroying agent, NATURE'S SCAVENGER, *nitrous acid*. The residues of six separate gallons of the water were examined for nitrous acid as follows:—Each residue, mixed with half an ounce of water was introduced into a Florence flask, fitted with a cork and long funnel tube. In the neck of each flask was placed a slip of bibulous paper, moistened with starch paste and iodide of potassium. Through each funnel tube was added half an ounce of dilute sulphuric acid, one part strong acid, and nine parts water, to liberate the nitrous acid, if present; but no indication of that gas was found, as the test papers remained perfectly white. Six other gallons of water drawn at the same time, were placed in open bottles, with two ounces of fine iron wire, and left for forty-eight hours. The waters were then filtered from the deposits, evaporated to dryness, and tested for nitrous acid in a manner similar to the preceding, and with the following results:—

- Experiment 1.—Paper becomes blue in ten minutes.
 “ 2.—Paper becomes blue in five minutes.
 “ 3.—Paper becomes blue in four minutes.

As it appeared probable that the nitrous acid liberated by the sulphuric acid might remain in solution, and in consequence not instantly affect the test-paper, in experiments with the residues of the other three gallons of the water *hot water* was used, and an acid of double strength. In each of these experiments the test-paper became blue in a few seconds.

These results prove beyond a doubt the production of nitrous acid by the action of iron upon the nitrogenous compound contained in the water. The Editor submitted masses of the Pike water to a similar treatment, and found results that confirmed in every respect those attained by MEDLOCK. Why is not this plan of purification adopted by the Water Committee in Liverpool?

EXAMINATION OF THE BROWN DEPOSIT PRODUCED BY IRON.—The brown deposits from three separate gallons of Thames water were collected in porcelain crucibles, and dried at 248° , till they ceased to lose

weight. When thoroughly dried they weighed as follows:—

NO. I.	NO. II.	NO. III.
4·4352 grains.	4·4243 grains.	4·4350 grains.

They were then separately analysed with the following results centesimally:—

	I.	II.	III.
Organic matter,.....	22·92	24·87	23·87
Sesquioxide of iron,....	65·36	63·20	64·39
Carbonate of lime,.....	11·11	11·04	11·20
Carbonate of magnesia, traces	trace	trace	—
Silica,.....	0·59	0·49	0·53
Loss,.....	0·02	0·31	0·01
	100·00	100·00	100·00

In order to arrive at a correct knowledge of the action of iron upon Thames water, MEDLOCK made a series of daily determinations of the mineral residue and organic matter in the water supplied to his laboratory, with the following results:—

	Solid residue. Gra. per gallon.	Organic matter Gra. per gallon
Jan. 4th, 1857,.....	20·867	2·248
Jan. 5th, 1857,.....	19·573	1·740
Jan. 6th, 1857,.....	21·159	1·424
Jan. 7th, 1857,.....	20·127	1·401
Jan. 8th, 1857,.....	21·452	3·249
Jan. 9th, 1857,.....	20·374	2·756
Jan. 10th, 1857,.....	20·920	3·062
Average,.....	20·638	2·268

At the same time as the water was drawn for the last analysis, he placed three separate gallons in wide-mouthed bottles.

Into the first gallon was put a coil of fine iron wire, weighing half an ounce. After standing two hours the water was filtered, and on being analysed in the usual way, gave—

Solid residue,.....	17·372 grains.
Organic matter,.....	1·232 do.

A second gallon with one ounce of wire for two hours gave—

Solid residue,.....	16·693 grains.
Organic matter,.....	1·170 do.

A third gallon with eight ounces of wire for two hours gave—

Solid residue,.....	13·182 grains.
Organic matter,.....	0·950 do.

In other experiments, too numerous to detail, the water was exposed to the action of a *large surface of iron* from twelve to forty-eight hours; and as a general result it was found that by allowing water to remain in contact with a large surface of iron for about twelve hours, every trace of organic impurity was destroyed, or converted from the soluble to an insoluble condition, in which state it admitted of being effectually removed by ordinary filtration.

After the preceding details on the nature of the organic impurities contained in ordinary well and river water, the offensive gases arising therefrom, and the functions of the numerous microscopic plants and animalcula which are contained in them, it now remains to describe the means that MEDLOCK has adopted for

placing the results of his discoveries at the service of the public.

PRACTICAL APPLICATION OF THE FOREGOING PRINCIPLES.—It has been proved by numerous trials with Thames water, sewage, and water artificially contaminated by mixing therewith sulphide of hydrogen, sulphide of ammonium, and urine, that however impure a water may be, it can be rendered perfectly pure and wholesome to drink by merely allowing it to remain in contact with a large surface of metallic iron for twelve or twenty-four hours, and then filtering through well-washed sand; or, better still, through a mixture of about one part animal charcoal and four parts sand.

The plan above stated is applicable to the purification of the supply of water to towns, as well as to small quantities for domestic and manufacturing purposes. To brewers, dyers, starchmakers, soda water and lemonade manufacturers, *et cetera*, a supply of water free from color and organic impurities is an essential requisite; and the Editor after long and careful study of the numerous processes recommended for purifying water, prefers the one above detailed, as being at once the most simple, easy, and effectual.

The following table exhibits in round numbers the degrees of impurity in water, used for the supply of towns in England, Scotland, *et cetera*, each degree being equal to one grain per gallon—

Distilled water,.....	0°
Loch Katrine,.....	2·0
Dee—Aberdeen,.....	4·0
Tay—Perth,.....	5·5
Dumfries,.....	7·0
Gorbals,.....	8·0
Leven,.....	8·5
Clyde,.....	9·5
Tyne—Newcastle,.....	11·0
Tweed—Coldstream,.....	11·5
Seine—Paris,.....	12·0
Liverpool well, purest,.....	13·0
Glasgow “ “.....	15·0
Kilmarnock,.....	15·0
Thames—1854,.....	15·5
“ —1851,.....	21·0
Glasgow well, most impure,.....	96·0
Liverpool well, “.....	417·0

Disease occasioned by the Organic Impurities of Water.—Dr. HASSALL remarks—In proof that water highly charged with decomposing organic matter frequently gives rise to severe and fatal diseases, often of an epidemic character, one is able to produce abundance of evidence. To occasion these effects, no doubt the organic matters, animal or vegetal, resolve themselves into carbide, sulphide, and phosphide of hydrogen, cyanides, *et cetera*, as well as other lethal products, and these disarrange the whole functions of the body. To enter more minutely into this part of the subject would be out of place in a technological work.

Disease occasioned by the Metallic Impurities in Water.—The Editor has known most serious illnesses to arise from water containing lead. Many hard as well as soft waters act injuriously upon lead, consequently, as a general rule, water should never be stored in cisterns of this metal. Why use lead when one can have slate cisterns and enamelled iron pipes? A

gentleman and his family residing in the neighborhood of Liverpool were constantly ill, but whenever they left home they recovered. The water was supposed to be the cause, and was tested from time to time, and pronounced good. The amount of lead was small, and had been overlooked—as is very often the case with inexperienced analysts. On examination of several gallons of the water—it was a remarkably soft water—lead was detected. The Editor recommended slate cisterns and enamelled iron pipes, and from that day to this all the ill effects of the water disappeared.

Microscopic examination of Water.—Most well and river waters, when allowed to stand in an open vessel for several days, especially in warm weather, deposit a sediment more or less copious, in which may occasionally be discovered, by means of a microscope, a vast number of the lower forms of animal and vegetal life, which have been made the subject of special study by several able microscopists, and especially by Drs. HASSALL and LANKESTER. Much misapprehension, however, appears to prevail regarding the extent to which these lower forms of organic life occur in water. In works treating on this subject, it is usual to group a large number of these objects together in a circular drawing, which convey the impression, and are generally understood to represent the animalcula contained in a single drop of water. Nothing, however, can be more erroneous, and nothing more calculated to convey false notions regarding the character of the water supplied to the public.

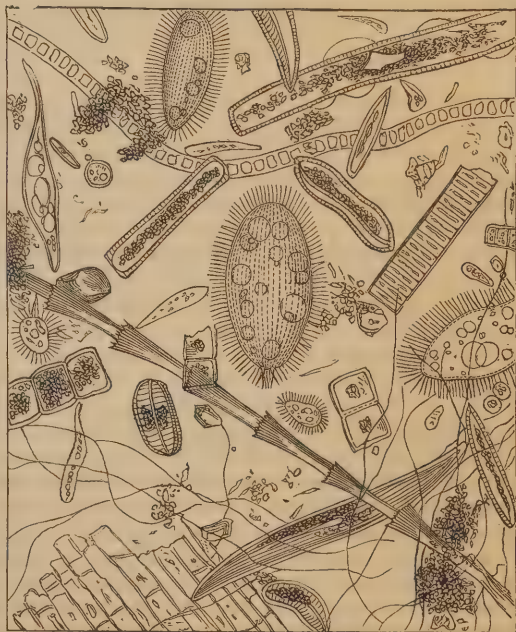
It appears to be a law of nature, that wherever the conditions of life exist, there life will manifest itself in forms suited to the circumstances. If a portion of earth be brought up from the deepest mine, and exposed for some time to the combined influence of heat, light, and moisture, various forms of vegetal and animal life will appear, even if the soil be entirely excluded from contact with the surrounding atmosphere. In the water of rivers containing animal and vegetal matter in a state of decay, are presented all the conditions of life; and hence the numberless forms of the lower organisations which are met with. That these are injurious to health, no one can venture to affirm; but their presence may form, to some extent, an index of the quantity of putrefactive organic matter which may be present. In cases where it is necessary to examine a water microscopically, the following is the plan recommended by the Editor:—

About a quart of the water to be examined should be placed in a conical glass vessel, very narrow at the bottom, in shape something like a tall champagne glass, and covered over with paper. After remaining at rest some hours, a slight deposit will generally be observed at the bottom; and in this deposit will often be seen numerous small animalcula moving about with wonderful rapidity; these have been named by naturalists *Cyclops quadricornis*. They are particularly abundant during the summer in river waters containing much organic matter. Other crustacea are also abundant, amongst which may be mentioned various species of *Daphnia*, which, by their number, often give a marked yellow color to water. Of radiate animals, the hydra and other forms of zoophytes are frequently

present. The fresh water sponge—*Spongia fluviatilis*—frequently occurs in great abundance. Numerous lower forms of the vegetal kingdom often abound in river waters, especially in those of shallow streams. These belong chiefly to families Confervaceæ, Dismidiæ, Diatomaceæ, and Fungi. Many of these lower organisms are beautiful objects under the microscope, and well worthy of the attention of all lovers of nature. Space will not allow of any detailed description of the almost numberless species found in water; they have been only briefly alluded to with the view of pointing out the fact, that when they occur in water used for dietetic purposes, they must be regarded as a proof of the presence of dead and decaying organic matter, and must not be looked upon as the only kind of contamination of the water. Their function appears to be to destroy the numerous organic matters which are present. To examine well the deposit formed in the conical glass, the clear water should be siphoned off, and a portion of the deposit placed in the field of the microscope—a quarter-inch glass is perhaps the best for such observations.

Dr. HASSALL examined several specimens of water, both upwards and downwards in the course of the river Thames from London, and they brought to light the singular and important fact that Thames water, from Brentford in one direction to Woolwich in an opposite,

Fig. 613.



swarms with living productions, principally of the genus *Paramecium*, and of one species of this genus *P. chrysalis* of EHRENBURG.

The engraving exhibits the principal animal and vegetal productions contained in the Thames water at Richmond, drawn with the camera lucida, and magnified two hundred and twenty diameters.

The subjoined cut exhibits the more remarkable vegetal and animal productions found in the water of the Thames at Waterloo Bridge.

Fig. 614.

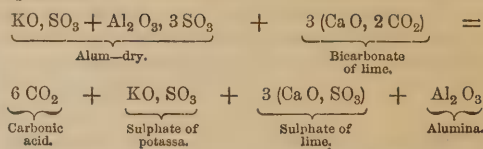


Color of Water.—In rivers the impurity of water is frequently visible to the eye. It is often of a red color, as it flows through rocks of red marl which contain much oxide of iron in their composition. It descends milky from the glaciers of Iceland and the slopes of the Andes, because of the white earth it holds in suspension. It is often grey or brown in the muddiest English rivers. It is always brown when it issues from boggy lakes, or runs across a peaty country, as at Rivington Pike. It is occasionally black to the eye when the amount of vegetal matter is excessive, as in the Rio Negro of South America; and it is green in the geysers of Iceland, in the Swiss lakes, among the islands of the South Sea, and around Great Britain and Ireland. Only in clear and deep water, like those of the Bay of Naples, and in parts of the Pacific, where minute objects may be seen on the bottom some hundreds of feet down, is the real blue color natural to water in large masses distinctly perceptible. This is the deep blue which is seen in the *grotto azzura* of the island of Capri, in the Bay of Naples, and in the deep indigo waters of some parts of the Mediterranean and Adriatic seas.—*Johnston.*

THE ADDITION OF CHEMICAL AGENTS TO WATER.—This head includes several proposed methods of purifying water, which consist in the addition of certain chemical agents to this liquid, by which its composition is altered.

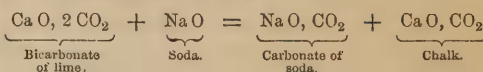
Addition of Alum.—In England, as well as in France, a popular method of clearing muddy water is

to add a few grains of powdered alum to it; two or three grains are usually sufficient for a quart of water. This process is called *alunage de l'eau*; and ARAGO states, that when practised on the Seine water, it causes the mud to agglomerate in long thick striæ, which are very quickly deposited. The theory of the process appears to be this:—The alum decomposes the bicarbonate of lime, and gives rise to the formation of sulphate of lime, which, with sulphate of potassa, remains in solution, while carbonic acid is evolved, and hydrate of alumina being precipitated in a flocculent form, carries with it various mechanical impurities.

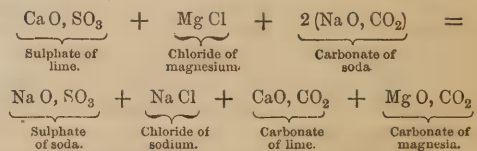


This method, then, is a kind of mechanico-chemical one. It clears the water, but at the same time alters its chemical composition, and by converting bicarbonate into sulphate of lime, augments the hardness of the water.

Addition of Caustic or Carbonated Alkalies.—Caustic alkalies, added to water holding in solution bicarbonate of lime, saturate the excess of carbonic acid, throw down carbonate of lime, and leave an alkaline carbonate in solution. If soda be the alkali used, the results will be as follows:—



If an alkaline carbonate be employed, all the earthy salts—calcareous and magnesian sulphates, chlorides, bicarbonates, and carbonates of the earths—are precipitated, while alkaline sulphates, chlorides, and bicarbonates which do not communicate hardness to water, are left in solution. If carbonate of soda be employed, its reaction on sulphate of lime and chloride of magnesium will be as follows:—



Addition of Lime.—A few years ago, Professor CLARK of Aberdeen took out a patent for the purification of water. His process consists in the addition of caustic lime to water, by which the bicarbonate of lime held in solution is decomposed; the caustic lime saturates the excess of carbonic acid, and forms carbonate of lime, which is precipitated.

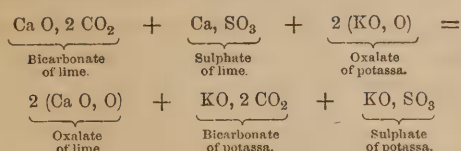


The Editor believes the process of CLARK to be *virtually impracticable on the large scale*, while its efficacy is but slight.

It must be remembered that this mode affects the bicarbonate of lime, not the more troublesome earthy salts, such as the sulphates and chlorides, on which the hardness of spring waters mainly depends. The difficulty of mixing lime and water, in definite proportions, on the large scale, must be obvious to every one. If too much be employed, the companies would supply their customers with *lime-water*! If too little, the bicarbonate of lime would not be completely destroyed, and the process would be a failure. Altogether, the difficulties of carrying out the process will ever prevent its adoption on a large scale.

Addition of Oxalate of Potassa.—Mr. HORSLEY of Cheltenham, some years ago, took out a patent for a new method of preventing incrustations in boilers, and also for depurating, filtering, and otherwise rendering water more fit for drinkable and other purposes. When sea-water is taken for generating steam, he purifies it by employing oxalate of potassa and ammonio-phosphate of soda; and the proportions he uses for the water of the British Channel are about two drachms of oxalate of potassa to about two ounces of the ammonio-phosphate of soda for every gallon. When his object is to februate and soften hard water, he employs such substances as are capable of decomposing the calcareous salts, such as calcined or caustic baryta, or baryta water, phosphate of soda, silicate of potassa, oxalic acid, or the oxalates, and caustic strontia, or strontia water; but he gives the preference to oxalate of potassa. He first ascertains the degree of hardness of the water, and then adds the requisite quantity of oxalate of potassa, by which an oxalate of lime is precipitated; and there remains in solution, instead of the lime thus displaced, a carbonate, sulphate of potassa, or chloride of potassium, as the case may be, and the water is purified and fit for use.

The following equation explains the reaction of oxalate of potassa; the salt is assumed to be neutral on bicarbonate and sulphate of lime:—

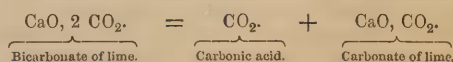


HORSLEY's patent process does that which CLARK's fails to do: it decomposes all the earthy salts on which the hardness of water usually and mainly depends. But it is open to still greater objections than those that have been raised to the other method. Besides being, like CLARK's, process virtually impracticable, it would prove very expensive, and as regards the metropolitan river-waters, it is quite unnecessary. Moreover, the idea of *physicking* or *doctoring* water, by the addition to it of a poisonous agent, would, if even no other objection existed to this scheme, be quite fatal to it. For though, in the hands of competent persons like Mr. HORSLEY, no possible injury could arise from its use, yet the public would always have some suspicion of water thus treated; and, as a celebrated English engineer observed to ARAGO, water, *like Caesar's wife, should be above suspicion*, which the Rivington Pike

water supplied to Liverpool is not. Liverpool was formerly supplied with spring water from the red sandstone, beautifully cool and refreshing, and free from organic matter. Now the inhabitants are forced by a stubborn water committee to drink a mixture of the *rock* and *surface* water—how the people suffer it is to the Editor a mystery—the latter certainly *blasting its wholesome brother*. The small town of Flint, North Wales, has infinitely better water than is supplied to any of the principal towns of England.

Purification and Filtration of Water.—JOHNSTON says truly, that the water used by a nation or country is an important matter in a well-considered and long-adjusted diet. It by no means follows in all cases, perhaps not even in the majority, that the *purest* water—see *Distilled Water*—is the best for the health of a given family, or for the population of a given district. The bright, sparkling, hard waters which gush out in frequent springs from the chalk and other limestone rocks are relished to drink, not merely because they are grateful to the eye, but because there is something exhilarating in the excess of carbonic acid they contain and give off as they pass through the warm mouth and throat, and because the lime they hold in solution neutralizes or counteracts acid matters in the stomach, and thus acts as a grateful medicine to the system.

On entering upon the purification and filtration of water, it may be stated as an axiom that *the best filter is no substitute for bad water*; still, as various towns throughout the kingdom are supplied with bad water, that is, water containing chemical and mechanical impurities, the Editor deems it necessary to explain to the reader how to remove these wholly or in part, so as to *better* the water. The depuration of water is greatly aided by repose, by which various suspended or mechanical impurities are allowed to subside gradually, and from these the supernatant fluid is drawn or siphoned off. Tanks, cisterns, and reservoirs become therefore important depurating agents. The purification of water by subsidence and decantation is the simplest of all methods of februation; but unfortunately it is a very slow one. It is stated that the water of the Garonne, taken when the river is swollen, does not regain its natural limpidity after a fortnight of perfect rest. The larger particles, of course, quickly deposit, but the finer ones precipitate very tardily. During the time that deposition is occurring, the water is exposed to the air, and consequently undergoes a chemical metamorphosis. The bicarbonate of lime which is dissolved in it parts with a portion of its carbonic acid, and carbonate of lime precipitates:—



In this way the atmosphere assists in softening those waters, which owe the whole or a portion of their hardness to the above calcareous salt. The atmosphere, however, is a source of contamination as well as of purification, and it is on this account that the Editor always condemns the use of *surface* water for dietetic purposes. EHRENBURG states that, exclusive of inorganic substances, he has detected three hundred and twenty species of organic forms in the dust of the

winds. It is obvious, therefore, that waters which are chemically very pure, must become contaminated by exposure in deposit reservoirs.

What are the best methods of purifying water on a large scale?

The water, says TOMLINSON, used for culinary, domestic, and industrial purposes, is exclusively derived from the rain which falls upon the earth, whether the immediate source of supply be the cistern, the well, the spring, or the river. Rain-water is usually so pure, that the action of the most delicate chemical tests is required to detect any foreign substance in it; so that, if cisterns were formed of proper materials, and the rain fell directly into them in sufficient quantity, no better water could be desired. But as the exposed surface of cisterns is too small to collect rain-water in any quantity, it is usual to discharge into them, by means of gutters and shoots, the water which falls upon the roofs of houses; and, as these are covered with dust, insects, and other impurities collected during dry weather, the rain-water of cisterns is thus contaminated in various ways. In some places the rain-water, collected on the surfaces of extensive roofs and flats, is made to pass through a bed of porous materials on its way to the cistern, and thus the solid impurities are strained and separated before the water is used by the public. Such is the case with the large cistern of the ducal palace at Venice.

Wells may be compared with cisterns; but the channels which discharge rain-water into them are not formed of masonry, brick, or metal, but of the rocks which exist immediately beneath the surface. These rocks may be porous, or may abound in minute fissures, through which the rain-water, sinking through the soil, finds a passage; and being divided into innumerable liquid threads, it dissolves and carries along with it a portion of whatever soluble matter it may encounter. Hence, the water obtained from wells is not rain-water, properly so called; it is usually as clear and limpid, but it contains nearly always certain substances in solution, which vary according as the geological structure of the country differs. The same remark applies to springs: their water is rain-water, which, after having traversed strata of greater or less thickness, is sent up to the surface by the pressure of the water in the neighboring hills or other elevations. The nature and proportion of the impregnation to which spring-water is subjected, depend also on the extent of its transit and the kind of rock traversed. The action of rain-water upon certain kinds of rock leads to the production of mineral springs; and if the water descends to a certain depth in the earth, its temperature will be so much raised by the internal heat, that on reappearing at the surface, it will be as a thermal spring.

In filtering on a large scale, for the supply of a city, for example, the cost and durability of the filter are important considerations. On the great scale of Nature, the rocks which filter the water, as it falls upon the surface of the soil, constitute a vast permanent filter, the durability of which arises from the great extent of superficial or subterranean surface concerned. It might at first view appear to be easy to imitate this natural operation, and pass the muddy water of a river through

the porous rock or sand which forms its banks; but this is often an expensive proceeding, on account of want of permanence of an artificial structure so contrived. Toulouse is supplied with water from the Garonne in this way, and it has cost upwards of forty thousand pounds at various times for supplying a city of only fifty thousand inhabitants. The cause of failure in this and other instances arises from the fact already noticed, that when water percolates sand, it deposits its solid impurities to a certain depth between the interstices of the filtering medium, rendering it necessary from time to time to renew the sand. This is illustrated by some experiments conducted by Mr. WICKSTEED. A sand filter which yielded at the rate of ten the first week, yielded nine the second week, six the third week, and only two the fourth week; so that a large natural filter—as this description of filter is called—may go on for some years, yielding a good supply of water, and then gradually diminish it until it ceases altogether. Hence the construction of these so-called natural filters requires much caution on the part of the engineer; and it will always be difficult, if not impossible, to calculate before hand the amount of water which a natural filter proposed to be erected will yield.

A second system of filtration on a large scale consists in the formation of extensive beds of sand of great thickness, resting on beds of gravel, *et cetera*. At intervals of time, from ten to fourteen days, the water is run off; and the filth which had accumulated during filtration is scraped off with a certain thickness of the sand of the filtering bed. Once or twice a year the whole of the sand removed is replaced. This method is costly, and not altogether satisfactory.

Of all the permeable substances used for filtration, animal charcoal possesses in the highest degree the combined mechanical and chemical influence. In addition to its power, in common with other filtering media, of removing suspended or mechanical impurities, it also abstracts from the liquid which percolates it, various *dissolved* bodies, and thus effects a metamorphosis in the chemical composition of the fluid which traverses it. These important properties of animal charcoal have oftentimes led to its use as a filtering medium for water; and hence it is introduced into many of the ordinary domestic water filters. But its deodorizing and decoloring power is soon lost; and, in order to enable it to reacquire its original efficacy, it requires to be re-formed.

There can be no doubt that of all known permeable bodies, the only ones which present all the requisites of filtering media for water on a large scale, are sand and gravel. They are cheap, allow the rapid passage of water through them, and, when *they have been previously well washed*, communicate no taint to the waters which traverse them. Their employment must have been suggested to man by the observation of the numerous limpid springs which are seen in arenaceous districts.

Their action, however, is chiefly *if not entirely* mechanical. They possess little or none of that power of effecting chemical changes on the liquids filtering through them, which animal charcoal possesses in so pre-eminent a degree. Yet, unless several distin-

guished writers have grossly deceived themselves, sand is not entirely devoid of this chemical influence. WAGENMANN, for example, found that when vinegar was filtered through pure quartz sand, the first portion of liquid that percolated was deprived of almost *all its acid*; and the vinegar did not pass through unchanged until the sand had become well charged with acid. The same authority also states that potato-brandy diluted with water, and filtered through quartz-sand, yields at first pure water, then a mixture of water and alcohol deprived of its fusel-oil; and, lastly, the original mixture unaltered. BERZELIUS filtered a saline solution through a long tube filled with sand, and found that it ran out more or less completely deprived of salt. MATTEUCCI repeated BERZELIUS' experiment, and confirmed his statement. He filled a tube about twenty-six feet long with sand, and filtered a saline solution through it; and he found that the density of the liquid introduced by the upper aperture of the tube was to that of the liquid escaping from the lower end, as 1.00 to 0.91. But he observed that this difference of density was not always maintained; for, after a certain time, the saline solution becomes as dense at its exit from, as at its entrance into the tube, proving that the decomposition of the saline solution takes place in the first action of contact between it and the particles of sand. But a still more remarkable result, the inverse of the one just stated, was obtained by the last-mentioned chemist, with a solution of carbonate of soda. He filled a tube nearly ten feet long with sand, and filtered a solution of carbonate of soda through it; and he found that the density of the liquid at its entrance was to that at its exit as 1.000 to 1.005. In this case, then, the sand had deprived the solution of part of its water, and had thereby increased the gravity of the liquid which percolated. Assuming, however, the accuracy of all these reported observations, it cannot be doubted that, *in a practical point of view*, the efficacy of sand, as a filtering medium, depends on its *mechanical, not on its chemical influence*.

Domestic Filters.—In coming now to notice small filters for domestic purposes, such a multitude of inventions and contrivances start up to view that, as TOMLINSON says, how to choose and where to begin is difficult. There are certain classes of subjects, says the same authority, on which the genius of inventors seems to run riot. *Filters* form one of these, and *fire-escapes* another. In either class examples are as numerous as the attempts to solve the problem of perpetual motion, or to square the circle. Almost every kind of porous substance has been enlisted into the service of filters. The animal, vegetal, and the mineral kingdoms have each contributed. Charcoal—animal and vegetal—sponge, flannel, cotton, straw, hemp, saw-dust, wood shavings, branches and leaves, various kinds of porous stone, sand, pounded glass, zinc and iron filings, are a few only of the materials that have been recommended or used; and the methods of employing them are as various and as dissimilar as the substances themselves. The Editor considers the best filter for home use to be that of FORSTER of Liverpool, which he employs in his own house. The water percolates a fine porous stone, which removes all mechanical impurities, and

imparts a freshness to the water, which is not the case when sponge, charcoal, and other substances are the filtering media. It is, as TOMLINSON states, remarkable that very few filters were exhibited in the foreign department of the Great Exhibition. France sent three—two of stone and one of charcoal. An ingenious form of filter was exhibited by the Wenham Lake Ice Company, which consisted of a siphon, the extremity of the short limb of which is furnished with a box containing the filter, so that on inserting this into a cistern or cask holding water, and applying suction at the extremity of the longer limb, a stream of filtered water can be obtained, which may be arrested or drawn at will by shutting or opening the tap, as seen in the figure. In the laboratory, unsized paper is almost exclusively employed as a filtering medium. Other substances, such as flannel, tow, sand, pulverized glass, may occasionally be used.

An arrangement is also made for retaining the liquor in the filter at the same height, until the whole of the fluid to be percolated is expended. To insure this, the menstruum to be passed through is held in a flask inverted, the neck of which, as the reader will perceive by the wood-cut, dips into the liquor already contained in the funnel. As the liquor descends, and the neck of the flask becomes uncovered, a bubble or two of air enters; more liquor exudes, until the neck becomes again immersed, and all communication with the air is again cut off.

VESSELS FOR CONTAINING WATER.—Lead and other metals are very useful to store water in. The Editor is very glad to find, however, that the clean, inexpensive, and beautiful material, slate, is coming into use for cisterns, instead of lead, which is a dangerous metal to have in contact with a liquid of such daily and universal consumption.

DISTILLED WATER.—Certain technical and analytical purposes demand that the water employed by the operator or analyst be perfectly pure. To insure this, distillation is resorted to, by which operation the foreign matters held in suspension or solution are separated. Dr. NORMANDY remarks, that the distillation should be arrested when the salts begin to precipitate; for if the process were continued, part of these saline matters might suffer decomposition, and thus contaminate the distillate. The annexed table from NORMANDY shows the characteristics of pure water. It must not become turbid, or produce a precipitate with any of the subjoined reagents:—

Baryta water—If a precipitate or opaqueness appear, carbonic acid is present.

Chloride of barium—Shows sulphates.

Nitrate of silver—Indicates chlorides.

Oxalate of ammonia—Evidences lime salts.

Sulphide of hydrogen, solution made slightly acid—Antimony, arsenic, tin, copper, gold, platinum, mercury, silver, lead, bismuth, cadmium.

Sulphide of ammonium, solution alkalinized by ammonia—Nickel, cobalt, manganese, iron, zinc, alumina, chromium.

Chloride of mercury, chloride of gold, sulphate of zinc—Prove organic matter.

Pure distilled water, evaporated on a piece of platinum foil, *should leave no residue*. As a drink it is insipid, and is not recommended except in some cases of calculi.

The following table, embracing the composition of some principal river and well waters, will prove interesting to the reader :—

GRAINS IN THE IMPERIAL GALLON.

RIVER.									WELL.	
	Clyde, Glasgow. Penny.	Leven. Penny.	S. vine. Deville.	Rhine. Deville.	Garonne. Deville.	Loire. Deville.	Rhone. Deville.	Doubs. Deville.	Arcnell Aquaduct, at Paris.	Dijon.
Carbonate of lime,.....	2·52	·50	11·609	9·511	4·524	3·374	5·334	13·397	12·958	16·133
Sulphate of lime,.....	·26	·52	1·886	1·030	—	—	—	—	11·490	—
Chloride of calcium,.....	—	—	—	—	—	—	—	—	—	—
Carbonate of magnesia,...	·72	—	·189	·350	·238	·427	3·430	·161	·575	·266
Sulphate of magnesia,...	—	—	trace	—	—	—	—	—	—	—
Chloride of magnesium,...	·40	·66	—	—	—	—	—	·035	1·163	—
Sulphate of soda,.....	1·94	·39	—	·945	·371	·238	·519	·357	·378	·189
Carbonate of soda,.....	—	—	—	—	·455	1·023	—	—	—	·147
Chloride of sodium,.....	·54	·73	·862	·140	·224	·336	·119	·161	2·637	·224
Sulphate of potassa,.....	1·94	·39	·350	—	·533	—	—	—	1·410	—
Nitrate of potassa,.....	—	—	—	2·660	—	—	·280	·287	—	·189
Nitrate of soda,.....	—	—	·659	—	—	—	·315	·273	—	—
Nitrate of magnesia,.....	—	—	·364	—	—	—	—	—	3·998	—
Phosphates—earthy,.....	·31	·18	—	—	—	—	·333	—	—	—
Alumina,.....	·28	·32	·035	·175	—	·498	—	·147	·371	·070
Oxide of iron,.....	trace	—	·175	·406	·217	·385	—	·210	—	—
Silicic acid,.....	·28	·32	1·711	3·423	2·813	2·848	1·669	1·114	2·146	1·068
Organic matter,.....	·89	·45	—	—	—	—	—	—	—	—
	7·86	3·75	17·840	16·247	9·585	9·437	9·082	16·142	37·126	18·283

Physiological Effects.—Water is an essential part of the blood and of the living tissues. It is from this liquid that the tissues derive their properties of extensibility and flexibility. It gives fluidity to the blood, and enables the transportation of organic particles from one part of the body to another to be effected. Lastly, it contributes to most of the transformations which occur within the body. Considered dietetically, aqueous drinks serve several important purposes in the animal economy: they repair the loss of the watery part of the blood, caused by evaporation and the action of the secreting and exhaling organs, and thereby assist the stomach in the act of digestion. If, however, they are swallowed in excessive quantity, they may impede digestion by diluting the gastric juice. It is not improbable that water acts as a real nutritive agent, that is, assists in the formation of the solid parts of the body. As an agent for the communication or abstraction of heat to or from the body, water has been before noticed. Furthermore, the influence of atmospheric humidity modifies the character of climates.

Water moderately warm, and which neither cools nor heats the body, acts locally as an emollient, softening and relaxing the various tissues to which it is applied. When swallowed, it allays thirst, becomes absorbed, mixes with and thereby attenuates the blood, and promotes exhalation and secretion, especially of the aqueous fluids. Administered in large quantities, it excites vomiting. The continued excessive employment of water has an enfeebling effect on the system, both by the relaxing influence on the alimentary canal, and by the excessive secretion which it gives rise to. Injected into the veins in moderate quantities, tepid water has no injurious effects; it quickens the pulse and respiration, and increases secretion and exhalation. Large quantities check absorption, and cause difficulty of breathing and an apoplectic

condition. Thrown with force into the carotid artery, it kills by its mechanical effects on the brain.

Besides the dietical and thermotic purposes for which water is employed in medicine, it serves as a diluent, humectant, emollient, evacuant, and, in pharmacy, as a solvent. Water, or bland aqueous fluids, are employed in some cases of poisoning. They serve to dilute the acrid and irritant poisons, the intensity of the action of which on the stomach they lower. Moreover, the presence of aqueous fluids favors the expulsion of substances by vomiting. In preternatural dryness and rigidity of parts—for example, of mucous surfaces, the skin, wounds, and ulcers—water and mild aqueous fluids are useful moisteners and emollients. The copious use of water augments the quantity of fluid thrown out of the system by the cutaneous and pulmonary surfaces, and by the kidneys. If the object be to promote diaphoresis, external warmth should be conjoined with the internal use of diluents; whereas, when one wishes to excite the renal vessels, the skin should be kept cool. In inflammatory affections of the urinary passages, the free employment of aqueous fluids is advised, with the view of diluting the urine, and thereby of rendering it less acrid and irritating. What is called water-dressing may be regarded as a modified and improved form of poultice. It consists in the application of two or three layers of soft lint dipped in water, and applied to inflamed parts, wounds, and ulcers, the whole being covered with oil silk or Indian rubber, which should project beyond the margin of the lint to retain the moisture, and prevent evaporation. Dr. MACARTNEY considers it to operate differently to a poultice; unlike the latter, he says, it prevents or diminishes the secretion of pus, checks the formation of exuberant granulations, and removes all pain. Moreover, the water is not liable to become sour like a poultice, and does not injure the sound part. Water

is frequently employed in pharmacy for extracting the active principles of various medicinal agents.—*Pereira*.

MINERAL AND OTHER WATERS.—GLOVER justly remarks that few subjects connected with medicine are more interesting to the general reader than that of mineral waters. The circumstances attending their administration, the natural mode of their production, the scenery in which they are often placed, and the associations frequently surrounding them, combine to give them, as remedies, an interest exceeding that of ordinary medicinal agents. Hygiene and medicine, in the narrow acceptance of the terms, join hand in hand at the salubrious fountain. Spas have been exalted, and are still exalted by interested parties, as panacean cures for all diseases; others unworthily decried; source has been pitted against source, and pump against pump; and battles fought between biassed spa-doctors, which only tended to raise doubts in the opinions of thinking men.

To enter largely into the subject of natural and artificial mineral waters would be quite out of place in a book of this description, and it would be incompatible with the assigned limits to give more than a general insight into their nature, character, composition, and manufacture. The great *furor* for saline and other springs is daily abating; a very striking proof of this being evidenced at Cheltenham, to which thousands used to rush yearly to partake of its waters, whereas now it is almost entirely deserted. The same, no doubt, will soon be the case with other places, and artificial will, in many cases, supply the place of natural waters. Is not more due to the diet, change of scene and air, than to the virtues said to be possessed by certain springs? What miraculous cures are stated to have been produced by the water of Holywell, Flintshire, North Wales; and yet analysis reveals *nothing* particular in this spring to impart to it medicinal properties, as illustrated by the annexed tabulated results of Mr. JAMES BARRATT, pupil of the Editor—

Temperature,.....	52°
Specific gravity,.....	1.0015
Grains. Per imperial gallon.	
Carbonate of iron,.....	traces
“ lime,.....	13.685
“ magnesia,.....	2.688
“ soda,.....	1.432
Chloride of calcium,.....	3.094
“ potassium,.....	traces
“ sodium,.....	0.821
Silicic acid,.....	2.737
Sulphate of lime,.....	5.202
“ magnesia,.....	traces
Total,.....	29.659
Direct determination of fixed constituents,.....	30.450
Free carbonic acid, 10.338 grains, = 21.874 cubic inches.	

This famous spring is the first in Great Britain; it never freezes, and scarcely varies in the quantity of water it emits, drought or wet weather, flinging out *twenty-one tons a minute*.

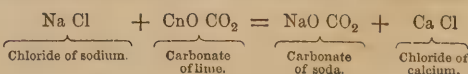
PEREIRA remarks—Mineral waters were known to mankind in the most remote periods of antiquity, and were employed medicinally both externally and internally. HOMER speaks of tepid and frigid springs. The *Æsculapide*, or followers of *ÆSCULAPIUS*, accord-

ing to SPRENGEL, erected their temples in the vicinity of mineral and thermal waters. HIPPOCRATES mentions mineral waters, although he does not prescribe them when speaking of particular diseases. Their medicinal properties are spoken of by PLINY.

The principal source of saline waters is the rain, snow, hail, dew, percolating a certain portion of the soil, and dissolving various matters in their passage, so as to reappear on the surface at the bottom of declivities as spring-water; or when procured by sinking pits or wells—well-water. But springs are sometimes observed, continues PEREIRA, under circumstances which are inconsistent with the supposition of their atmospheric origin. The boiling springs, says GAIRDNER, which emerge on the verge of perpetual snows at an altitude of thirteen thousand feet above the level of the sea, as in the Himalayas, cannot be derived from the air.

Mineral waters, of course, procure their particular and distinctive properties or qualities from the strata through which they flow. Those of the primitive formation are almost all thermal, generally possessing a high temperature, while those of the older secondary formations are generally cooler. The hot or thermal waters are those possessing a degree of heat more or less raised above the mean of the latitude or elevation at which they are found, and the changes of which, if any, observe no regular periods coincident with the revolutions of the seasons. Three causes, says PEREIRA, have been assigned as the source of the temperature of mineral waters, namely, volcanic action, now in existence; volcanic, now extinguished, but the effects of which still remain; and a central cause of heat, which increases in descending from the surface to the interior of the earth. The *Geysers*, or boiling springs of Iceland, are evidently the result of volcanic action.

PEREIRA proceeds—The origin of the saline and other constituents of mineral waters is another interesting topic of inquiry connected with the natural history of mineral springs. As water, in its passage through the different strata of the globe, must come in contact with various substances which are soluble in it, one refers certain constituents of mineral waters to solution and lixiviation merely, as chloride of sodium, carbonates of lime and magnesia, oxides and bromides of sodium and magnesia, iron, silicic acid, *et cetera*. Chemical action must, in some cases, be the source of other constituents. Sulphide of hydrogen is most likely the result of the action of water on some metallic sulphide, especially iron pyrites; sulphurous or sulphuric acid from the oxidation and combustion of sulphur, free or combined. In acidulous or carbonated waters the carbonic acid probably arises from the decomposition of chalk either by heat or sulphuric acid. The disintegration of chlorides of sodium or ammonium would eliminate hydrochloric acid, while carbonate of soda, found so largely in the native lakes of Egypt, might, as BERTHOLLET supposes, be proved by the action of chloride of sodium or carbonate of lime; thus—



GAIRDNER states that the different orifices of the Karlsbad Sprudel discharge annually about thirteen thousand tons of carbonate of soda and twenty thousand tons of sulphate of soda, in a crystallized state; and further adds, that a very simple calculation is sufficient to prove that the Donnersberg alone, the highest of the Bohemian Mittelgebirge, a cone of clinkstone two thousand five hundred feet in elevation, eviscerates soda sufficient to supply the Karlsbad waters for more than thirty thousand years.

The Editor agrees with PEREIRA that the best classification to adopt is that of grouping mineral waters into four classes, *videlicet*, chalybeate, sulphurous, acidulous, and saline.

CHALYBEATE OR FERRUGINOUS WATERS.—These terms are applicable to those waters, the active principle of which is *iron* in considerable quantity. These waters possess a styptic taste, and when they contain the protoxide of the metal, yield, with ferrocyanide of potassium, a *white* or bluish-white precipitate; and if the sesquioxide be present, they give a *blue* precipitate with ferrocyanide of potassium, and become *red* with

the alkaline sulphocyanide. The carbonated chalybeates are of two kinds, those containing the carbonate of iron, associated with much carbonic acid, which renders them acidulous and effervescent. The Pyrmont, Trinkquelle or drinking spring, Schwalbach Spa, and Pouhon, are of this nature.

The noneffervescent ones are Oddy's saline chalybeate at Harrowgate, the Islington Spa near London, and the waters of Tunbridge Wells. These are also sulphated chalybeates, but they are not of so much importance.

SULPHUROUS OR HEPATIC WATERS.—The most celebrated of these waters are—in England, those of Harrowgate, the appended analyses by Dr. A. W. HOFFMANN being given; Scotland—Moffat and Rothesay; of the Continent—Enghien, Barèges, Aix, near Geneva, Aix-la-Chapelle, and Baden. They have the disagreeable smell of rotten eggs, and give, with salts of lead, bismuth, copper, *et cetera*, black precipitates.

Subjoined are analyses by Dr. HOFFMANN of several of the most important saline chalybeates at Harrowgate:—

GRAINS OF SALINE CONSTITUENTS IN THE GALLON OF WATER.

	Old sulphur well.	Montpellier strong sulphur well.	Montpellier mild sulphur well.	Hospital strong sulphur spring.	Hospital mild sulphur spring.	Starbeck sulphur spa.
Temperature,	48.2°	46.4°	42.8°	41.9°	44.6°	48.2°
Specific gravity,	1.01113	1.01045	1.00314	1.00515	1.0026	1.0018
Ammonia,	trace	trace	trace	trace	trace	trace
Bromide of sodium,	trace	—	trace	trace	trace	trace
Carbonate of iron,	trace	trace	trace	1.060	trace	trace
“ lime,	12.365	24.182	20.457	25.560	19.794	6.960
“ magnesia,	—	—	3.251	5.797	—	—
“ manganese,	trace	trace	trace	trace	trace	trace
“ potassa,	—	—	—	—	—	12.207
“ soda,	—	—	—	—	—	5.133
Chloride of calcium,	81.735	61.910	—	—	—	—
“ magnesium,	55.693	54.667	17.140	11.595	0.336	—
“ potassium,	64.701	5.750	3.975	10.751	24.970	—
“ sodium,	866.180	803.093	232.413	369.014	220.630	121.798
Fluoride of calcium,	trace	trace	trace	trace	—	faint trace
Iodide of sodium,	trace	—	trace	trace	trace	trace
Organic matter,	trace	trace	trace	1.327	trace	1.740
Silica,	0.246	1.840	0.165	0.535	1.49	1.753
Sulphate of lime,	0.182	0.594	12.104	51.660	1.215	0.870
Sulphide of sodium,	15.479	14.414	3.398	7.155	0.301	1.711
Total,	1096.581	966.450	292.903	484.454	279.046	157.562

GASES DISSOLVED BY THE WATERS AND EXPELLED BY EBULLITION IN VACUO.

Composition in one hundred volumes.

	Old sulphur well.	Montpellier strong sulphur well.	Montpellier mild sulphur well.	Hospital strong sulphur spring.	Hospital mild sulphur spring.	Starbeck sulphur spa.
Carbonic acid,	61.06	70.62	62.50	31.79	44.07	49.78
Carbide of hydrogen,	16.17	2.71	3.99	0.52	22.80	27.71
Nitrogen,	8.08	24.21	33.51	65.88	25.31	22.51
Oxygen,	—	2.46	—	—	7.82	—
Sulphide of hydrogen,	14.69	—	—	1.81	—	trace
Total,	100.00	100.00	100.00	100.00	100.00	100.00

CUBIC INCHES OF THE GASES IN THE GALLON OF WATER.

	Old sulphur well.	Montpellier strong sulphur well.	Montpellier mild sulphur well.	Hospital strong sulphur spring.	Hospital mild sulphur spring.	Starbeck sulphur spa.
Carbonic acid,	22.03	14.01	14.28	9.54	10.20	9.26
Carbide of hydrogen,	5.84	0.53	0.90	0.15	5.28	5.15
Nitrogen,	2.91	4.82	7.67	19.78	5.87	4.21
Oxygen,	—	0.48	—	—	1.81	—
Sulphide of hydrogen,	5.31	—	—	0.54	—	trace
Total,	36.09	19.84	22.85	30.01	23.16	18.62

COMPOSITION OF THE GASES, IN ONE HUNDRED VOLUMES, RISING FROM THE WATER IN BUBBLES.

	Old sulphur well	Hospital strong sulphur spring.
Carbonic acid,.....	3.28	0.09
Carbide of hydrogen,.....	40.00	—
Nitrogen,.....	56.72	99.91
Oxygen,.....	—	—
Sulphide of hydrogen,.....	trace	trace
Total,	100.00	100.00

The sulphide of hydrogen exists in the above waters, partly free and partly combined. Only a portion can be expelled by ebullition. The amount of the sulphide of hydrogen in the waters varies, which may be partly due to influences affecting the strata through which the waters ascend; to a great extent, however, they must be ascribed to the action of the air.

The general operation of these waters, says PEREIRA, is stimulant. They are adapted for chronic complaints, and are supposed to possess a specific power over the cutaneous and uterine systems, and are said to be beneficial in chronic rheumatism and gout. As previously remarked, would not an iron salt, judiciously administered, act just as well in the above-mentioned diseases?

ACIDULOUS OR CARBONATED WATERS.—The name here implies waters charged with carbonic acid. Most waters contain a few cubic inches of carbonic acid in the gallon, but the acidulous will eviscerate from thirty to two hundred cubic inches. It is stated by ALIBERT that the waters of Saint Nectaire hold four hundred cubic inches in one hundred of the water.

Carbonate or bicarbonate is contained in waters of this kind, and, when this is the case they are called *acidulo-alkaline*. The Selters, Altwasser, Salzsbrunn, Reinerz, and Pymont acidulous waters are of this description. Protocarbonate of iron is sometimes present in them, classifying them under *acidulous carbonated chalybeates*. The spring at Ilkeston, near Nottingham, is the only water of the above class in Great Britain.

Acidulous waters are cooling, refreshing, and exhilarating, and oftentimes relieve nausea. The acidulo-alkaline waters are useful in the lithic acid diathesis, in gout and rheumatism, *et cetera*.

SALINE WATERS, according to PEREIRA, may be divided into five kinds:—

Purging Saline Waters.—Sulphates of soda or magnesia are the active ingredients of these waters: some owe their efficacy to sulphate of magnesia, others to sulphate of soda.

Bitter Purging Waters, Bitter Waters, Bitter-Salt Waters.—Sulphate of magnesia predominates in these waters. Epsom and Scarborough in England, and Seidlitz, Saidehütz, and Püllna on the Continent, are of this kind. Some thermal springs, as those of Acqua del Pozzeto, near Pisa, contain sulphate of magnesia.

Glauber Salt Waters.—Some writers give this name to those waters holding sulphate of soda in solution. Some of these are warm, and on this account are called the *warm alkaline glauher salt waters*. To this division belong the famous springs of Carlsbad,

now so much resorted to for good—or evil! Further on analyses are given of the Carlsbad water, and of several others of the leading and well-known Continental springs. Some of this class of waters are devoid of alkaline properties, but contain, besides sulphate of soda, various earthy and alkaline salts. They are the *earthy glauher salt waters*. To this division belong the deserted springs of Cheltenham, and those of Leamington and Spital.

In large doses the waters of this kind are mild cathartics. PEREIRA says they are useful in diseased liver, dropsical diseases, *et cetera*.

Salt or Brine Waters.—The characteristic ingredient of these springs is chloride of sodium. Iodine or bromine, or both, have been found in some of them, and these most likely add to their medicinal effects. The small quantity of iodine recently found in the water of St. Ann's Well at Great Malvern, Worcestershire, by the Editor, is doubtless the active ingredient in that water.

The Kreuznach and Salzhausen springs in Germany are among the brine springs, and in England the principal ones are at Middlewich and Nantwich in Cheshire, Shirleywich in Staffordshire, and Droitwich in Worcestershire.

Taken in large quantities, saline or brine springs are emetic and purgative. They have been principally celebrated in glandular swellings. The water of Baden Baden contains a large quantity of chloride of sodium.

Analysis of the water of Baden Baden by the Editor:—

	Imperial gallon. Grains.
Alumina,.....	trace
Carbonate of iron,.....	1.356
“ lime,	14.184
Chloride of calcium,.....	11.040
“ potassium,	13.720
“ sodium,.....	132.644
Organic matter,.....	trace
Phosphate of lime,	trace
Silicic acid,	2.947
Sulphate of magnesia,.....	5.236
	181.127
Specific gravity.....	1.00284
Carbonic acid.....	4.5 cubic inches.
Sulphide of hydrogen.....	trace.

Calcareous Waters.—These saline mineral waters, the leading constituent of which is either the sulphate or carbonate of lime, belong to this order.

The Buxton, Bath, and Bristol thermal waters, come under the same category. Annexed is an analysis of the Buxton water just completed by the Editor; it differs materially from the one made by his friend PLAYFAIR some time ago, except in the amount of gases:—

	Grains in the imperial gallon.
Carbonate of lime,.....	8.541
Carbonate of magnesia,.....	3.741
Carbonate of protoxide of iron,.....	0.082
Sulphate of lime,.....	0.330
Chloride of calcium,.....	1.227
Chloride of magnesium,.....	0.463
Chloride of sodium,.....	2.405
Chloride of potassium,.....	0.260
Silica,.....	1.044
Nitric acid,.....	trace
Organic matter,.....	0.341
Fluoride of calcium,.....	trace
Phosphate of lime,.....	trace
Total per gallon,.....	18.434
Free carbonic acid,.....	3.5 cubic inches.
Nitrogen,.....	504 "

Calcareous waters are stimulant, alterative, and constipatory. Externally they are said to be beneficial in the cure of rheumatism, gout, chlorosis, chronic skin diseases, *et cetera*.

The quantity of nitrogen gas accompanying this water has been previously alluded to. Dr. ROBERTSON, in treating of the physical characters of the Buxton waters, ascribes their brilliancy when drawn to the quantity of gas *held in solution*. Of course, this must be fallacious, for very little gas is *held in solution* or *dissolved*. As GLOVER remarks, what occurs in the baths, where a quantity of the nitrogen has been forced along by the current of water, three hundred gallons per minute, furnishes no indication of the amount of *gas in solution*. The great use of the Buxton water is, of course, externally, but upon what its effects mainly depend *still remains unexplained*.

Mr. J. ARMITAGE PEARSON, the eminent consulting surgeon of Buxton, has informed the Editor that he does not look upon the *nitrogen* in any water to be an effective element; and although one sees the gas constantly gurgling forth in strong streams, still Mr. PEARSON agrees with the Editor, that being an *insoluble* gas, it is not absorbed into the system; and even *supposing that it could be absorbed*, it could not exert any beneficial result. All water is a diuretic, more or less. Mr. PEARSON places very little value on the Buxton waters *per se*; but administered with a certain and most valuable medicine—an alkaloid—which he has prescribed, he has effected several wonderful cures. The lime salts in the water no doubt exert a beneficial influence.

To divert the reader's attention a little, the following anecdote with regard to how waters of one kind or another become celebrated, is given by the writer of *Bubbles from the Brunnens of Nassau*, with regard to the discovery of the far-famed waters of Sclangenbad. It is characteristic of the supposed origin of many similar watering-places, and as such it may amuse, if it does not much edify, the reader:—In the history of the little Duchy of Nassau, says that graceful writer, the discovery of the spring forms a story full of innocence and simplicity. Once upon a time, there was a heifer with which everything in nature seemed to disagree. The more she ate, the thinner she got. The more her mother licked it, the thicker and more staring was her coat. Not a fly in the forest would bite her. Never was she seen to chew the cud; but, hide-bound and

melancholy, her hips seemed to be actually protruding through her skin. What was the matter with her no one knew; what could cure her, no one could divine; in short, neglected by her master and her species, she was, as the faculty would term it, *given over*. In a few weeks, however, she suddenly reappeared among the herd with ribs covered with fat, eyes like a deer, skin as sleek as a mole, breath smelling sweetly of milk, saliva hanging in ringlets from her jaw. Every day seemed to re-establish her health, and the phenomenon was so striking, that the herdsman, having watched her, discovered that regularly every morning she wound her way in secret into the forest, until she reached an unknown spring of water, from which, having refreshed herself, she quietly returned into the valley. A young Nassau lady showed symptoms similar to those of the heifer, and the herdsman recommended the water, which cured her!

GLOVER says justly in his very readable work on mineral waters, that there is a certain mystery connected with the origin and mode of operation of some of them, which no doubt with many is attractive, just as in the extraordinary doctrines of HAHNEMANN and others. Many of these waters, and especially the thermal ones—Buxton, *et cetera*—produce effects in general estimation far beyond what can be accounted for, either by their chemical composition and the power of their *known* ingredients, or by their temperature as shown by the thermometer, in comparison with those of ordinary water baths.

ALKALINE WATERS.—Carbonate and bicarbonate of soda are the characteristic ingredients in such mineral waters. The thermal springs of Teplitz and Ems come under this class, also the Vichy waters, which have long been noted for the cure of stone and gravel; but of late years they have been the subject of discussion among French physicians as to their efficacy in these disorders.

Among the mineral waters in this country which contain carbonate of soda are those of Ilkeston in Derbyshire, near Nottingham, and Malvern in Worcestershire, an analysis of the latter being appended. These waters have only recently been minutely analyzed in the Editor's laboratory:—

	St Ann's Well, Great Malvern. Editor.	Holy Well, Malvern Wells. Barratt.
	In the imperial gallon.	
Alumina,.....	—	traces
Carbonate of iron,.....	0.0331	0.22470
" lime,.....	0.4310	1.02480
" magnesia,.....	0.4111	1.48400
" soda,.....	0.2844	0.93310
Chloride of magnesium,.....	0.1443	—
" sodium,.....	0.8768	0.94570
Iodide of potassium,.....	0.0021	—
" sodium,.....	—	0.00029
Silicic acid,.....	0.2057	0.19250
Sulphate of lime,.....	1.1521	1.65690
" soda,.....	0.4382	0.09660
Organic matter,.....	—	traces
	3.9772	6.55859
Specific gravity,.....	1.0013	1.0012
Carbonic acid in cubic inches,.....	1.382	6.722
Temperature,.....	48°	46°

The above waters issue from the rock at the rate of

about three gallons a minute, and they have been renowned as highly advantageous as an external application to indurated scrofulous tumors, ulcers, and many eruptive diseases, owing to the trace of iodine, as well as efficacious and beneficial when taken internally, for acidity, dyspepsia, *et cetera*—if so, why not take the active ingredient *per se at home*?

Dr. BOOKER thus apostrophizes the Holy Well—

Ever could I stray
Beside thy stream thou purest spring that flows;
Climb each bold eminence, and daily find
Some object new for wonder—ever gaze
On the wide scene around me, and regale,
When thirst demands, or pleasing taste invites,
At thy clear rill that sparkles at my foot,
And think it luxury.

Chemically it is not *the purest spring that flows*, that of St. Ann being much *purer*. Poetically, however, it may be.

Silicious Waters.—Most mineral waters contain traces of silicic acid, but some hold it in such quantity that the term *silicious* is applied to them. In the boiling springs of Geyser and Reikum in Iceland it amounts to nearly the half of the solid constituents. The action of such water—of course the silica is united to an alkali—will be similar to those of the soda or potassa waters. Annexed are analyses of several of the most important mineral waters on the Continent:—

	Sprudel Carlsbad.	Ems. Kesselbrunnen.	Selters.	Gastein.	Tepiltz, Hauptquelle.	Wildbad.	Kissingen.	Kreuznach Karlsbeller- brunnen.	Pymont Trinkquelle
	Temp. 165° sp. gr. 1·00497.	Temp. 115° sp. gr. 1·0034.	Temp. 60·6° sp. gr. 1·0336.	Temp. 95° sp. gr.	Temp. 1·9° sp. gr. 1·00065.	Temp. 90·5° sp. gr.	Temp. 62° sp. gr.	Temp. 61·5° sp. gr. 1·006.	Temp. 57° sp. gr.
Carbonate of baryta,.....	—	0·03	—	—	—	—	—	—	—
“ iron,.....	0·27	0·26	1·54	0·22	0·37	0·20	6·80	3·64	4·90
“ lithia,.....	—	—	—	—	1·82	—	—	—	—
“ lime,.....	23·70	11·40	18·67	3·97	3·25	3·40	35·50	6·13	59·88
“ manganese,...	0·06	0·03	—	trace	0·80	—	trace	6·54	0·48
“ magnesia,...	13·69	7·88	15·95	0·35	0·53	0·70	25·00	4·73	3·23
“ soda,.....	96·95	107·50	58·55	6·90	26·84	5·30	8·20	—	—
“ strontia,....	0·07	0·10	trace	trace	0·19	—	trace	—	—
Sulphate of lime,.....	—	—	—	—	—	—	25·00	—	72·21
“ lithia,.....	—	—	—	—	—	—	—	—	0·09
“ magnesia,....	—	—	—	—	—	—	—	—	26·97
“ potassa,.....	—	5·40	—	0·55	4·34	0·20	—	—	0·42
“ soda,.....	198·69	—	2·48	14·95	—	4·00	20·00	—	21·45
“ strontia,....	—	—	—	—	—	—	—	—	0·20
Phosphate of alumina,....	0·02	0·018	—	—	0·22	—	—	—	0·14
“ lime,.....	0·01	—	—	trace	—	—	—	—	—
“ soda,.....	—	—	2·81	—	trace	—	1·70	—	—
Chloride of ammonium,...	—	—	—	—	—	—	0·50	—	—
“ calcium,....	—	—	—	—	—	—	—	25·61	—
“ lithium,....	—	—	—	—	—	—	—	0·56	—
“ magnesium,...	—	—	—	—	—	—	68·50	6·79	11·26
“ potassium,...	—	0·45	3·58	—	1·04	—	9·10	4·07	—
“ sodium,.....	79·75	76·34	162·85	3·40	4·33	18·20	620·50	596·65	—
Iodide of magnesium,....	—	—	—	—	—	—	trace	—	—
“ sodium,.....	—	—	—	—	0·56	—	—	0·44	—
Bromide of magnesium,...	—	—	—	—	—	—	7·00	66·02	—
Fluoride of calcium,....	0·24	0·019	—	—	—	—	—	—	—
“ sodium,.....	—	—	—	—	1·30	—	—	—	—
Alumina,.....	—	—	—	0·50	—	—	1·80	4·32	—
Silicic acid,.....	5·77	4·14	2·89	2·02	3·12	3·90	22·50	0·31	4·96
Glairine,.....	—	—	—	trace	0·90	—	5·30	14·72	—
	419·22	213·567	269·32	25·96	49·61	35·90	857·40	760·53	206·19

SEA WATER—*Aqua Marina*.—The waters of the ocean and inland seas are comprised under this head. It is rather a remarkable fact that the Dead Sea differs greatly in its constitution from sea-water, and might, as stated by PEREIRA, to whose excellent work the Editor is indebted for most of the preceding valuable information, be ranked amongst mineral waters.

According to the analysis of MARCET, the water of the Dead Sea contains 24·6 per cent. of fixed matter, and possesses an extraordinary density, 1·211—

	Centesimally represented.
Chloride of sodium,.....	10·360
“ calcium,.....	3·920
“ magnesium,.....	10·246
Sulphate of lime,.....	0·054
Water,.....	75·420

100·000

different seas, as instanced by the following results from PFAFF. The solid constituents are in ten thousand parts of the water of each:—

Mediterranean.....	410
English channel.....	380
German ocean {	
At the Island of Föhr.....	340
“ “ of Norderney.....	342
In the Frith of Forth.....	312
At Ritzebüttel.....	312
Baltic Sea. {	
At Apenrade in Sleswick.....	216
At Kiel in Holstein.....	200
At Doberan in Mecklenberg...	168
At Travenmünde.....	167
At Zoppot in Mecklenberg....	76
At Carlsbam.....	66

To assume that the average quantity of solid matter is three and a half per cent., and the density about 1·0274 will be very near the mark.

Annexed are the analyses of SCHWEITZER and LAURENS, of two samples of sea-water:—

The amount of saline matters varies considerably in

	English channel. Schweitzer.	Mediterranean. Laurens.
Chloride of sodium.....	27.05948 ..	27.22
Chloride of potassium.....	0.76552 ..	0.01
Chloride of magnesium.....	3.66658 ..	6.14
Bromide of magnesium.....	0.02919 ..	—
Sulphate of magnesia.....	2.29578 ..	7.02
Sulphate of lime.....	1.40662 ..	0.15
Carbonate of lime.....	0.03301 ..	} 0.20
Carbonate of magnesia.....		
Water.....	964.74372 ..	959.26
	1000.00000	1000.00

SCHWEITZER also detected iodine and ammonia, and BALARD found iodine in the Mediterranean; and no doubt it contains bromine and other constituents. In fact MALAGUTI detected *silver* in sea-water.

To render such water fit for drinking, it is evident that the greater part of these saline constituents must be removed; and, as TOMLINSON remarks, it has long been a desideratum to enable ships' crews to employ sea-water for different culinary purposes, with the view of removing the necessity of carrying large supplies of fresh water. Almost innumerable are the contrivances invented to meet this end, and, according to the above-cited authority, the most effective is GRANT'S, by which the cooking of victuals and the purifying of water are carried on synchronously. The apparatus is called *the distilling and cooking galley*. The galley contains the fires and vessels necessary for cooking. During the time when the fires are ignited, a portion of the heat is applied to the external part of vessels containing sea-water; the water boils, and steam distils over, leaving, of course, the salts in the still. The steam condenses in a worm, and is nearly pure water, which, of course, is vapid; but the taste may be improved by access to open air and agitation. Where steam-power is used, GRANT'S apparatus affords a ready and effective means of separating fresh-water from salt. PEREIRA says that CLARK'S patent improved pyrohydropneumatic apparatus for easily converting sea-water into fresh is a convenient form of still adapted for sea service. Congelation separates fresh from sea-water. In freezing the pure water only congeals, not the saline ingredients; hence the ice of the polar seas yields fresh water.

Physiological Effects and Uses.—Sea-water taken into the stomach excites thirst, nauseates, and in large doses occasions vomiting and purging. The repeated use of it in moderate doses has been found of service on account of its alterative and resolvent operation in scrofulous affections, especially glandular enlargements and mesenteric diseases. Its topical action is more stimulant than ordinary water. It is used as an embrocation in chronic diseases of the joints. Baths of it are not so exhausting as those of common water. It is a popular opinion, perhaps well founded, that patients are less likely to catch cold after the use of salt than of fresh water.—*Pereira*.

ARTIFICIAL AND AERATED WATERS.—About forty years ago, when the fabrication of mineral and spa waters commenced, a very violent opposition arose with regard to them, especially from the members of the faculty. They were said to be devoid of all the good qualities of the natural ones—to be minus a certain *conditio sine qua non*, in the shape of a *spiritus rectus*, or vital force,

which imparted the medicinal qualities. The Editor has lived to see such statements reversed. Chemistry, the great revealer of hidden treasures, has demonstrated to a certainty what the constituents of the natural waters are; and thus one is now enabled to produce artificial waters quite equal, if not superior to the natural ones. At the Brighton pump-room many artificial waters are prepared imitative of those of Carlsbad, Pyrmont, Vichy, Kreuznach, Ems, Seltzer, and many others, too numerous to detail. Messrs. ELLIS of Ruthin prepare a beautiful imitation of the Seltzer water which, on being analysed by the Editor, yielded exactly the same constituents as the far-famed Bohemian spring. The artificial is certainly more palatable than the natural water, owing probably to the freshness of the carbonic acid infused into it by the admirable apparatus of TYLER, which will be explained further on. To dwell particularly on artificial waters would be tedious and uninteresting to the reader; it is sufficient to state that in their manufacture the salts, in the same proportion as contained in the natural spring, are dissolved in as pure a water as possible, and are then more or less charged with carbonic acid or other gases.

It was PRIESTLEY who, in 1772, proposed to impregnate water direct with carbonic acid, and in 1774 prescriptions for the artificial production of Selters and Pyrmont waters, founded on an accurate analysis of the same, were published by BERGMANN.

Some years ago LIEBIG analysed the Friedrichshaller water, and it is now prepared in large quantities exactly with the salts, *et cetera*, and in the same proportion as given in his results; and if one may judge by the success the imitation has met with, the artificial has almost entirely supplanted the natural beverage. The Editor may here remark, that it is to a certain extent immaterial whether one dissolves carbonate of magnesia, carbonate of lime, sulphate of lime, chloride of sodium, sulphate of soda, *et cetera*, or, on the other hand, chloride of magnesium, chloride of calcium, carbonate of soda, and sulphate of soda, if care be taken that the proportion of the respective bases and acids are strictly in accordance with the figures given by analysis; since they will, in all probability, combine in the same manner as they are associated in the natural spring. The rapid increase and spread of the manufacture of artificial waters, is the best proof that physicians find the medical and therapeutic effects of them are *identical* with those of the natural ones, whilst their *identity* in a physical and chemical point of view can hardly be questioned.

Now that the chemist is able to distinguish the ingredients actually efficacious in a water, a much more active mixture than the native spring can be prepared. To show the extent to which the manufacture of aerated waters has advanced, Messrs. ELLIS and SON, the celebrated manufacturers of soda and other carbonated beverages, inform the Editor, that at Ruthin alone, North Wales, they send out yearly *many thousand gross of effervescing beverages*. So that with other factories at London, Malvern, Liverpool, Manchester, Glasgow, *et cetera*, the trade has within the last few years become an enormous one.

Soda-Water.—This is certainly the principal aerated

water manufactured. How many thousands or millions of bottles of it are drunk annually either alone or mixed with sirups, wines, or spirits? The materials for soda water are carbonate of soda and tartaric acid.

It is a well-known fact that a large portion of the SODA water in general use is simply carbonated water, without the alkali, and as such, is a safe and agreeable beverage; but the physician, or the invalid, or any one who seeks therapeutic and corrective influences of the water, will be greatly disappointed in the use of these fluids, as they are inert, and for such purposes worse than useless. It is difficult to find a person who is not subject to occasional annoyance from acidity. To such an individual a glass of soda-water has been found to impart immediate relief. The carbonic acid appears to produce a peculiar sedative action upon the irritated mucous lining of the stomach, and the alkali neutralizes the excess of acid, and restores the organ to a condition of comfort which few but those who have suffered from the annoyance of heartburn can appreciate. Dr. BENGE JONES, in a treatise upon gout, strongly recommends the use of soda or potassa waters, but laments that the waters so-called in commerce are not alkaline at all; and numerous physicians of eminence have expressed the same complaint.

Some time ago the Editor was greatly pleased in inspecting the admirably conducted establishment of ELLIS at Ruthin, North Wales. Everything was so nice and clean; and, as for the water employed from a deep and splendid well upon the premises, it might be said to be absolutely pure; and it is on this account that he considers the soda, potassa, and other beverages prepared in these works superior to any other in the market. Messrs. SCHWEPPE and others, no doubt, manufacture equally well; but they do not start with *as pure a fluid*. The quantity of soda or potassa in each bottle at Ruthin is twenty-five grains of the bicarbonate of either alkali; and the carbonic acid is equal to about two hundred and fifty or sixty cubic inches, showing how well the gas is compressed. The water from the well only holds *two grains* of solid matter in solution, and *has not a trace of organic matter*; hence it is not liable to alternate or decompose, if kept for any length of time. The apparatus will now be described; and for the following, the Editor is again, as in several instances, indebted to TOMLINSON'S excellent Cyclo-pedia.

An elegant little apparatus has been brought into use within the last few years, patented by M. MATHIEU, as an improvement upon an earlier invention. It is calculated for the preparation of aerated beverages in private houses rather than for sale, since it can yield but a small quantity at a time. There are two oval glass vessels—the larger one placed vertically over the smaller. There is a passage of communication from the one to the other, and in this passage there is a tap for drawing off the aerated liquid. The upper or larger glass is filled with water by removing the cover; and the lower or smaller glass is supplied with the powders. These powders are, as in other cases, of different kinds, according to the sort of beverage to be produced. A small pipe descends from nearly the top of the upper to nearly the bottom

of the lower vessel; a little water descends through this pipe, mixes with the powder, and produces gases; and these gases ascend to the water in the upper vessel. Of course, such gases only as are soluble in water are generated. The gas chiefly used is carbonic acid, of which water will absorb its own bulk, and by pressure can be made to take up another volume. As the gas accumulates in the upper vessel, the pressure increases, and the water is thus enabled to take up its additional supply. The two vessels are generally surrounded with a netting of wire or cane for security. In the simpler forms of the apparatus, nothing further presents itself; but in M. MATHIEU'S improvement there is a refrigerating contrivance. The upper vessel is surrounded by an external shell and sheath, so as to leave an intervening space; and into this may be introduced either ice, or cold water, or freezing mixture.

GAILLARD and DUBOIS' gazogene, or aerated water apparatus, is a much more complicated contrivance. It contains three distinct chambers or vessels—one for the water to be aerated, one for the effervescing powders, and one to contain a small quantity of water which is to act upon the powders. It is necessary to separate all three vessels when the apparatus is to be prepared for use; and this is one cause of its complexity. When all three have been properly supplied, the finger is pressed upon a stud or button at its top. This pressure opens a valve which allows the water in the small upper vessel to descend into the one containing the powders. The gas, thus generated, can only escape from the powder-vessel by descending a small tube which dips into the larger one; and the water with which this larger vessel is nearly filled becomes impregnated with the gas. A second finger-stud governs the valve of a small pipe, which enables the aerated water to flow from the apparatus, which is elegant in construction, but has not the elegance of simplicity.

Mr. MASTER'S aerating machine is similar in principle to MATHIEU'S, though differing in details. The powders are placed in the lower part, and the water in the upper; a little water descends to the powders, and the generating gas ascends. A stud, acted upon by the thumb, draws off the beverage when required.

Messrs. TYLER, HAYWARD and Company's patent double soda-water machine is adapted for bottles, and can make three hundred dozen *per diem*. There are two distinct machines in one frame, which can be worked together or separately. It consists of a condenser divided into two by a partition inside. Each half has an agitator, worked by a wheel. There are two condensing pumps, with regulating taps for admitting aerated water. The pumps are worked by a beam. The beam, by its reciprocating motion, causes the plungers beneath the pumps to ascend and descend in their barrels, forcing at each successive stroke the gas and water together into the condenser. About ten minutes are required to get the charge up, and the bottling then goes on uninterruptedly.

Messrs. TYLER and Son have invented single and double soda-water machines of ingenious construction. Mr. W. Cox of Manchester has patented an apparatus

in which the impregnating gas may be sustained at a pressure sufficient to cause its absorption by the water without the aid of force-pumps. BAKEWELL'S apparatus is another contrivance, applicable to the preparation not only of cooling drinks, but of effervescing draughts also, whether tonic, aperient, diuretic, antacid, or pectic. In short, every aerating apparatus may be said to comprise these two parts—one to produce a gas, and one to mix it with plain water, or water containing carbonates of soda, potassa, magnesia, *et cetera*, or orangeade, lemonade, gingerade, and the like.

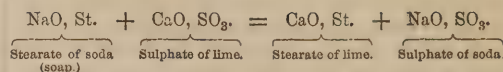
ANALYSIS OF WATERS.—*Method of Testing for and Determining Nitrous and Nitric Acids.*—Almost all river waters, and especially the shallow well waters of towns, contain variable quantities of nitrous and nitric acids generally in combination with lime, as nitrite and nitrate of that base. Their constituents have hitherto been generally overlooked by analysts, but on their presence and quantity the chemist may form a more correct idea as to the contamination of the water by organic matter than by any other means. The Editor, therefore, attaches the greatest importance to the determination of these constituents, especially when the water is selected for domestic use.

It has been previously stated that ammonia is one of the principal products of the decomposition of animal matter. This ammonia very speedily becomes oxidized and converted into nitrous acid— NO_2 —which, by longer exposure, is further oxidised into nitric acid— NO_3 . The above-mentioned acids depend for their origin on the presence of organic matter capable of yielding ammonia, and the solvent action of waters upon lead, is almost entirely due to these acids.

Method of Determining the Hardness of Water.—The so-called *hardness* of a water is dependent, as already stated, upon the presence of a certain proportion of the salts of lime and magnesia, which possess the property of decomposing an equivalent quantity of soap, and rendering it useless as a detergent. These salts are bicarbonates of lime and magnesia, and the sulphates of the same basis. The former impart to water its *temporary*, and the latter its *permanent* hardness. The two bicarbonates are decomposed by boiling; the insoluble monocarbonates being deposited, and, mixed with small quantities of the other mineral constituents, form the incrustations which are frequently observed on kettles and boilers in which hard water is employed. In order to determine the temporary and permanent hardness of water, the following method is adopted:—

Into a six ounce stoppered bottle put one thousand grains of water; agitate briskly, and suck out the air by means of a piece of glass tube. This is necessary in order to remove the free carbonic acid, which might interfere with the soap test. Fill the graduated burette with soap test solution, add one measure, and agitate briskly. If no lather is produced, add more, and shake again. Continue adding the soap-test till a permanent lather is produced. Even in moderately hard water a white opalescence appears immediately on adding a few drops of the test, and a white curdy mass will be seen to collect on the surface. Pure soap, such as is used in

making the test solution, is a stearate or palmitate of soda, which is readily soluble in pure water; but when it is added to a water containing salts of lime and magnesia, the soluble soda-soap is decomposed, and an insoluble soap of lime and magnesia produced. The decomposition is represented in the following equation:—



A similar decomposition takes place with soluble salts of magnesia, and hence, when hard waters are used for washing, not a particle of soap will act as a detergent until the whole of the lime and magnesia is removed.

In accurate analysis it is important to make a double determination of the hardness—one before the water is boiled, and another after a portion has been boiled for about six hours. The degree of hardness after boiling represents the hardness due to sulphates and chlorides of the alkaline earth metals, while the difference between the hardness obtained after and before ebullition indicates that which is due to the carbonates of those metals. For example, if a water has a hardness of fourteen degrees before boiling, and of four degrees after, the water is then said to have a temporary hardness of ten degrees, and a permanent hardness of four degrees.

That the determination of the hardness of water is important cannot be denied, since it furnishes a certain guide to the proper association of the acids and bases when one comes to arrange the results of a complete analysis. But until chemists are agreed upon the character of a type-water, its true value cannot be properly appreciated.

Determination of the free Carbonic Acid in Water.

—Water which has been allowed to stand for some hours in an open vessel becomes insipid and mawkish to the taste, or in popular language, it is flat. This is owing to the escape of carbonic acid, which occurs in many spring and well waters. Hence, in giving a correct opinion of the value of a water for dietetic purposes, it is sometimes necessary to determine the number of cubic inches of free carbonic acid in a given measure of the water. This is an operation which ought to be performed at the source, and is best done in the following manner:—A well-stoppered glass bottle holding a gallon is required for the purpose. Put into it two fluid ounces of strong ammonia, and two fluid ounces of a saturated solution of chloride of calcium. If both materials are pure, the mixture will remain perfectly bright. After observing that no milkiness is produced, depress the bottle into the stream or well, and fill it gradually, taking great care not to dip the neck entirely beneath the surface, but only partially, so as to allow space for the air to pass out, while the water is flowing in. This precaution is essentially necessary, since, if the water were to be agitated by the air escaping from the bottle, much of the free carbonic acid would be expelled by the agitation so occasioned, and hence erroneous results would be obtained.

After carefully filling the bottle with the water, it is

to be stoppered and left for three or four days. After that time, the whole of the carbonic acid will have been precipitated in the form of carbonate of lime. This is to be filtered off, dried, and weighed. From the total weight of the precipitate is calculated the quantity of carbonic acid according to the following formula—

$$50 : 22 :: \text{the weight of carbonate of lime} : x$$

The value of x will give the quantity of carbonic acid contained in the water.

Some, however, of this carbonic acid is in combination with lime and magnesia, and it is therefore necessary to determine the quantity, in order to ascertain how much exists in a free state. This requires a separate operation. A gallon of the water is introduced into a large glass flask, and boiled for six hours. The diminution in bulk occasioned by evaporation is made up with pure distilled water. The precipitate produced by boiling is collected on a filter, and the portion adhering to the bottom of the flask is dissolved by a little dilute hydrochloric acid. The precipitate on the filter is dissolved, and the two solutions mixed together. The solution will contain traces of silica, iron, alumina, and phosphate, which may be disregarded; its chief components are carbonate of lime and carbonate of magnesia, which being separately determined, their weight is to be deducted from the weight of the precipitate obtained from the bottle in which the ammonia and chloride of calcium had been used. From the difference may be calculated the quantity of carbonic acid per gallon. One grain by weight measures as nearly as possible two cubic inches. Therefore, if the difference in the weights of the two precipitates amount to a weight of carbonate of lime containing twenty grains of carbonic acid, the water will be proved to contain forty cubic inches of that gas in a free state per gallon.

Determination of the Alkalinity of Water.—By the alkalinity of water is understood the quantity of potassa or soda which may be present in combination with carbonic acid. For ordinary drinking purposes it is quite unnecessary to perform this operation, but when water is used for brewing, dyeing, and starch-making, the presence of the alkaline carbonates is a matter of great consequence. The following method, though by no means perfect, is generally adopted. Two gallons of the water are evaporated in a large platinum dish down to about four fluid ounces. This is filtered from the deposit, colored with tincture of litmus, and then neutralized by a standard solution of sulphuric acid, containing in a hundred cubic centimeters as much acid as will neutralize one grain of alkaline carbonate.

Determination of Chlorine.—Half a gallon of water is evaporated to about four fluid ounces. Dilute nitric acid is then added to dissolve the precipitated carbonates. The whole is transferred to a beaker glass and filterer, the filter being thoroughly washed. To the solution is now poured in a slight excess of nitrate of silver, which throws down all the chlorine as chloride of the metal. The menstruum is now boiled, filtered, and the precipitate well washed with hot distilled water, then dried at 212° , ignited in a porcelain crucible, and weighed—143.5 of chloride of silver contain 35.5 of chlorine.

In determining the chloride of silver, the filter containing it should be completely exsiccated, then ignited very gently in the porcelain crucible; as soon as it ceases to burn, the carbonaceous residue of the filter should be slightly moistened with concentrated nitric acid, and again burned. By repeating this process several times, until all the carbon of the filter is destroyed, any loss of chloride of silver will be avoided; but before weighing, it is well to moisten the residue with hydrochloric acid, and ignite, in order to convert any reduced metal into chloride.

Determination of Sulphuric Acid.—Half a gallon of the water is, as in the preceding instance, evaporated to three or four ounces, and acidified chloride of barium is then to be added, and the whole boiled, and left for twelve or more hours in repose, then filtered, and the sulphate of baryta washed thoroughly and dried. 116.5 of sulphate of baryta represents 40 of sulphuric acid.

Directions for determining in Water the Non-volatile Organic Matter—Silica, Iron, Alumina and Phosphates; Lime and Magnesia.—Evaporate slowly half a gallon of water to about a pint, over a gas flame; then transfer the dish to a sand-bath, and continue the evaporation till the bulk is reduced to about two fluid ounces. Now accurately weigh a clean platinum dish. Scrape the deposit carefully from the bottom of the porcelain basin, and rub off that which cannot be removed by the platinum knife with the middle finger; rinse the whole into the platinum dish, and then evaporate to dryness on a water-bath. Be careful to observe that every particle of the deposit is removed from the porcelain vessel. When the residue is dry place the dish in an air-bath, and heat it for half an hour or an hour at a temperature of 260° .

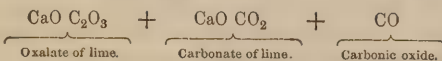
The object of heating the residue to this temperature is to expel the water of crystallization combined with sulphate of lime, which is almost an invariable constituent of well and river waters. Note down the weight. The difference between the weight of the basin when empty and that of the dish and residue will, of course, represent the actual weight of the residue in half a gallon of the water. The residuum being thoroughly desiccated and weighed, place it on a platinum triangle, over a good gas flame, or the flame of a BERZELIUS lamp, and ignite until the blackening produced by the carbonization of the non-volatile organic matter disappears, and the mineral constituents are white. The time required to produce this change should be carefully noted. If nitrates or nitrites be present, as is invariably the case in waters containing sewage and other animal matters, then gently facilitate combustion of the organic matter, and the residue becomes white in a few moments.

On the other hand, if the water be contaminated with organic matter which has undergone but little decomposition, and especially if urine be present, the carbonaceous residue will require very lengthened ignition in order to consume the carbon. If it be necessary to heat to redness for any length of time, some of the carbonic acid in combination with lime and magnesia will be expelled, and consequently the loss of weight occasioned by the ignition would not correctly represent the actual quantity of organic

matter. It is, therefore, necessary to *recarbonate* the lime and magnesia. This is done by moistening the residue with a few drops of a strong solution of carbonate of ammonia, and again drying it at 260° till it ceases to lose weight. The dish being now weighed again, and the weight noted, the difference will represent the quantity of non-volatile organic matter present with the mineral constituents. By the continued ignition which is necessary to burn the organic matter, the *silica* is rendered *perfectly insoluble*. To the residue in the platinum dish is now added a fluid ounce of water, and, drop by drop, strong hydrochloric acid—about one in two fluid drachms—until effervescence ceases. Particular attention should be paid to the odor of the gas evolved; if it smells of sulphide of hydrogen, this will be a further indication of the contamination of the water by *animal refuse*.

After the effervescence has ceased, the dish should be gently heated on a water-bath and the solution filtered. The silica left on the filter should be washed well with hot distilled water, till a drop of the washings, evaporated on a platinum knife, no longer leaves a trace of residue. The filter containing the silica is dried, ignited in a weighed platinum crucible until the whole of the carbon is consumed, and then weighed. The filtrate from the silicic acid, after the washings have been added, is to be neutralized and made slightly alkaline with ammonia. The iron, alumina, and phosphates of the alkaline earths are precipitated, then filtered and washed with the same precautions as given in the determination of the silica, and when dried, weighed. As the iron, alumina, and earthy phosphates occur in water in very small quantity, rarely exceeding together a grain per gallon, it is for general purposes quite unnecessary to separate them. The precipitate produced by ammonia is usually recorded as *iron, alumina, phosphates*. After the precipitate is completely affused, and the washings are added to the filtrate, the lime is next to be thrown down, and this is done by adding oxalate of ammonia in excess; allow the whole to stand till the supernatant fluid becomes bright. Add the washings to the filtrate.

The precipitate is to be dried, ignited, and weighed. By ignition the oxalate of lime is converted into carbonate, and is weighed as such. The following decomposition occurs during ignition:—



As a portion of the carbonic acid of the carbonate of lime might be driven off during the heating, it is advisable to moisten the residue in the crucible with strong carbonate of ammonia, once or twice igniting after each addition, and taking the weight when it becomes constant. Fifty of carbonate of lime represent twenty-eight of lime. The washings being evaporated and added to the filtrate, about half a fluid ounce of a solution of phosphate of soda is added, and the menstruum allowed to repose for twenty-four hours in a moderately warm place. The magnesia is thus precipitated as phosphate of magnesia and ammonia— $2\text{MgO}, \text{NH}_4\text{O}, \text{PO}_5$. This salt must be well washed with dilute ammonia—one part alkali to six of water—dried, ignited,

and weighed. By burning, the precipitate is converted into pyrophosphate of magnesia— 2MgO PO_5 —from which the quantity of magnesia is ascertained. One hundred and twelve of the pyrophosphate contain forty of magnesia.

Determination of the Alkalies.—The determination of the alkaline salts in water is generally omitted in ordinary analysis; but it must be acknowledged that when water is required for certain purposes, as for instance, for brewing, it is very important to determine not only the quantity of potassium and sodium present, but especially the form in which they occur, whether as chlorides or as carbonates. For brewing purposes it is usually considered that waters containing sulphate of lime are best suited for the manufacture of pale ales, since beers made with selenitic waters are paler than those made from water free from gypsum; but notwithstanding the presence of sulphate of lime, if potassium and sodium be there as carbonates, it is impossible to obtain a pale infusion of malt, owing to the alkaline carbonates extracting certain constituents which are not soluble in water free from alkalies. The following is the best method of determining the alkalies. Half a gallon or a gallon of water is evaporated to dryness in a porcelain dish in the usual manner. The residue is dissolved in hydrochloric acid, and evaporated on a water-bath to dryness. The soluble constituents are then extracted by water, and to the aqueous solution is added an excess of baryta water. After the precipitate has subsided, the solution is filtered, and to it is added a *very slight* excess of *pure* carbonate of ammonia. The excess of baryta thus precipitated is filtered off, and the solution which now contains only the alkalies, as chlorides, is evaporated to dryness in a weighed platinum dish, to determine the quantity of mixed chlorides of potassium and sodium. The weight being noted, the chlorides have now to be separated. This is accomplished by dissolving in water, adding excess of bichloride of platinum, and evaporating to dryness on a water-bath. The mixed platinum salts are now treated with alcohol and ether, filtered and washed with a mixture of ether and alcohol till the washings come through perfectly colorless. The precipitate of bichloride of platinum is then weighed, and the quantity of chloride of potassium it represents is calculated. This is deducted from the weight of mixed chlorides, the actual quantities of potassium and sodium calculated.

Having now determined the actual proportions of all the ordinary acids and bases present in the water, one has then to associate the acids and bases together as salts, in the form in which they probably existed in the water previous to analysis.

The association of the acids and bases is founded entirely on arbitrary rules, the usual plan being to unite them in the order of their respective affinities—the strongest acids with the strongest bases. But this is obviously an incorrect method, since it is often found that two chemists analyzing the same water will give entirely different forms of analysis, although they may both have found the same proportions of the respective acids and bases; the one will associate all the sulphuric acid with potassa and soda, the other may place it with

lime, and regard the alkaline bases not as sulphates but as carbonates. Now, as before shown, it is a question of the greatest importance, when water is required for special purposes, to determine not only the proportions of acids and bases present, but the form in which they are associated. In order to do this properly the analyst must have regard—1st, To the geological characters of the source of the water; 2d, to the nature of the country through which it flows; 3d, to the contaminations from sewers and manufactories to which the water is exposed.

Rain-water, it is to be presumed, cannot differ materially in the nature and quantity of its impurities, but yet it has been shown that one rarely finds two river waters of precisely the same composition. In the water of the Dee, the analyst finds only about four grains of mineral matter, because the rocky soil over which it flows is soluble only to a slight extent in native water. The water of the Trent flows over a soil abounding in gypsum, and consequently the water is very hard, while in the water of the Thames, which flows through a line of country composed essentially of chalk, the prevailing constituent is bicarbonate of lime. The presence of a superabundance of earthy salts in water, exercises an influence of some importance in many of the industrial works of the kingdom, and especially in brewing. Paradoxical as it may seem, it is now an ascertained fact, that the hardest waters, that is, such as contain most earthy salts in solution, have the greatest extractive power for the brewer; and further, that the chemical changes that take place between certain constituents of the malt and those salts, serve in the case of ale brewing to fine the beverage in the natural way, without the aid of disgusting and corrupt *stuffs* employed for this purpose very frequently.

A glance at the composition of the waters which are used by ALLSOPP and BASS, the Great Burton brewers, and by TETLEY, of Leeds, *et cetera*, gives at once the clue to the superior excellence of the manufactures of these parties over ales made from such liquids as the *Liverpool Pike*, which is not only devoid of earthy salts in the requisite quantity, but contains an amount of animal and vegetal matter in such a state of fermentation, that the action is engrafted on the glucose, and proceeds in the tun collaterally with the alcoholic fermentation, which it ultimately modifies into the lactic and acid fermentation long after the natural ferment—the gluten of the malt—has been thrown off:—

	Burton water, Dr. Bottinger, Allsopp's brewery.	Leeds water, Tetley's brewery, Editor.
	Grains.	Grains.
Carbonate of lime,.....	15.51	19.78
“ magnesia,.....	1.70	
“ protoxide of iron,.....	0.70	
Sulphate of lime,.....	18.96	4.97
“ potassa,.....	7.65	—
“ soda,.....	—	13.09
“ magnesia,.....	9.95	9.73
Chloride of sodium,.....	10.12	7.11
“ magnesia,.....	—	4.74
Silica and loss,.....	0.79	1.72
Total per gallon,.....	65.28	62.07

The quantity of calcareous salts in the above waters is a proof of the beneficial action of lime in the preparation of the best malt liquors.

ELECTRICAL PROPERTIES.—This article on water
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would be incomplete without making some allusion to its electrical properties, which are not only turned to useful account in the numerous and increasing applications of electricity, but also perform an important part in the great phenomena of nature. It would be improper, perhaps, to particularize under this head the hydro-electric machine, because although in that apparatus very large quantities of electricity are generated by the issue of steam through narrow apertures, the effect has been attributed by FARADAY to mere friction, and therefore exhibits no new property of the water itself. It is in the electricity which it generates by contact with oxidizable metals in the galvanic battery, and in the variable conducting power of the liquid according to its greater or less admixture with different acids and salts, that water assumes its chief importance in electro-chemical action. In the working of the battery, for example, it is the decomposition of the water which accompanies the oxidation of the zinc or other positive metal, and not the action of the acid or salt superadded, that really produces the electricity. This was demonstrated by KOHLRAUSCH, who showed that the electric tension was the same at the poles of two similar batteries, one of which was charged with distilled water and the other with a mixture of water and sulphuric acid. The remarkable effect of certain acids and salts in increasing the energy of the current, is chiefly due to the peculiar property which they possess of increasing the conducting power of the liquid. The following table exhibits this property in a very striking light:—

	Conducting power
Distilled water,.....	0.0125
Do. with 1-20,000 of nitric acid,.....	0.075
Sulphate of copper, saturated solution,.....	5.42
Sulphate of zinc, do. 	5.77
Nitrate of copper, do. 	8.99
Chloride of sodium, do. 	31.52
Sulphuric acid diluted with eleven measures of distilled water,.....	88.68
Nitric acid, specific gravity 1.31,.....	93.77

From which it appears, that the addition of only one twenty-thousandth part of nitric acid to distilled water increases its conducting power about sixfold, and that one measure of sulphuric acid, added to eleven of distilled water, increases its conducting power seven thousand times. Distilled or absolutely pure water is therefore a very bad conductor of electricity; but it has been shown that water of this extreme purity is not to be found in nature; that even rain-water is more or less impregnated with certain foreign ingredients, and that the waters of rivers and wells vary immensely in the amount and character of their saline constituents. It is therefore that, in rainy weather, the moisture of the atmosphere, acting the part of a conductor, destroys the insulation of the telegraph wires, and obstructs the working of the instrument; it is therefore that the earth, and still better, the briny waters of the ocean, not only transmit natural currents, but submit themselves as willing agents to the purposes of telegraphic communication; and lastly, it is to the moisture of the atmosphere, floating in clouds charged with an opposite electricity to that of the earth, that the grand phenomena of the thunderstorm chiefly owe their existence.

WINE.—*Vin*, French; *Wein*, German; *Win*, Anglo-Saxon; *Wyn*, Dutch; *Vino*, Spanish and Italian; *Vinho*, Portuguese; *Vinum*, Latin; *Oinos*, *Ovos*, Greek. —All these denominations were probably derived from *Oinos*, with the digamma prefixed, answering to F or V in English, as *Voinos* and thence the Latin *Vinum*. The Hebrew term for wine in general, is *Yayin*, but if medicated or, in other words, made more potent by the admixture of herbs or drugs, it was denominated *Shekhar* or *Strong Drink*, in common with other fermented liquids. The Greek name being the parent of the Latin, confirms the tradition that wine came into the more Western parts of Europe from Greece by way of Italy, and from Asia into Greece.

When man was driven from that peaceful asylum originally assigned to him by his Creator, and condemned to earn his bread by the labor of his hands, his attention was no doubt powerfully exerted in procuring the necessaries of life; such as food, clothing, and habitation. As a cultivator of the earth, he must have been constantly employed, and, as his occupation varied with the seasons, his mind was continually disciplined on contrivances to diminish and sweeten his toil. His activity, when thus excited, soon extended its influence to every department of life, and having procured its necessaries, he was doubtless early led to task his ingenuity in the attainments of its luxuries. Among these, the preservation of fruit and their juices, however rudely practised, might have led to the use of inebriating drink—a beverage which was discovered by some of the most savage nations, and is deemed a luxury by the almost universal testimony of mankind.

Wine, when an uncompounded word, signifies the fermented juice of the grape only; but when compounded, it is applied as a general term to the fermented product of other fruits in conjunction with the name of those fruits, tendrils, stems, leaves, or similar substances from which it is made, as gooseberry-wine, ginger wine, and all the varieties denominated *domestic* wines.

Wine of the grape is divided into dry and sweet, and under one or the other of these great divisions every variety is included. The characteristics and causes of each of these divisions will be fully explained.

The juice of the grape, which is usually called *must*, is known to ferment *per se* at 70°, which proves that wine was very early known, particularly in hot climates, where drink is so much required to allay thirst; and this is a further sign that the vinous fermentation was familiar long anterior to the deluge.

Carrying this idea still further towards the Creation, MILTON seems to have entertained the opinion that the fruit of which ADAM and EVE had eaten—

— whose mortal taste
Brought death into the world, and all our woe,

was of an intoxicating nature, when he says:—

Soon as the force of that fallacious fruit,
That with exhilarating vapor bland,
About their spirits had played, and inmost powers
Made err, was now exhaled.

Wine is the oldest fermented liquor, its invention being ascribed to NOAH in the traditions of the Jews

almost immediately after the deluge. The Greeks with their fabled DIONYSUS from Egypt, originally from India, threw no light upon the discoverer; but if they learned the art of making wine from the Egyptians, that liquid may be thus traced up to the days of MOSES. HERODOTUS reports that there was no wine made in Egypt, a singular error, when Marcotic and Tæniotic wines were notorious. The wine of Merœ called *indomitum* by LUCAN was far-famed. The writings of MOSES show that the kings of Egypt drank wine, as all who have perused them will not fail to recollect in reading the story of JOSEPH and the chief butler of PHARAOH. The ruined temples of Thebes also display the emblems of the vintage in bas-relief, and figures of men pressing grapes with their hands, the must flowing into goblets emblematic of the wine-press. Some have used this as an argument against fermented wine; but must unfermented, would not keep from decomposition for many hours, even in the Eastern land of miracles; nor would the simple juice have intoxicated NOAH, because to occasion ebriety fermentation is absolutely necessary, as in all other alcoholic liquors.

Next in antiquity to the volume of the Jewish faith are the works of HOMER and HESIOD, who lived so near together in point of time, that even concluding HOMER to have flourished in the tenth century before CHRIST or about the reign of SOLOMON, the difference so much discussed by the learned is of no moment in a scientific sense. HOMER mentions the names of several kinds of wine, and alludes to their potency.

The frequent allusion to wine, the praises bestowed upon it, the flowing goblets, the luxurious banquets as described by the great Grecian poet one thousand years before the Christian era, exhibit its value and his attachment to the comforts of the table and to jovial society.

HORACE was of this opinion when he says—

Homer, in praise of the profuse,
No doubt loved well the balmy juice.

The wines referred to required twenty parts of water to make them potable, as in the case of the Maronean ones. Poets are not to be literally trusted; and in the present case, as the object of HOMER was to intoxicate the giant POLYPHEMUS through his hero ULYSSES, full latitude must be given for poetical fiction, which can seldom be quoted in reference to the exact sciences. This Maronean wine was made from vineyards on the side of Ismarus, a hill of Thrace, by MARON a priest of the Sun. The circumstance of the Greeks mixing water with their wine, might after all mean no more than it does in France at the present time, where water is often mingled with common wines of the country by no means remarkable for their strength. Thus the wine of Scyathos is said to have been used with half its bulk of water. The wines most in repute with the Greeks were, in the first place, the wines of Chio or Chios, which, with the Thasian, were ranked among the superior growths. Lesbos was also celebrated for its wines. Many of the Greek islands were distinguished for wines of delicacy and flavor, for the most part rich and sweet. The Ariusian wine of Chio was in high esteem as a luscious

product of one of the vineyards of the island. The Pannonian was celebrated for its healing qualities. This wine was red, from a vineyard in Lesbos. The wines of Rhodes, Crete, and the Clazomenian from the shores of Ionia, were much valued, and often taken with an admixture of sea-water, a singular custom, thought to impart smoothness to the wine. The quantity thus mingled was very small, and was always boiled before it was mingled with the wine. The Greeks classed their wines, as in modern times, into sweet and dry, but had an intermediate species. They seem to have preferred the thick sweet wines to all others, that species, for example, which the moderns denominate malmsey, differing little perhaps from the modern wine of Cyprus, or the malvasia of the Morea. Some of these wines possessed what is now called the bouquet. As soon as they were opened to the air, the perfume was immediately perceived, but this might have arisen from the infusion of odorous substances at the time of fermentation, a practice then common. Sappian wine was one of those celebrated for its odor on being uncorked. This odor, it is pretty clear, did not arise, as it does in the pure wines of France in modern times, from the natural perfume after fermentation, but from the addition of odorous substances. Port and the strong Anglo-medicated wines at present, possess no bouquet from its being destroyed by the admixture of alcohol with them artificially, rendering them heavy and dull. The wines of Bordeaux, Champagne, and Burgundy, on the other hand, have the perfume in a high degree from nature.

The wine of Chio, called the Phanean, was celebrated among the Romans, who imported both that and the wine of Argitis. The wine of Mende in Thrace was a white wine of no great strength. The wines of Zante speedily intoxicated; and those of the other Greek islands, as well as of Lydia, Phœnicia, and Cilicia on the mainland, were of good quality, producing growths the mere names of which it would be superfluous to record.

Rome, as she learned the other arts from Greece, acquired also that of making wine, as soon as she extended her power beyond the limits of her home empire. In the days of HOMER milk was substituted in the sacrifices in place of wine, because of its scarcity at Rome. The wine first made seems to have been from the grape grown in the Campania Felix. The most celebrated sites for the vine were near Naples, on the sides and at the foot of Vesuvius, now covered with the lava and ashes of that celebrated volcano; a spot in which Bacchus was said to have delighted in consequence of its rare fertility and excellent adaptation for the vine culture. The sea washes the limits of this beautiful vine-climate in one direction, and in the other delightful hills, named the Falernian, Surrentine, Massic, Gaurean, and others, arose with the choicest aspect and the most propitious slopes from the low country, giving names to the products since wedded to immortal verse. Thus the Falernian, Surrentine, Cæcuban, Setine, and other wines of the vicinity, were named from their native hills. One or two of the more celebrated writers left passages in their works which enable us to give a guess at the nature of some of the wines in use among the

Romans, whether the growths of Greece or Italy. It is certain from these that, except in the sweet wines of the South of Europe at present, no great similarity could have existed between the ancient wines and those most prized by the moderns. The writings of ATHENÆUS and PLINY give a tolerable account of the treatment of the vine under cultivation, but we learn little from them in relation to the constituent parts, flavor, or qualities of the produce. The same remark will hold good in relation to the extant works of VARRO, CATO, COLUMELLA, and PALLADIUS. In short, no source remains from which any tolerable approximation can take place as to a knowledge of quality and flavor. It is well known on the other hand that the Campanian vine once enriched a considerable territory of great fertility, and that a number of large towns which have now disappeared, once adorned that favored spot. The more famous wine was the Falernian, which some suppose to have been made on the present Monte Barbaro. The Cæcuban, a sweet wine, was made on the palmus lands of Amycle. The Falernian was of three kinds, the dry, sweet, and weak. A celebrated vintage called the Opimian, from the name of the consul that year, L. OPIMIUS NEPOS, took place in U.C. 632, the wines of which bore a great price a century afterwards. The Falernian required nine or ten years to ripen, and when aged was bitter. Some have imagined it was a dark red wine, others that it was white. The Surrentine wine was durable, and generally taken out of cups of the same name. The Massic came from Sinuessa; Trifoline from a hill near Naples; Tarentine from Mount Aulon, near Tarentum; Alban from a hill near Rome; Mamertine from Sicily, near Messina; Cereton from Etruria; Signian from Latium; and Massican from the Abruzzo. The vicinity of Rome also produced the Nomentan, Sabine, and Venafran wines. The north of Italy produced no wines of note. Spain sent the wines of Tarragona to Rome, and France those of Narbonne, Marseilles, and Vienne; but these were said to flavor too much of the smoke of the *fumarium*, or else of pitch.

The Romans suffered their vines to grow high and weakened the must. How the fermentation was managed nowhere appears. The wines were placed in a smoky receptacle to ripen, the object being the same in ancient as in modern times, to assure maturity. The Carthaginian MAGO, who wrote five hundred and fifty years before CHRIST, says, that to make the best wine, that of the sweet or luscious species, the bunches of grapes were gathered when shrivelled by the sun's heat, the bad fruit picked out, and they then were placed upon a frame of open-work covered with reeds, exposed to the sun by day, but sheltered from the dew at night. When they were sufficiently shrivelled they were thrown into a cask and trodden, and thus the first must was made. When drained, they were submitted to the wine-press for the first wine. They were then trodden a second time, and cold must added to the pressing. This second wine was placed in a pitched cask, to prevent it from becoming acid. After it had remained for twenty days in this state it was racked into another vessel, closed up from the air, and covered with a skin.

Such was the ancient mode of making sweet wines of the luscious malmsey species. For the wines in general, the fruit was gathered at intervals as it ripened, and carried to the press in baskets. The must was received in a stone or plastered cistern, and the fermentation was completed as quickly as possible. The process, there is reason to believe, was not very different from that hereafter described. In certain cases the fermentation appears to have been unnecessarily prolonged, and a part of the must that flowed from the grapes by their own pressure was reserved in a separate vessel and set aside, as it is the custom to do now in making Tokay-Ausbruch in Hungary. This must, the most valued, was often stored by itself. Sometimes it was plunged, when in a state of fermentation, into deep water, being previously hermetically sealed. Weak must was often boiled down, so that much of the aqueous portion evaporated, and it was denominated according to the quantity of the portion unevaporated. If two-thirds were left, it was called *calenum*; if only one-third, *sapa*. This was evidently copied from the Greeks, and is still practised, being called in Italy *vino cotto*, and in France *vins cuits*.

The custom of adding sea-water to wine is said to have been discovered by accident. The water was boiled down to a third part, but the quantity used differed according to the nature of the wine. The act of perfuming the wine must have ruined its delicacy; pitch, rosin, cassia, myrrh, saffron, and cypress leaves were, one or the other or several of them, thus infused. The true principles of fermentation were evidently unknown to the ancients, who had not the advantage of modern chemistry. It was the same with the causes of the difference between dry and sweet wines. There was no deficiency in the attention paid to the vines, except that they were permitted to weaken themselves by too luxuriant a growth; this in consequence tended to aid acetous fermentation. In aspect, soil, grafting, and training, all seems to have been well known in ancient times; the Greeks understanding this point better than the Romans. The Aminean grape was the species most cultivated for wine, at least in the Campania Felix, but it cannot be identified with any modern species. October was the vintage month.

The treatment of the ancient wine after the first fermentation included a further progress in the vat, and it was then placed in earthen vessels, hermetically sealed, denominated *amphoræ*, each of which held 6·7827 English gallons, or in other vessels of a different capacity, as the *urna*, which held just half the quantity of the amphora. If an inferior wine, or one designed to be carried to a distance, it was placed in pitched skins—the bottles of the New Testament. When designed for the amphora and cellar, after being exposed to the smoke of the *fumarium*, it had the year of the vintage or the consular year marked upon it, and was set in the ground. Under this treatment in the *fumarium* and elsewhere, some of the wines grew so thick that they could not be drunk until they were dissolved in water. That sometimes the wine tasted of the smoke is not matter of wonder. It is well known that Madeira ripens rapidly if the bottles are plunged into a hotbed or into stable dung. The amphoræ were

vessels without bases, shaped as in Fig. 615, and made of pottery clay. The consulship of the famed Opimian year is marked on some of the existing amphoræ in the way thus exhibited—L. O. NEPOS, U.C. 632. The wines of the ancients were thus different in quality from those of modern times, and could only have been relished by long habit.

The different varieties which have been transmitted by name in Italy, Gaul, and the East are reckoned at a hundred kinds, rough, soft, and sweet. That the wines of the ancients were more durable from this after-management than from any knowledge they possessed of their chemical combinations when treated scientifically according to their nature, and unmingled with substances foreign to them, is evident upon a due consideration of the subject.

Regarding the wines of Asia Minor, little is known in respect to the treatment. Some kinds were kept in the *fumarium* until they became as hard as salt, and it was necessary to dissolve them too in water before they were drunk. The prices they bore, considering their age, were not extravagant; those more than a century and a half old costing less than seven shillings the English quart. In Rome the quantity of wine consumed was considerable. The servants of CATO were allowed about a pint and a half per day. The stocks of the more precious wines kept by the opulent were surprisingly large. Of the best and dearest Greek wine, that of Chio, HORTENSIVS left ten thousand casks at his decease. The celebrated MÆCENAS introduced a rare wine of his own, called *mæcenatianum*. Of the common wine made in Italy, too, the produce was large, being in one recorded case no less than two thousand one hundred and fifty gallons per acre, or eight *culei* on the jugerum or twenty-eight thousand eight hundred square feet. In these computations, however, there is much uncertainty.

Wine was drunk in Rome out of murrhine cups when the eternal city was in its greatest height of luxury and pride. What this substance was is unknown, but it appears to have come from Egypt or the East, and to have possessed an inherent perfume; many dissertations have been written upon its nature, all alike unsatisfactory.

Among names of ancient wines, is that of Helbon or wine of Tyre, called by the Greeks *kalibonion*, and alluded to by the prophet EZEKIEL—the name meaning sweet or fat; it was made near Damascus, originally by the Persians. This wine was common in England in the reign of RICHARD III., being imported in Venetian vessels. The wine of Lebanon in HOSEA, is praised for its perfume. But the different conjectures regarding the nature of ancient wines, built upon no satisfactory data, cannot, any more than their names, be of any real moment, however amusing to the scholar. It may be observed, however, that a marked distinction anciently existed between pure wine, and that which

Fig. 615.



was perfumed or medicated, as with certain wines imported into England, brandy is added for the same purpose, particularly to port wine. The Jews have preserved this distinction in scripture, by using the term *mixed* or *strong wine*; thus—In the hand of the Lord is a cup, and the wine is red; it is *full of mixture*; and he poureth out of the same; but the dregs thereof, all the wicked of the earth shall wring them out and drink them.

Leaving a subject so much of which must be conjectural, the wine of the present time, naturally the most important, comes to be considered, together with the processes adopted by the moderns in its manufacture. The variety of the plant which produces it, and the nature of the soils in which the best grape is matured, are subjects copiously treated of both by French and Spanish writers. In the catalogue of the national collection of vines at the Luxembourg in Paris, there are five hundred and seventy varieties, classed black oval, black round, white oval, white round, grey and violet oval, and grey and violet round. CHAPTAL collected fourteen hundred sorts, and CLEMENTE states that two hundred and fifty species exist in Andalusia alone. The treatment of the vine and the entire culture of the plant belong to the rural economy of the wine-producing countries. To enter largely upon this subject would be out of place here; still the following on the kind of soil best adapted for the grape, and on the best description of grapes to employ, will interest and instruct the reader.

The wine-producing countries in the Northern hemisphere are included between the parallels of 33° and 51° North; but this rule is limited by local circumstances, probably by the line of the biting North-east winds, which keep back the vine in spring. An oblique line drawn a little north of Coblenz, concave to the North, and continued to the mouth of the Vilaine, in 47° 25' North, will nearly define the vine limit. Wine once made in good quality at Estampes and Beauvais, so as to be celebrated, cannot be made there now. Thus it was once made too in the counties of England South of Cambridgeshire. Wine in 1553 was made of the muscat grape at Mâcon in Burgundy, where it cannot now be made at all. In Asia no good wine is made South of latitude 33° North, in Persia and Shiraz. In regard to the Southern hemisphere, except a little sweet wine from the Constantia vineyards at the Cape of Good Hope, none of any mark is yet produced, though much of an inferior quality is made. With the wine-producing countries of the North the world is too familiar to need the exact enumeration.

Keeping in view wines of the first and second class in excellence, nearly all which lay claim to the greatest delicacy and purity are produced in France, where science and long experience have been brought to bear upon their management. In a first-class wine there must be no mixture of any foreign matter whatever. The fermentation must be natural, and no extraneous substance introduced, not even brandy. Nothing must be allowed to prevent the development of the perfect character of the particular species expected—lightness, freshness, a rich odor conferred by nature, such as are found in Romanée-Conti, Chambertin, Vin du

Roi, or Hermitage of the first class, because of such wines only can the term *pure wine* be understood, or a standard be found by which the first-class can be established, and the test be fixed for the inferior kinds. France, Spain, Germany, Italy, Portugal, Hungary, Greece, and Sicily are the principal wine countries of Europe. Tolerable wine has also been made in the extreme South of the Russian dominions.

Passing over the vine culture, the best sites, the diseases of the vine, the training, and the incessant and laborious calling of the vine-dresser, all belonging, as before observed, to rural economy; and therefore only observing that the practice of grafting is pretty general—it may be added that some vines will bear well for a century and a half. There have been examples of three centuries, while others will not be productive for more than forty years.

The extent of the vineyards that produce the finer wines is well known to be very limited. The differences of soil and treatment do not appear sufficient to account for this fact. Although the best vines are grown on a calcareous soil, as on the chalk hills of Champagne and the albarizas of Xeres, of which carbonate of lime forms two-thirds, and in three-fourths of the more celebrated vineyards this is the case, though the necessity of such a description of soil has been denied.

In the vineyards of Andalusia, while some of the above soils contain even seventy per cent. of carbonate of lime, the remainder is a compound chiefly alumina, with a very small portion of silica, and sometimes a little magnesia. In certain spots the soil is almost pure carbonate of lime. This kind of earth absorbs every particle of moisture which falls upon it, and never cracks nor opens in the hottest summers. The albarizas are a series of calcareous hills. The best Spanish wines produced on such a soil, exhibit its virtues very strikingly in the fineness and durability of the product, and militate against the opinion expressed in some districts, that if the soil be porous, light, and free, the presence of lime is of little moment. The fences of the vineyards on the albarizas consist of the prickly pear. Adjoining the albarizas, or chalky soils, come the arenas, or sands; but these are intermingled, more or less, with calcareous particles. About Malaga, where the surface of the country is extremely rugged, the soil consists of limestone, intermixed with slaty schist, over which the rich raisins for export are produced. In the South of France, in Rousillon, the soil resembles that of Malaga, particularly near Perpignan, being slaty schist, or gravel, interspersed with calcareous matter. In some places where the soil is not six inches thick, a hole is bored in the loose rock with an iron bar, in depth about a foot, into which the plant is thrust, among the stony and arid ground. In Burgundy the soil varies much. At Chambertin it is a brown loam, full of gravel, and friable. This gravel consists of small pieces of broken limestone, in some places; in others, of marl with small shells—while, in another place, the vines grow in pure clay, but still with traces of lime in some form. The champagne district, in like manner, is almost wholly calcareous, at least where the best wines are made. Thus the famous sillery is produced from vineyards on chalk,

with an Eastern exposure. At Ay, on the Marne, on both sides of the river, the hills are chalk, and the soil often supported by terraces. *By the river of Marne, and on the hills of Rheims are the celebrated localities*—proverbially so. The chalk, whether it lie deep or superficial, produces the same effect in respect to dry wine of superior quality, agreeably to its treatment and the aspect of the vineyard. The hermitage wine has been cited in proof of the goodness of wine grown on the debris of granite.

Wines of the finest quality are undoubtedly grown upon soils where lime is not immediately visible. Sands in the vicinity of Bordeaux, and granitic soils near the Rhone, flinty and argillaceous earths, are found to produce excellent wine. But hermitage, for example, although produced from vines grown among fragments of granite, is no doubt affected favorably from the calcareous soil hard by, having portions intermingled with them; nor can it be any exception to the fact as respects the finer dry wines, that their superiority is due to their connection with calcareous matter. Sweet wines are produced in almost every kind of soil. Dry wines produced on schist, for example, are poor, compared to those the fruit of which is grown on chalk land; while the sweet wines, such as those of Malaga, are good on that description of soil. The Rivesaltes, a sweet wine of France, is produced on granitic land upon which lies a stratum of pebbles, while the dry wines of the same land which produces those celebrated growths, are sufficiently mediocre. At Ay, where the finest champagne is made, the soil lies upon chalk in some places from ten to fifteen feet thick; but the superincumbent earth is full of pieces of chalk, the surface only being argillaceous; and where most so, causing some difference in the quality of the wine. Very little manure is applied to the vines that produce the best and finest wines. In argillaceous soils the roots of the vines are found not to branch off in a desirable manner; and the facility with which the soil retains the water, causes a degree of humidity prejudicial to the bud. Volcanic soils, on the other hand, give excellent wines, particularly when they are of very ancient date, and rival those the fruit of which is grown on calcareous strata; generally, too, possessing a flavor peculiar to themselves. In all cases the soil must be light, friable, porous, so that water shall not lodge around the plant. The exposition may vary. *Bacchus loves the hills* is an old, but not an unexceptionable adage, as gravelly plains may produce good wines. Sometimes, according to the nature of the country, an Eastern aspect is best; at others a Southern, and even a Northern has yielded excellent wine; much in such a case depending upon the latitude and the more obnoxious winds, as well as the atmospheric temperature. It is remarked, however, that good wine is rarely produced in narrow valleys, especially if a river flow through them.

It will thus be perceived that the nature of the soil for the dry and finest wines must be calcareous, even to pure chalk; in all events it must be sufficiently so to influence the vine most essentially during its growth; and that for sweet and luscious wines, the nature of the soil is of far less moment, such wines being grown

on every kind of soil, except that which produces the most valuable and rare dry growths. In the English colonies, and in the United States of America, not long ago covered with primeval forests, the soil, enriched by the autumnal spoils of ages, is too good for the vine, the fruit of which, for making good wine, differs so much from the character of fruit in general, when intended for the table.

The grapes are various that give out the more precious must. In Rousillon in France, the best wines are from the carignan, grenache, and mataro grape. The celebrated Rivesaltes wine is principally from the white macabeo, the muscat, and grenache blanche; the hermitage comes from the scyras or ciras grape, the roussette, and the marsan. The pineau blanche and pineau noir before mentioned produce the celebrated Clos Vougeot wine in Burgundy. In the Bordeaux wine district, the Graves, Barsac, and Sauterne, come from the white sauvignon, the semillon, the rochelin, blanc-doux, and primeras—all three white—and the black muscade. The best Spanish wines are the produce of the pedro ximenes grape, both at Malaga and Xeres. At Malaga and Grenada one half the plants are of this species; at Xeres, one-eighth; at Motril, four-fifths; and at Paxarete, one-fourth. The grape, giving fine wine in the North, may be productive of wine of very moderate merit in the South. In consequence every country, and even district of the same country, differs in the variety of the fruit prepared. This arises naturally from the circumstances of the temperature and soil affecting one species more than another, for which it may have less affinity. The growths are often mixed. Thus the marsan grape of itself gives a sweet wine, and the rousanne or roussette a dry, therefore they are mixed to prepare the white hermitage, for example. In Burgundy the black pineau is much used, as well as the chandenev. In champagne the norien and pineau prevail, with some of the gamet and gibaudot. The black morillon, and the magdelaine, and the meunier, are early bearing species. The chasselas, supposed to have come from Cyprus, the cioutat or black grape of Corinth, the muscat noir, isabelle, verdet, and black muscade, the carbenet, violet, and corinth in France, the Uva del Rey, the mollar, the listan of Xeres, the larga and doradillo, with the moscatel gordo, are used in different proportions in some places in Spain, but one kind rarely or never alone. To enumerate and describe the five hundred and seventy species in the garden of the Luxembourg in France, could not enable a cultivator to discriminate what species would be best to adopt, so much depending upon site, climate, and annual temperature. The grenache blanche, for example, is only used in the district of Collioure in France. The Hungarian varieties also are numerous; but site and experience can alone determine, as elsewhere, the species most in accordance with the views of the cultivator in producing the best wine.

By a remarkable peculiarity, nature, and habit of the vine, it adapts itself to those parts of the country which are least fitted for the cultivation of the cerealia. Those vines which bear the best fruit for the finest dry wines, invariably grow on soils which would be unproductive

with respect to the food crops. Gravel, sand, volcanic debris, flint, and such like soils, are favorable to the growth of the vine, whilst rich, deep, warm, fat earth, and all rich lands, are unsuited.

The names of the different kinds of vine fruit in Hungary are so untranslatable in the West of Europe, and so far off, that they can hardly be identified with those of the West without inspection by qualified cultivators. Thus the Furmint is used in making the Tokay-Ausbruch in the Hegyallya; the Fejér-Szőllő of the same district; the Szemendrian or white Servian grape; the Sár-Fejér or honey grape, believed by some to be the magdalen; the Balafant, the Rók-Szőllő or silver white; the Zapfner which, some contend, is identical with the Orleans of the Rhine; the Hárs-Levellő or linden-leaved; the purple Kadarka or real Hungarian; the Blue of the Banat, the Csoka, or Sloebblack, and a great variety of others, which it would be useless to name, are grown to produce the celebrated wines of Hungary.

The climate of Hungary is peculiar, and in extremes; so that, in some places, they are obliged to bury the stocks to keep them from the cold. The cellars are badly built in many places, and the casks too small, and new and unseasoned wood is continually adopted, spoiling the flavor of the wine. Marble store-vats are used in many places; one at Ofen will contain thirty-nine thousand gallons. That wines ripen best in a large volume, is proved in this district by these vats, or rather cisterns. The wines of the plains are inferior to those of the hills from the same description of fruit.

In Germany, the Riessberg, a small white grape; the Kleinberger, a very productive species; and the Orleans grape—make the more celebrated wines. The Orleans is the favorite at Rudesheim; but all the other wine-makers, except at that place, throughout the Rhinegau prefer the Riessberg. The grapes for the Joannisberger of the first class are carefully selected, and only a small quantity is ever made; about sixteen aums of thirty gallons each. The black pineau of Burgundy, and the teinturier are grown on the Rhine, as well as the chasselas. The traminer, white clüvener, franken, gutadel, frühroth, black clüvener, and muscatelles, are cultivated to a considerable extent in Germany, and on the Moselle, where only the kinds adapted for a Northern class of wines ripen well. This may suffice to afford a faint idea of the great extent to which that portion of wine-making connected with agriculture must be carried, to embrace the entire subject over an extensive and ever varied field.

The grapes depending for perfect maturity upon their Northern or Southern latitude, the vintage takes place accordingly in September or October. Upon the excellence of the must rests the purity of the wine, and that depends much upon the season, the character and soil being the same. The utmost development of saccharine matter is watched until the fruit is ready to burst with ripeness, if all goes on well. The sun having dried up the dew, the work commences; the gathering being expedited most in warm weather, because the fermentation is then most active; and it is desirable to ferment at once the largest possible quantity of must.

The riper clusters are separated from the branches when the skin is thin, transparent, and not apt to break between the teeth; when the color is become deep, that is, when, if the grape be of a white sort, it becomes grey, or if red, from a violet hue appears black; when the stem is woody in fibre, losing its green color, and becoming brown like the main stock, the grape hanging loosely; lastly, when the grain gives way easily to the pressure in gathering, or when crushed, has a vinous odor. The bunches are gathered with great care, for which purpose scissors are commonly used, in order to shake the fruit as little as possible; as the ripe grapes are easily detached, and are bruised with the slightest fall. The baskets—Fig. 616—in which the bunches are placed are small; and the deposition in them takes

Fig. 616.



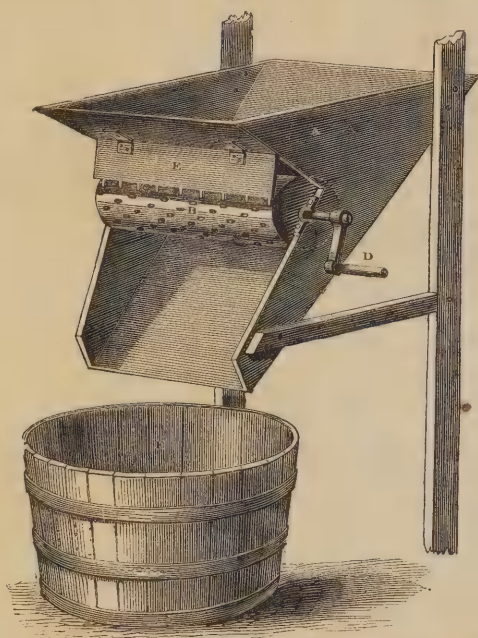
Osier baskets and mode of carrying the grapes to the press.

place with great care lest the fruit be injured. With large baskets the grapes are crushed; and the must is too often wasted, owing to the superincumbent weight. All the bad or green grapes must be taken off and put aside, as the unripe are apt to impart acid to the sound must. The grapes in different states of maturity are not to be mingled, because they cause an inequality in the fermentation of the must by their acidity, and consequently it is deteriorated. The baskets of osier of a peculiar make are carried to the press strapped on the backs of men, or in carriages. The backs of men, or even of animals, are preferred to carriages, because the motion is less. The stems of the clusters are cut short off. Some farmers take the grapes off the clusters, an operation in France denominated *egrappage*, but the practice is by no means uniform, nor is it universal.

The next part of the process is treading the grapes, or breaking them with machines, before they are set to ferment. This operation facilitates the fermentation. Square troughs are used, having holes in the bottom to admit of the must flowing out. The grapes are then trodden by men with sabots or wooden shoes, at the best, though an ancient, a clumsy, and not very agreeable operation. The must which escapes is thrown into the fermenting vat either with or without the murk, as may be required; and the same operation is repeated until the whole is trodden. The disengage-

ment of the coloring matter from the skins is mainly effected by this process, and no substitute would answer which did not obtain that object. The subsequent fermentation and the heat it produced would not alone obtain and fix the color; the skins must be broken. Several inventions have been exhibited and others carried into practice to meet an end so desirable. Of these machines at a reasonable cost, one is the invention of M. ACHER of Chartres, and has the recommendation of being among the cheapest. This machine is shown in Fig. 617. It does its work well, having the recommendation of the more experienced of the wine-

Fig. 617.



makers that it was capable of giving the must the utmost effect of which it was susceptible, before submitting the grapes to pressure. All were found to be equally and uniformly crushed—none escaping the action of the cylinder. By its use the fermentation proceeds in a more uniform manner, and the action of the press becomes more effectual. A, a hopper in which the grapes are placed; B, a cylinder, one metre in circumference, and sixty-five centimetres in length; it is armed with small nails; the heads large and flat, placed in curved or oblique lines on the cylinders, distant from each other five millimetres. This cylinder is placed beneath the hopper, to crush effectually all the grapes which descend to it. The cylinder is turned by a handle, D; E is a species of wooden flap armed at the lower edge with a series of teeth, perpendicular to the axis of the cylinder, disposed in such a manner as to play between the nail heads on the cylinder, and to crush all the fruit which approaches it; F, the vat which receives the must when crushed.

There is another French invention for the same purpose by a mechanic of Toulouse. It consists of two

horizontal cylinders, which act in the same mode as those of a laminating engine, not only by pressure, but by friction. It moves by means of two toothed wheels attached to one end of each cylinder. In order to communicate to one cylinder a movement more accelerated than that of its fellow, the diameter of each wheel as with its cylinder, is different. A handle is fixed to the end of the smaller cylinder. The larger is ten inches in diameter; the smaller six. These two cylinders are placed at the bottom of a hopper, in which the grapes are deposited. The whole is constructed over a cask or vat, five feet nine inches in diameter, or in length, if of a different form from that of a cask, and this receives the must. It is effective, and dispenses, equally as well as the machine of M. ACHER, with the old uncouth mode of treading out the fruit with sabots.

In order to prevent white wine from becoming colored, the red grapes are not trodden, because it would bruise the skins and discharge the coloring matter; but they are submitted to the press, as they arrive from the vine, and then taken to the vat, husks and all in some places; in others, the muck is reserved after the first pressure. The mode adopted in the use of the little press, which is directed rather to make a little choice than a large quantity of a middling class of wine, is as follows:—Planks are laid upon the bottom of the press, which is uneven, so that the must may run into one channel, and thence into a cask placed below the level of the floor of the press. The grapes are carefully piled on the *maye* or planks at the bottom of the press, other planks are laid upon the grapes, then several transverse beams of wood, and upon these the press is screwed down. The pressure at first is but slight, that there may be no waste of the must. The pressure is then increased until the utmost force of the screw is exerted, and the muck becomes as hard as a stone. The press is afterwards relaxed, the edges of the hardened mass cut square with an instrument for that purpose; and the cuttings being heaped upon the top, the screw is again applied, and the wine thus produced is called, *wine of the first cutting*. This pressing and cutting are repeated more than once. Finally, the muck is steeped in water, and again pressed, when a small wine is the produce, given to the laborers, called in France, *piquette*, and in Spain, *agua pié*.

The wine-press, an instrument as old as the days of the Israelitish lawgiver, is made in various modes in the same country. In Spain at this day presses are clumsy troughs, about eight feet square and a dozen inches deep, with a wooden screw in the centre. Into such a trough, in Andalusia, the grapes are carelessly flung, with a sprinkling of powdered gypsum in making white wine, to saturate the malic acid. The must is received in jars from holes in the trough, and carried thence to the butts. A bar or lever, of about five feet long, is used for turning the screw. The wine-press used in France for the hermitage wine, is a trough seven feet square, having an iron screw of vast power in the centre. This is turned by a wheel having projecting spokes for the workmen to pull it round. There is a stage round the press for the workmen to

stand upon. The grapes are built up in the trough as high as the screw will admit. The must flows from spouts in the sides, at the bottom of the trough. Wine of the first cutting is then taken. This press will make at once forty casks of wine, of fifty gallons each. The muck is generally distilled. In Burgundy, the trough or place for the grapes is twelve feet square, having a lever worked by a wooden screw. There is the *Bascule*, a large press requiring a dozen men to work it. The *Pressoir à étiquet*, moved by levers, or a horizontal wheel worked by four men; and the *Pressoir à coffre*, single and double. One in a vineyard in the Saone and Loire acts by percussion. This press is novel, and is the ingenious invention of M. RÉVEILLON. The press before spoken of as used for making a small quantity of choice wine, in use in France, almost universally, though now somewhat improved, is here represented. In making white wine with red grapes, the want of care in the carriage of the fruit to the press, and the previous pressing, will sometimes cause the wine to assume a tinge of red, which, though slight, is very perceptible, and hence the epithet of *Partridge-eye* has been applied to it. Of course the quality of the wine is in no way altered by this circumstance. There is but one species of grape, the tintilla, which has a colored pulp. The grapes for the red wines thrown into the vat after being

trodden, bruised, and evolving these colors before pressing, it becomes fixed by the heat of the fermentation. In some wines there is apt to be an astringency from the tannin in the stalks, attributable to the desire to preserve the tint; the stalks being acted upon by the heat of the wines, as well as the color in the skins.

Fig. 618.

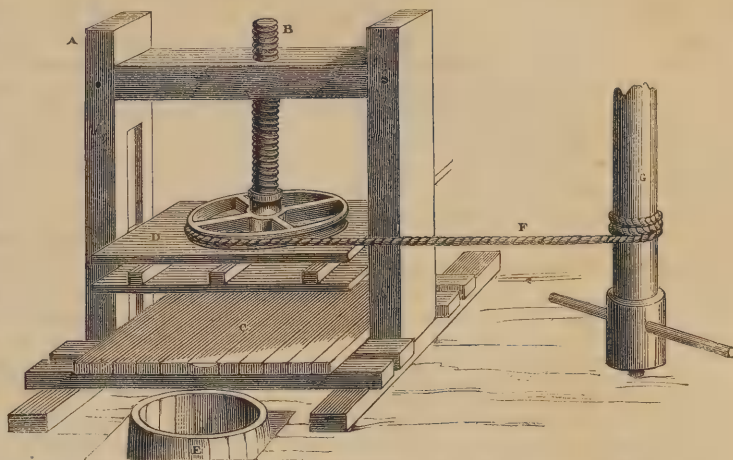
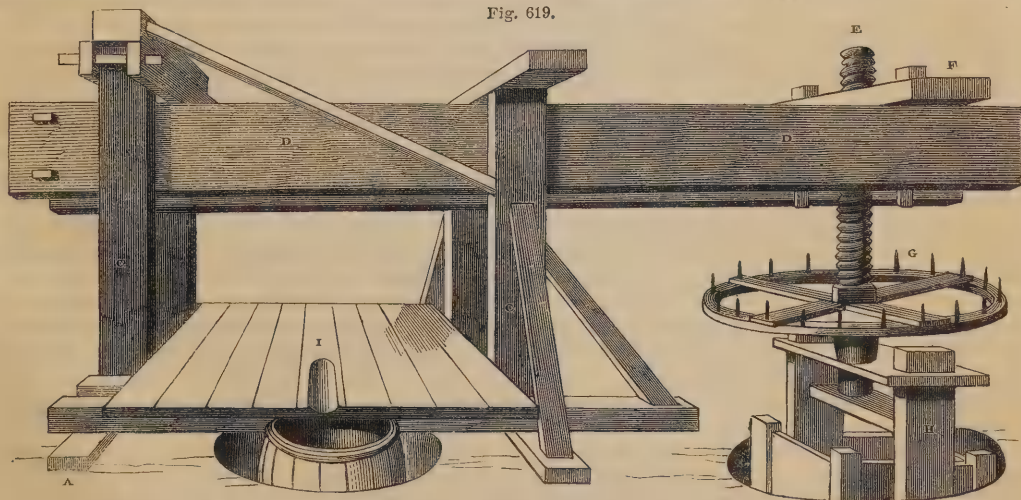


Fig. 619.



which the rope F runs; E, the cask to receive the must; G, the capstan that turns the wheel and its screw.

The great press, which will make from twenty to thirty barrels of wine in four or five hours, was, in the last century, constructed in the following mode—Fig. 619—and is the most common of the older kind. A A, the base and supporters; C C, the cheeks; D D, great

beams of timber, sometimes four or six in number; E, the screw; F, the nut; G, the wheel turned by five or six men, holding the upright shaft; H, the cage, a square of timber lined with masonry, ten feet long and four and a half square on each side; I, the *maye* or platform on which the grapes are placed, as in the small press, with blocks and planks over them; L, a

grooved channel by which the wine runs into the vat *K*. The cage will rise or sink into the pit; it is here shown ascending, and is in weight a couple of tons. Suspended at the end of the lever by means of its conjunction with the screw, it possesses immense power, increased according to the length of the lever, and thus it rapidly effects its object.

In some parts of the East the grapes are not pressed at all, but are beaten with wooden mallets on an inclined plane of marble, with a gutter at the bottom, which conveys the must into the cask or other receptacle.

On the sublimation of wines by the alembic, now the *still*, to which in recent times the term of distillation is applied, alcohol is separated. The name of this substance is derived from a *el*, more commonly *al*, the mark of the dative case in the Arabic language, joined to the word *coholmo*—in Spanish shortened to *colmo*—to rise to the top of anything; the invention having been brought into Spain by the Arabs.

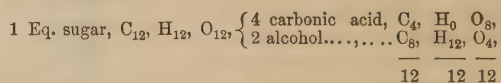
Hence, too, the word *alembic*—*alambique*. The meaning of the original name was retained in the verb to *sublimate*, *sublime*, or *raise up*, to the head of the chemical vessel or retort. Whether this substance was first sublimated or distilled from the must of the grape, or being of eastern origin, from the fruit of the date, or what other fruit, is uncertain; but in wine it is an important natural constituent. Distilled from the grape, it exhibits a superiority over that from every other substance, existing as it does in a variety of vegetal productions. The mode in which alcohol is formed or evolved by the natural process in the fermentation of the must of the grape, it is necessary to explain; its disengagement from other substances by the still having been already detailed under ALCOHOL.

The preparations for fermenting the must by which alcohol is formed, and the process of wine-making completed, are made with great care on the eve of the vintage. In France where the art is most perfect from superior science, the vats are in some places rubbed with over-ripe Portugal quinces; over those of stone elsewhere, a thin coating of whitewash is passed, to saturate the malic acid in the must. Instead of lime, the wooden vats are by some washed with warm water, and afterwards a little brandy is passed over the staves, while others rub them with decoctions of aromatic plants, salt water, or boiling must. These methods are all beneficial, except the use of the lime, which, without great care and judgment, is apt to detach itself and communicate a bad taste to the must, which is deposited in the vat at once from the receptacles at the press, with or without the murk according to the views of the maker.

The whole of the must being in the vat, the fermentation is the next and most important part of the process. It is divided into two stages; the first rapid, sensible, and tumultuous; the second slow, and of considerable duration. The second is often denominated insensible, though sometimes the escape of the carbonic gas is perceptible to the ear in close-covered vessels. The first demands the access of air to proceed promptly through its regular course, which, although rapid, has always a slight progression to the end

of the operation, which is at once discoverable by its being no longer turbid, and by the subsidence or depression of the head or *chapeau*—as the French denominate the scum, stems, and other substances, which float and form a crust upon the surface of the must, or rather of the wine, into which it has now become changed by the fermentative process—and the conversion of the sugar or glucose into alcohol. The reader will find the particulars of glucose described under STARCH and SUGAR, page 000.

One equivalent of anhydrous grape sugar is resolvable into four of carbonic acid and two of alcohol, whence this deduction:—



Sugar of starch and sugar of milk may be converted into sugar of grapes. In the sugar of the cane, and in that of grapes, oxygen and hydrogen are found in the same proportions as water. Grape-sugar, found also in honey and in most fruits, is the slowest of all sugars to undergo fermentation, during which the sugar is resolved as above into alcohol and carbonic acid by the presence, in only a slight degree, of a substance tending to set it in action. This substance results from the nitrogenous constituents of the grape-juice, and is named *diastase*. In making all natural wines, this substance found in the must comes into action spontaneously. Yeast is the product of decomposed gluten. This yeast added to a solution of pure sugar disappears; but when mixed with juices which contain gluten as well as sugar, it is reproduced by the decomposition of the sugar. Gluten is present in the wine-must undecomposed; decomposed in the state of yeast, it would ruin the flavor of the wine, and should never be used to ferment either grape or domestic wines.

The immediate presence of the fermenting agent at once causes chemical decomposition. Oxygen and hydrogen exist in grape-sugar in the same proportion as they are found in water. Carbonic gas is given out; and in consequence alcohol is formed from the sugar, while water is decomposed during the putrefaction of the gluten. A temperature of 65° is most congenial to vinous fermentation, during which the heat increases. At 60° the fermentation is perceptible, but exceedingly languid. There are instances where it has been known to rise as high as 97° or 98°. Thus the fermentation in warm weather is found to be considerably accelerated. When the weather is cold, boiling must has sometimes been thrown into the vat, and red hot-iron bars have been plunged into the must with the same object.

Fermentation in a very small active mass will communicate the principle to a large quantity at rest. The magnitude of the volume submitted to the operation shows, too, that large quantities proceed more satisfactorily than small, though, in the latter case, the alcoholic strength and aroma are better preserved. After the lowering or fall of the crust or head, the sign of the first fermentation being over, the must is covered up from the air; no more opening being left than is sufficient to suffer the carbonic gas to make its escape.

But there are other substances formed in wine besides those already mentioned—some of which amount to little more than perceptible traces, and these are not found in all wines. Their quantity and even presence will depend upon the nature of the soil in which the vine was grown which produced them, and the cold or heat of the season; for in cold summers the fruit is acid. Starch, gum, albumen, gluten, extractive or coloring matter, bitartrate of potassa, malic, tannic, gallic, and a little citric acid, traces of tartrate of lime, of alumina, and potassa, sulphate of potassa, chlorides of sodium and of potassium, and in some, perhaps traceable in all wines, there are racemates and paratartrates. Racemic or paratartronic acid was discovered by M. KESTNER, and mistaken by him for oxalic acid. It is a modification of tartaric acid, and distinct in its nature. It was first thought to be peculiar to the grapes of the Vosges, and was called *acide de Vosges*. This acid is obtained from a solution, containing as well tartaric acid. The crystals are an oblique prism, with a rhomboid base; those of tartaric acid have a rectangular base. Its formula, as given by GREGORY, is $2\text{HO}, \text{C}_8\text{H}_6\text{O}_{12}$.

There is also an odorous principle called oil of wine, which is sweet, quite neutral, and is formed during fermentation, and obtainable from alcohol by pouring two and a half parts of sulphuric acid on one part of anhydrous alcohol. It boils at 536° , and has a specific weight of 1.133. It has a flavor somewhat resembling peppermint, and imparts a vinous smell to the wine newly formed. The salts procured from this oil are identical with the sulphovinatates procured from sulphuric acid and alcohol. There is also a lighter species of oil of wine, specific gravity = 0.917 to 0.920, resembling olive oil. It is composed of $\text{C}_{16}\text{H}_{16}$, or very nearly the proportions of olefiant gas.

Climate makes an important difference in the component parts of the wine-must, as well in the acid as in the sugar dissolved. Hot climates produce a must rich in sugar; but this difference does not appear to affect the extent of the nitrogenous matter in the must, for it seems to be all expended in some wines before the sugar is converted into alcohol; and a part remaining undecomposed, it produces the thick sweet wines of the South. In colder regions the nitrogenous matter and sugar being alike expended, and the wine as it were balanced in regard to these principles, as in some German wines, dry long-enduring wines are produced. When the gluten is in excess, the wine, not preservable with facility, is soon converted into acetic acid if great care be not taken. It absorbs oxygen, and the oxidation is communicated to the alcohol. This oxidation may be prevented, and the conversion into acetic acid arrested, by the addition of a small quantity of sulphuric acid. Fermentation has been ascribed to the growth of fungi and infusoria; but much more evidence must be given before this can be received as a fact.

To return to practical vinification—the method of treating the produce of the vine in fermentation differs with the climate, season, nature of the fruit, temperature of the vineyard, soil, mode of culture and fancy of the proprietor, who is often guided by local custom. In some places the wine is not suffered to remain in the

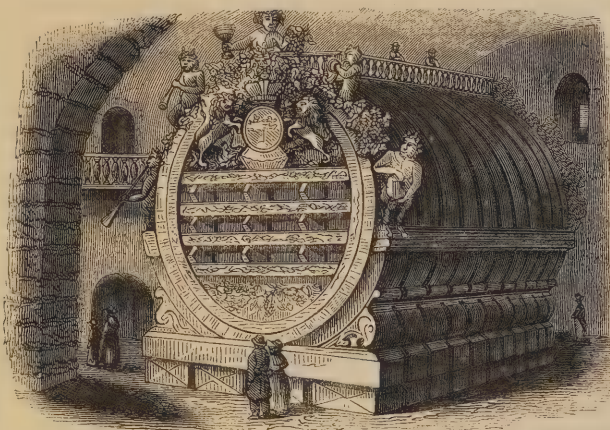
vat more than from thirty-six to forty hours. Near Lyons in France, it remains six or eight days, and in general from ten to twelve. In the South-west of France, it remains from twenty-five to forty; and at Narbonne, it is carried up to seventy days. When the farmer is asked how, the fermentation being over and the wine at the temperature of the atmosphere, he suffers it to remain still in contact with the stalks and stems to clear itself in the vat; he replies, It is the custom, and, if warned again of acidity through the breakage of the scum or crust, he answers he only acts according to usage—it should be *ignorance*. It is true the crust is almost always compact; but it is a hazard unless the saccharine principle be abundant, and the albuminous matter all taken up.

Vinous fermentation in general takes place under the free admission of air. An attempt was made by a Madame GERVAIS of Montpellier at the close of the last century, to introduce fermentation in close vessels. The idea was not new. M. DE LA PLOMBANIE, M. PORTA, a Neapolitan, and the German chemist, BECKER, at the commencement of the seventeenth century, had recommended the same process. But the admission of the atmospheric air is indispensable to the operation. A considerable noise was made about the invention, which, it was supposed, would preserve the aroma, and prevent the escape of alcohol. M. DELAVEAU instituted some experiments with great care under a fermentation for nineteen days, when it was found that the return from the vat had the most agreeable flavor; that the wine distilled afforded a spirit only equal to that fermented the usual way; the latter if anything yielding the largest quantity of alcohol. The vat with the invention gave sixteen and a half alcohol at a temperature of 80°F ; the vat with a simple cover, generally used in the South, sixteen and three-eighths; and that not covered at all, sixteen and an eighth. It was thought that the color of the red wines was somewhat deepened by the invention; but neither the aroma nor the vinosity was increased, nor was the invention considered of moment, so as to come into general adoption. Long experience had proved the efficacy of the old mode, and chemistry could find no ground to impugn it in a scientific sense. The strength of the wine, besides that which may be denominated alcohol, or rather its endurance, is in some degree due to the stems and the tannin it contains; but though used in port and some similar second-class red wines, they are excluded from the delicate red wines of France, though adopted in some of the white, while they are also excluded from the Rhine wines. In Spain the wine, having in Andalusia a great enduring power, is left to ferment in the butts, into which it is taken in the *mosto* or must state. The bungs are left open, and the wine and froth thrown up in the fermentation are poured back into the barrel to feed the wine, as they phrase it. This causes a renewal of the fermentation at every atmospherical change, and even on any accidental motion of the cask. In the month of March after the vintage, for the first time, the wine is racked. The advantage of large vats has made no way with the Spaniards. It might be best, *quien sabe*, but he keeps to the old track. The delicate and choice French

wines would be ruined by such a mode of conducting the fermentative process.

On the Rhine the fermentation, after the must is ready made from picked fruit, the stalks put aside, and the different pressings set apart, takes place in casks, to preserve the aroma. The wine is then repeatedly racked, and placed in tuns holding about eight hogsheads and a half, where it remains for many years to acquire perfection. Some of the older tuns, in which the wine no doubt mellow best, are those locally denominated *fuders*, and will contain three hundred and fifty tuns. The celebrated tun of HEIDELBERG has long been renowned. It is thirty-one feet long by twenty-one high, and holds one hundred and fifty fuders, or six hundred hogsheads. It was built at Heidelberg in 1663, as a successor to one which held only a hundred and thirty-two. There was once a larger tun at Dresden, shown in Fig. 620, which held three thousand seven hundred and nine hogsheads.

Fig. 620.



It will be interesting to the reader to know the strength of the must at different periods. The specific gravity of the Pedro Ximenes must at San Lucar, after two days' exposure to the sun in September, was 1.092. At Paxarete in October, its must, after four days' exposure, was 1.121. The must of the Mantuo-Castillan grape at San Lucar in September was 1.069. The black mollat grape at San Lucar gave a must in the middle of September of 1.064; and at Paxarete, the last day of the same month, 1.089. At Chipiona, in the middle of September, the muscatel called gordo-blanco, a large white variety, after three days' exposure to the sun, gave 1.089; at the end of the month 1.096; and in October a specific gravity of 1.114. At San Lucar, in the middle of September, the white Temprana grape gave about 1.075; but, on three days' exposure to the sun, the specific gravity was 1.114. This last grape at San Lucar is cultivated to the extent of nineteen-twentieths of the vine lands. In the Paxarete, Ximenes, Muscat, and Tintilla wines, it enters largely.

In Hungary are made the celebrated rich liqueur wines *Essences*, *Ausbruchs*, and *Maslas*, *vins cuits*, and wines suppressed in fermentation mingled with

other substances, and so long noted for their excellence; the grapes are carried in sacks, for the making, as those of Szamorodny, for example. They are treated in fermentation in the ordinary manner. The fruit or the essence, already obtained without pressure, and over-ripe, is carefully picked upon a large table, called a sorting-table, and placed in a cool vessel covered over. It is then put into a large vat, where men with cleanly washed feet, under a superintendent, tread them into a paste. This grape paste is then placed in a second vat, and covered over. New must of the common wine of the country is then poured upon it, the quantity of which used determines the quality of the wine, or wine *de liqueur*, according to the owner's pleasure. Sometimes two measures, or four, five, or six of the essence are added to ten of the common wine. The proportion of six to ten is rarely exceeded. The wine and paste are then mixed, and left for a couple of days, or for three, if the tempera-

ture be low, stirring the mass frequently. This thick must is then conveyed to the press, a slight pressure producing the richest kind; it is next conveyed into a cask, and thus becomes the celebrated Tokay Ausbruch, or flowing syrup. It is skimmed while fermenting, and strained into casks. It has a fine aroma, but never becomes very bright. It is soft and oily on the palate. There are two species, one containing generally sixty-one parts of essence, and eighty-five of wine; and the other called *maslas*, having sixty-one parts of essence to a hundred and sixty-nine of wine. The best sells for twelve pounds sterling the dozen. The fermenting and purifying proceed together. That of 1811 was celebrated, the fermentation having been perfect. There is besides a great variety of wine in Hungary, but all of a peculiar character.

The greatest care in manipulation, and the most scientific methods in the treatment of wine, have been tried in France, and the result has been the production of the finest wines in the world. The removal of the wine from the vat to the cask is there as carefully regarded as the work of fermentation. The casks are all made ready at the same time as the vats. If the wood of which they are made is new, they will not fail to communicate an astringency and bitterness to the wine. To prevent this, the casks are repeatedly washed with cold water, and then with hot, in which peach leaves and salt are infused. They are repeatedly shaken while the fluid is hot, and then are left so that the wood may absorb them, and they may penetrate into the pores of the timber. The casks are now emptied, and boiling hot must, to the extent of two or three quarts, is introduced. The bungs are put in, the casks shaken, and then left to cool. Some use only hot wine in place of the above substances. If the casks are old, they scrape off the tartar that lines the staves, and wash them with hot water and must, or wine. If they have contracted an ill smell, or show the least mark of decay, they are burned at once, because, in

spite of all that can be done, sooner or later the bad effects will appear. Casks should be sulphured, if the least suspicion attach to them, by the introduction of a match at the bung. Such casks are generally made of oak staves, but some prefer beech. They bear different names in different parts of France, as *barrique* at Bordeaux, *botte* at Lyons, *tun*, and *pipe*, *et cetera*, in other places. When large, they are called *muids*, and very large ones *foudres*. Some have proposed vases of clay varnished, but they are considered porous, and cannot be easily conveyed from place to place.

The wine being fermented, the duration of the fermentation, depending upon the state of the temperature, the amount of sugar and similar things, to be decided upon observation and according to the season, the wine is drawn off into the cask. Some of the finest Burgundies, called wines *de primeur*, only remain in the vat from six to ten hours. The rest in the vat is only important on account of the color. If the skins were sufficiently broken, so that the coloring principle stands in no need of the action caused by the tumultuous fermentation to bring it out, the fermentation with the fruit and its grains being often more mischievous than useful, it is omitted. If the skins are sufficiently bruised and torn, when the fruit is trodden, to give out all the coloring matter, it is not considered wise to suffer the must to enter the vat after pressing.

The drawing off the wine into the cask at the exact moment is a point of great importance. The crust or chapeau having fallen, and active fermentation ceased to the eye, all being perfectly quiet, the examination with a wine glass, the taste, color, and odor, except tested by experience, are often fallacious. Taste and smell are so different in individuals that there is much uncertainty upon the time when it is best to operate. The heat generated in fermentation depends mainly upon the quantity of glucose or grape sugar which has entered into the spirituous state. No fixed rule exists. It is frequently found that the maximum of heat is attained after twenty-one hours of fermentation in one case, and in another after ten, while the wine is not really perfected perhaps for twenty hours longer, so that the thermometer is no reliable guide as to the vinification. Something to determine the fact of the vinification mechanically, was long considered a desideratum by the French producers. There were the differences of climate, soil, and species of fruit to be considered. An attempt was made to ascertain this point by means of a vertical rod, marked with a scale to show the elevation and depression of the fluid. It was placed in the middle of the vat to indicate the depression of the must after its previous repulsion by the fluid, and that the time thus indicated should be that of drawing off the wine from the vat. This was found to be correct in seasons when the sugar was abundant, and then the moment of the retrogradation of the must was the best for emptying the vat. In wet seasons, on the other hand, the indicator did not seem to answer, but the inventor had little doubt of success in establishing a scale to indicate the time sought in different seasons when the temperature varied; but he was unable to carry out his experiments beyond three seasons, having been compelled to become an exile.

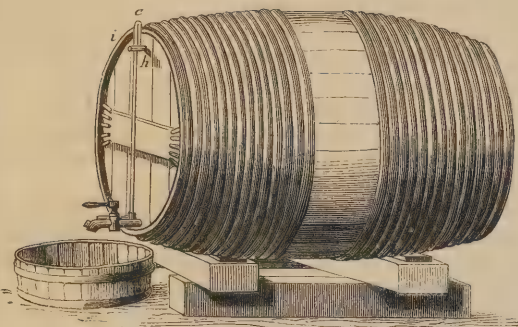
In drawing off the vat it is necessary, before commencing, to take away with great care, by the use of a wooden shovel, that part of the head or crust which, having contracted acidity by exposure to the air, if it broke and became mingled with the must beneath would spoil the whole mass. The must drawn off, the murk remaining in the vat is pressed for the wine called that *of the press*, which is equal in quality to that which has been drawn from the vat without pressure. The wines thus made are called that of the first, second, and third vatting, as before stated. The first taken is the most spirituous, and the last the harshest, sharpest, and deepest-colored. The second pressing holds a middle quality. The residue of the murk is used for the manufacture of verdigris, for the food of cattle, for vine-dressing, or for nourishing pigeons, which greedily devour it. These later wines of the press are sometimes mingled with that of the vat, an indefensible practice, because the wine from the vat will often by such a mixture lose its own peculiar delicacy.

The wine being in cask is, in the pure wine countries, directly placed in the cellar. The cellars vary in different countries. In Spain those of the Xeres district are of great size, to the extent of three hundred English feet long by above two hundred broad. Four thousand casks of wine are arranged in similar cellars in tiers, and are called *soleras*. The wines of different seasons are mingled in these, so that one will contain some of each vintage for thirty seasons. The wine is fermented in the butts, the bung-holes being left open without endangering the wine; nor is the cellar temperature much regarded, such is the firmness of the wine. In Valladolid the cellars are deep in the earth, like mines, with huts over them. In France the cellar is an object of peculiar care, the exquisitely delicate wines of the first-class in that country demanding great attention as to safe-keeping in their highest and most perfect state. The best and favorite cellars are held to be such as are situated under uninhabited buildings, as is observable in the places most noted for the culture of the vine, having a Northern exposure, and fifty or sixty feet deep, according to the dryness or the humidity of the soil. A uniform degree of moderate humidity is best. A cellar too damp causes the decay of the barrel staves, or covers them with a mouldiness which communicates a bad taste to the wine. If a cellar be too dry it makes the staves of the casks shrink, and the wine is wasted by leakage. The air should be admitted only by small openings, facing the North, made near the roof or vault, and susceptible of being closed when the weather is too hot or too cold. The vault or roof should be as solid and thick as possible, in order that no external concussions should be communicated to the wine. The soil above the vaulted roof should be united and well beaten down, and that part designed to receive the bottled wine should be covered with sand or fine fresh-water gravel.

The casks should be placed in a position perfectly horizontal, upon wooden beams six or seven inches square, supported by others transverse. Wedges should be forced under the casks on each side to keep them steady, and neither the casks nor their supports should

touch the wall of the cellar. If the casks are not set perfectly level, the wine lees will collect in the back part and prevent the wine flowing clear out of the cask the usual way. If the front be too much raised, the lees will come to it when the cask is elevated behind, in order to draw off the last of the wine, and thus stop the passage. The lees should settle in the belly or hollow of the staves, which will take place when the casks are kept perfectly horizontal with wedges, as shown in Fig. 621. Attached to the cask here given is

Fig. 621.



an air tube, to illustrate the mode adopted in some parts of France to prevent the admission of air over the wine, so apt to cause acidity.

The tube or canal, *abc*, is of the common form, except that the bottom of the tap at *d* is pierced with two apertures, of which the lower serves for the passage of the liquor, and the other corresponds with tube *efgch*, by which air is introduced into the tube to replace the liquid drawn out. The result is that it suffices to turn the tap, *k*, to cause the liquid to run; and to shut it, that all communication with the exterior air shall be cut off. It is evident that when the tap is turned the wine will run out, and that the exterior air will replace that wanting by the tube *efgch*, and that on shutting, *k*, the pressure of the air will cease with the running of the wine. The tube is carried higher than is necessary, that the wine may not enter the tube at *h*, and may have the least possible distance to the surface of the wine, and thus prevent agitation. The tube at *h*, and the tap at *b*, both enter the cask. When the cask is to be all drawn off at once, of course such an application is superfluous, but it is invaluable where small quantities are taken in draft.

No garden stuff, green wood, flowers, fruits, or similar substances must be permitted in any cellar in which wine is kept, because the gas disengaged from them promotes aescency. The wine being deposited in the cellar, the insensible fermentation commences but too sensibly if that in the vat was imperfect. Carbonic acid gas still makes its escape, augmenting the volume of the wine, and forcing itself out at the bung in froth or scum. Hence it is necessary to take care that the casks are not quite filled when they leave the vat. At least two inches' space is left, and the bung driven home to prevent the slightest entrance of the atmospheric air. A gimlet hole is made on the upper side

of the cask, and stopped with a peg or *fausset*, in order to let the carbonic gas escape. Some wine-makers place in the bung-hole a linen cloth, filled or covered with sand or vine leaves pressed down with a tile.

When this fermentation ceases, and the wine has sunk down, the cask must be filled up and hermetically closed with linen round the bung. The operation of filling up by the bung is denominated *ullage*. In some places ullage is performed every day for the first month, every five days for the second, and every eight until the wine is racked. The celebrated Hermitage wine is thus treated. At Bordeaux ullage is performed on the eighth day—filling up exactly every ten days during the first month, and then once a month to the time of racking. In other places, if the cellars are dry, twice in two months; if humid, every three months. Ullage is performed in fine weather with wine fully equal in quality to that in the cask. The cellars are to be visited daily to guard against accidents, such as a leak in a stave from a wormhole, injury from commotion in carriage, mouldiness of the staves if the cellar be too damp, or shrinking of the staves or heads in those which are too dry. The wine from time to time is tasted, to ascertain its state and remedy any perceptible mischief. When ullage is neglected, a white mouldiness, called the *Flower*, is observed on the surface of the wine—a certain forerunner of acetous degeneration. The air is at once forced out, the nozzle of a bellows being introduced for that purpose, and then it is agi-

Fig. 622.



tated. A sulphur match is introduced, and the bung inserted. The cask is struck from below, to raise any concealed air bubbles to the surface, and to carry all the mouldiness possible to the bung-hole, which is filled so as to make the wine run over, and these efforts are continued until no vestige of the *Flower* appears. The wine in the cellar is observed to work much when the vine commences to bud, and when the fruit ripens,

which BUFFON attributes to the changes in the juice of the vine. FABBIONI and other authorities have stated that this phenomenon is only observable when the particles of the wine have not been separated by a sufficient quantity of alcohol—in other words, when the glucose was not equal to the subjugation of the gluten, and the other constituents were not in due proportion. This fermentation is prevented by the use of sulphuric acid, sulphate of lime, mercurial oxides, additional alcohol, camphor, ice, and water at the boiling point. When the wine is still, it is perfected, and only deposits its lees, consisting of portions of the pulp of the fruit, of the coloring matter, and of the tartar, which last is found crystallized on the interior of the staves of the cask.

The next process is that of racking, undertaken to clear the wine of the substances which tend, by mixing anew with the wine, to form a fermentation. It is an operation not generally performed at a stated time. In some places it is done in December, after the vintage, when the wine is required to be moved; if not, it is done annually, generally in the months of February or March. In some countries this operation is performed twice the first year, in spring and at the end of September; in others, at the end of December and middle of May—the first during a sharp frost. Much, however, depends upon the quality of the wine. Generous wines may rest upon the lees three or four months, and be only racked once in two years, but in general they are separated from their lees before the first equinox of the spring succeeding the vintage. There are times when, on the other hand, in lieu of racking, it becomes necessary to recombine the lees with the wine, in order to establish a fermentation which may ameliorate them and promote their maturity. This operation being of importance, it is necessary to describe. The smallest inadvertence will produce, in conducting it, the acetic action, the tendency to which, the moment it is perceived, must be met by racking at once, and moving it to the coldest place possible, and before racking it must be fined. The weather most proper is that which is dry and clear.

The wine is drawn off carefully that it be not disturbed, and when the cask is stouped for the last of the liquor, it must be done with great care and judgment by hands accustomed to the operation. The Beaune wines in France are generally racked by the introduction of an instrument into the cask well calculated to draw off the fluid without disturbance, and these wines are always remarkably fine. At Condrieu on the Rhone, the wine is racked eight days after it is made, and before the end of the month it is fined, then racked anew, sometimes twice or thrice at an interval of fifteen or twenty days, in order to procure the limpidity so desirable. Wines not cleared sufficiently by racking are fined, the substances used for the purpose being isinglass and whites of eggs. The isinglass is cut up and steeped in a little wine, until it becomes viscid and softened. It is then thrown into the cask. The wine is afterwards strongly agitated. The quantity of finings used is about five drachms to every five or six hundred litres or quarts of wine. The whites of eggs, preferred in some places, are well beaten up in a little wine, poured into the cask, and left to rest for ten or fifteen

days, when the wine is racked during the first Northerly wind. From six to ten fresh eggs are used for every twenty-two gallons imperial. Various substances have been applied for the purpose, as gum-arabic, hartshorn, calcined flint, rice, milk, and starch, but none produce the desired effect so promptly as isinglass or the white of the egg. Ordinary wines lose their acidity by fining, and the finer classes increase their brilliancy and clearness.

Wine is sulphured at times, in other words, impregnated with sulphurous gas, by burning sulphur matches over it. These consist of a roll of linen or cotton an inch and a half broad, and six or seven long, dipped in melted sulphur, to which powdered leaves of aromatic plants are sometimes added. Those made at Strasbourg are noted. The match is suspended from the bung-hole by a wire, and being lighted, the bung is closed. The air within dilates and escapes through the smallest opening. The operation contributes greatly to the preservation of the wine, though some say it injures the color of red wines. Those who object to it throw a little brandy into the cask, to which they set fire with a bit of lighted string, and while it is burning close up the bung, leaving only just air enough to keep up combustion. In other cases a wine is made; the fermentation is arrested, and the must placed in a cask until it is a quarter filled, and a number of sulphur matches are burned over it. The cask is then closed and strongly agitated, until no gas escapes on opening the bung. More must is then added, and the agitation repeated, until the cask is full. This must never ferments, has a sweet taste, smells strongly of sulphur, and when a certain quantity of alcohol—of the strength *trois-six*—is added, a wine named *wine of Calabria* is the product, employed principally to give strength and sweetness to wines deficient in those qualities.

MULDER states that wine, stored in wooden casks, loses water, whether mixed with alcohol or not. But if evaporation affects the contents of the cask, the loss must be repaired, otherwise the action of the air would turn the wine acerb, and convert the alcohol into acetic acid. It is chiefly water which is evaporated, and its loss is made up by adding wine. All the constituents of wine, with the exception of water, are hereby increased, and the wine becomes not only stronger, but better flavored. The vinous components being more concentrated, are better able to act chemically upon each other, and this, *per se*, would account for the improvement of the wine. Here one has a general statement of the causes upon which the difference between new wine and that which has been stored in casks mainly depends. But the change is carried still further. The concentration of the wine, or rather the diminution of water, which is continually replaced by wine, causes a constant augmentation of tartaric acid in the wine. Wines which are poor in sugar may easily become too sour, and all wines cannot, therefore, undergo this process. The quantity of tartar in the wine is not increased; for, being insoluble in alcohol, the continual increase of alcohol precipitates it. That which is augmented is tartaric acid, which is soluble in alcohol, and insoluble in cream of tartar.

Madeira, and such like wines, are sent to warm countries to improve. MULDER had Madeira which had been seven times in cask to the East Indies and back, and truly, says he, *such nectar was unknown to the gods of the ancients*. The drier the atmosphere is which surrounds the casks, the greater will be the evaporation. To avoid this, care must be taken to prevent draughts, and to keep the air of the wine stores or cellars moist.

Wines remain in wood different periods, according to their qualities, and while thus resting are in a state of improvement. Some repose only three or four years before bottling. Tender, delicate, light wines gain little in the bottle, while strong spirituous ones preserve well in that state, and to a certain point improve. In bottling fine wines the bottles and corks should be new; the smallest defect in the latter determining their rejection. The French dip the corks and the bottle necks in a composition differently colored, to distinguish the wine, and thus shield the external part of the cork and a little of the neck of the bottle with it from the action of the air. This composition is made for three hundred bottles with two pounds nine ounces of rosin, half that quantity of Burgundy pitch, a fourth of yellow wax, and a small quantity of red mastic melted together, so as to form a liquid mass in which the corked necks of the bottles are dipped. In the cellar the bottles should be placed horizontally, to keep the corks always wet. Fine fresh-water gravel or sand is their best bed, and keeps the wine cool, but sea-sand from the salt in it, is pernicious. Sawdust only answers for coarse wines.

Wines of fine quality can only be mixed with others of a like quality to render them more generous, or to have a larger quantity of one particular flavor. It is a robbery or a great abuse to sell wine mixed in any other way for a genuine growth. Wines of Bordeaux are sometimes strengthened with hermitage or wine of Cahors, and are known as Medoc wines; but they are genuine and of good quality. Wines are liable to alteration and to degenerate. Such are loss of color, bitterness, acidity, tasting of old, of the wood, of musk, mouldiness, and what the French call *graise*, milkiness or cloudiness. To amend the last they use pure tartaric acid, taking care that little of the carbonic gas given out shall escape from the cask. This acid is composed of 2HO , $\text{C}_8\text{H}_4\text{O}_{10}$ and is found in a good many fruits beside the grape. The acid is mingled with sugar and introduced hot into the cask, which is closed and agitated for five or six minutes. Two days after, the wine is fined in the ordinary way. The carbonic gas is the agent of the cure. Wine is sometimes passed over fresh lees as a remedy for the same disease; and then racking is had recourse to afterwards. Acidity generally attacks wine which wants body. This never amends itself, but proceeds to the acetic state if left alone. Taken at the earliest moment, it is transferred into a cask impregnated with sulphur by the means before described; and different modes are employed for the cure of the mischief. Some dissolve honey, others liquorice, in the wine. Acetate of magnesia, bone gelatin, and similar substances are used; but the best mode of cure is to pass the wine over the relics in

the vat, after the vintage product for the year has been drawn off. Even then it should be drank early, for it cannot be trusted over another season. Oftentimes the acetous fermentation has already commenced, and there is no resource but to leave it to the vinegar-manufacturer. The bitterness in wine will sometimes become cured by itself when in bottle. It takes place in old wine. If not cured by passing the wine over fresh lees or mingling new with that attacked, it should be reserved for the still. Loss of color generally happens to the deepest-tinctured wines approaching age, arising from a species of fermentation for which recourse is had to purified tartar reduced to a fine powder and mingled. If unsuccessful, it must be mixed with a younger growth. The taste of old and musk—the latter thought to be caused by insects—the depositions of different wines, and the taste of the wood, add to the multiform cares of the wine-grower and admit of a variety of applications for cures not always successful. There is a wide road here for chemical investigation and experiment yet untrodden, as there is also to determine exactly those constituents which give to certain wines their delicate aroma and flavor. The odor which is peculiar to all wines must, to a certain extent, be ascribed to enanthic ether.—*Vide* ALCOHOL, vol. i., page 105.—The volatile substance existing in wine, which imparts to it, conjointly with enanthic ether, its vinous fragrantcy, is alcohol. Other beautiful volatile compounds have been detected in wine, but there is much yet to be discovered. To what substance does a fine Sauterne owe its most peculiar but magnificent bouquet? Acetic ether appears in most, perhaps in all, aromatic wines, and is developed in them by time. The adulterators of wine are well acquainted with this fact, and know how to make use of it. Acetic ether is largely sold for this purpose, and added in proportionably small quantities to wines which are not aromatic, to improve their fragrantcy. Two or three drops are ample for a bottle of wine. The reader is here referred to the article ETHER, vol. i., page 832, for full particulars with regard to the properties, *et cetera*, of the delicate ether existing in wine and spirits.

Besides the wines denominated sweet and dry, prepared from the fruit in the mode, and their difference arising from causes already stated, there are prepared wines in which the must is concentrated by evaporating a portion of the aqueous part, a very ancient custom wherever wine of the usual kind is made, called in France *vins cuits*, in Italy *vino cotto*, and in Spain, from the Arabic, *arropé*. The wine is boiled down to a third part, being skimmed of its froth, and sometimes, while boiling, aromatic substances are infused, or else it is used in its unperfumed state for strengthening other wines.

Dry and sweet wines, or wines of *liqueur*, are distinguished principally by the saccharine principle, in sweet wine, not being all converted into alcohol, the glucose surpassing the gluten in proportion, and the change being in consequence only partially effected. Such are the wines of Malaga, Rivesaltes, and Frontignan, and the wines from the rich muscatel grape more especially. Straw wines are also sweet wines, made of grapes for some months suspended upon straw bands

and afterwards pressed and fermented. The produce is about a sixth only of that obtained at the vintage. It has a strong rich flavor of the dried raisin. There is also a wine called *de Grenier* in France, made in nearly the same manner, and a sweet white styled *de Garde*.

Another wine of a very distinct character and of two kinds, one drier than the other, is procured by suppressing the fermentation, in other words, retaining the carbonic gas to a considerable extent. This species comprehends the wines of Champagne and their unworthy imitations, called sparkling Burgundies, Moselles, and others, all managed in the same mode. There is a genuine wine at Arbois of the same kind, or *mousseaux*, as the French term it, made in a mode somewhat different. The crust or chapeau is allowed to rise and settle over the must, as in the common mode of fermentation, so far as that the fermentation is not visible and no further, in order that the wine may be racked off in a clear state, being watched day and night for the period when bubbles of carbonic gas begin to appear on the surface. It is then racked into a vat and remains until a second crust or scum forms, and this is repeated until the wine is perfectly limpid. It is now placed in casks carefully kept filled. The bungs are daily examined in case of starting, that the cask may be filled up immediately. The air is excluded when the fermentation ceases, racked again in January or the following month, and in March fined and bottled. The corks being wired, the wine is deposited in a cellar of the requisite temperature.

To return to the more celebrated wines of Champagne, distinguished as still, creaming, and sparkling wines, or *mousseaux*, *crémans*, and *non-mousseaux*, of which the two last are most in esteem. The best froth very slightly, as Sillery; and the finest, called *vin du roi*, not at all. These wines come from the banks of the Marne and constitute a unique class. They are made for the most part of the blackest grapes, gathered with care, and only the sound fruit used. The grapes are carried to the press in baskets, covered up from the sun, and placed on the press with as little motion as possible. The must is poured into a vat for a term of from six to fifteen hours, that the dregs may be deposited. As soon as ever fermentation appears, the wine is transferred to the cask. The product of the first pressing is set aside as the choicest. The second pressing, or the wine of the *first cutting*, lightly colored and spirituous, partly composes the effervescing wines. The wine of the third pressing is kept for giving strength to the ordinary red wine of the country. This wine is put into bottles in March or April. At Rheims, on the other hand, they bottle the Sillery in January, although at the risk of its imbibing the effervescing quality. It having been thought advantageous to secure champagne of a uniform quality, which it was difficult to do from its being put into small casks; tuns holding twelve thousand litres were a few years ago introduced at Rheims by a German house, and the advantage of their use became evident.

The next step is to procure bottles of great strength, free of air bubbles, of the exact size, and without a flaw. The number required to bottle the effervescing wines in the department of the Marne is enormous; eight hundred

and sixty-six thousand gallons having been bottled in one season in the arrondissement of Epernay alone. In March or April the bottling commences. If done earlier, the breakage would be greater, fifteen per cent. being the ordinary loss. In the fermentation the carbonic gas not being allowed to form sufficiently or fully develop itself in the cask, it is quickly reproduced in the bottle; the saccharine principle renews its progress towards alcohol; and if the latter be sufficient to prevent the decay of the wine, the quality is good. This wine does not effervesce in uniform times. Some kinds will do so in a fortnight; others will be months before the signs appear. One wine will require a change of temperature for the purpose, and must be brought up nearer to the surface of the ground, if the cellar be deep. Another kind will not exhibit itself until the month of August, and a third kind only at the time the owner's patience is almost exhausted, when it will appear unexpectedly. If a wine shows no sign the first year, it is mingled the next year with new wine known to possess the effervescing principle. Nothing is certain; the cellars, their soil and depth, the air-holes, the difference of the place of growth—all seem to have an inexplicable effect upon the operation.

The bottles, carefully cleaned by rinsing and shotting, are placed in the working shop or *atelier*. The barrel-heads are bored, and a small brass pipe with a gauze-strainer, is inserted. The bottles are filled so as to allow about two inches clear space between the cork and the wine. This space diminishes, while the carbonic gas is generating; and the fractured bottles show that the expansion of the fluid has primarily quite filled the void. A workman who fills the bottles passes them on the right hand side to the principal operator, who is seated upon a stool, with a little table before him covered with sheet-lead, and about as high as his knees. He inspects the allotted space between the cork and the wine, regulates it exactly, selects a cork, moistens it, introduces it into the bottle, and strikes it so hard two or three times with a wooden mallet, that an observer wonders it is not broken by the violence of the blows; and yet fracture this way is rare from the attention paid to the management of the bottle at the same moment. This workman then passes the corked bottle to his right, where a third workman, seated precisely in the same manner, crosses the cork with pack-thread, and ties it strongly. He then passes it to a fourth workman who wires the bottle, cuts the wire, and hands it to a youth who places the bottles upright in the form of a parallelogram, so that they can be counted in a moment. The daily labor is calculated at a drawing of from sixteen hundred to seventeen hundred bottles. The best cellars of Epernay are those of M. MOET, and the bottles run in a pile from end to end, six feet high, and are carried down in osier baskets, having in each twenty-five cases for the bottles. Two men carry them by leather belts drawn through the handles of the basket. Slopes are prepared beneath in cement to carry away the wine from the broken bottles in the piles, with reservoirs to collect it. The bottles are placed head to tail on laths, the corks one way the reverse of the other.

The piles are very solid; and any one of the bottles, with the neck to the rear of the pile, can be easily with-

drawn in order to examine its state, and see if the carbonic gas is developed. If not, all must be got into the proper state, cost what it may. When a bottle is drawn from a pile, and kept in a horizontal position, a deposition is generally observable called the *griffe*, or claw, from its branching appearance. Before a bottle breaks, the vacancy below the cork disappears by the expansion of the carbonic acid, which generally occurs in July or August, when commonly from four to ten per cent. of breakage is experienced; too often the mischief reaches from thirty to forty. Sometimes, of the same wine in the same part of the cellar, one pile will remain with the gas undeveloped, while the other shows no sign of effervescence. A current of air will sometimes make the wine effervesce furiously. Thus great expenses are incurred, not only by breakage, but in attempts to excite the carbonic development. The loss by the breakage is often not equal to that of correcting the inertness of the wine, independently of the trouble. If not exceeding ten per cent. in breakage, the maker is satisfied. If it is deemed necessary to take down the pile, the bottles are set upon their bottoms for a longer or shorter time, and this causes a difference in the quality of the wine. At one time it is removed into a deeper cellar; or, lastly, the bottles are uncorked to disengage the gas, and clear the space under the cork. When the carbonic gas is furious in its development, the wine is wasted in large quantities. The wine of the broken bottles becomes scattered among the sound, or fragments remain which contain wine, and become acid and even putrid. The gutters become infected, and in the air of the cellar new principles of fermentation ensue. In August workmen have been obliged, owing to the fragments of glass projected from the piles, to put on wire masks, and entering the cellar to throw cold water over the wine. The breakage ceases in the month of September. In October the piles are *lifted*; the bottles being taken down one by one, putting aside those broken, and placing on their bottoms those in which, on examining the necks, the corks and sealing seem to have moved. Some bottles are found to have lost a portion of their contents, and the loss must be repaired. The deposition, too, must be removed. For this purpose the bottles are placed in an inclined position of about 25°, and are shaken two or three times a day, to detach the sediment, for ten or fifteen days successively. Planks with holes in them receive three or four thousand bottles together, keeping them in the right slope. The workmen then, with considerable dexterity, get all the deposition into the neck of the bottle, near the cork, the wine being perfectly clear. Every bottle is then taken by the bottom, kept carefully reversed, and the wire and twine being broken—the bottle resting on the workman's knees—the cork is dextrously withdrawn, so as to permit the gas to explode, and carry the deposition with it. An index is then introduced into the neck to measure how high the wine should ascend, and the deficiency is made good with wine that has before undergone the operation. The bottle is then a second time corked and wired. If the wine remain long in the cellar afterwards, before it is sold, it is submitted to a second clearance or *degorgement* of a similar kind about a fortnight before it is sent away; the

process to the last being laborious and expensive. These wines do not admit of being mingled with any but those of their own growth, and those genuine are rarely mingled at all. Grey champagne is made by treading the wine slightly before pressing, and rose-colored by a longer treading; but the latter is generally wine of inferior quality. In good cellars these wines will retain their excellence for twenty, and even as far as thirty years, in the last case imbibing only a slight degree of bitterness. The temperature of the cellars in which the wine is kept, is best at about 53° almost unvaryingly. The receptacles at Epernay are excavations in the calcareous rock, thirty-five feet below the surface of the ground. The creaming and still wines keep the best; those very frothy are most liable to change, and are really the least worthy of the class.

The finest red wines in the world are those of Burgundy, in the district called the Côte d'Or. They are produced principally from the grape called the Pineau. From twenty to thirty hours in the vat are sufficient to convert the glucose into alcohol, and then in two or three years they are fit for drinking. If moved in the cask in the least as they deposit, they are apt to spoil. On this account the finer kinds are only removed in bottle, and should be kept with great care. When old they take an amber color. In England the first classes of these wines and their proper management are unknown; the second classes alone being imported as the first, the coarse taste of the English palate in wine preventing the discovery of the difference. The finer wines are all produced in the districts of Nuits and Vosne; of these the Romanée-conti and the Chambertin are among the more celebrated. The white wines of the same district are not so well known or esteemed as the red. In the Mont Rachet wine, a celebrated growth, made near Beaune, occurs one of those extraordinary phenomena in wine which no scientific investigation has succeeded in explaining. Three kinds of wine are made of fruit grown on the same land, so contiguous as only to be separated by a footpath, having the same exposure, the soil appearing the same, as well as the species of vine; yet the last brings only one-third the price of the first. The whole ground is about thirty-seven hectares, of which the most prized is but seven, the next quality eighteen, and the third twelve. The wine of the first fruit sells at twelve hundred francs, the second six hundred, and the third four hundred.

The climate of Italy so congenial to the vine, produces no wines of export much valued, owing to the ill management of the vintage. No attention is paid to sorting the grapes; ripe and unripe are thrown into the vat together. Nicety and even cleanliness are neglected. The grapes are trodden and thrown into a vat, where the must remains fourteen days in a state of continued fermentation until the wine is spoiled. Sometimes the must is left exposed to the air for a month together, and the wine, ill-managed, has no reputation. In Tuscany more attention is paid to the process than in other parts of the country, and very palatable wine is made, but with little improvement in the process. The Montepulciano is a sweet wine long

noted there. This wine is racked repeatedly for two months after it is made, but the fermentation is often continued until the wine has begun to contract acidity before it is removed into the cask. In Naples they make a sweet wine called *lacryma Christi*, but the process is as careless as in other parts of Italy—in fact there are four or five wines of that name, some pretty good, others execrable. In Sicily the Mazzara wines, and the sweet wines of Syracuse, are made with little care; but English capital and some pains having been bestowed on the Marsala and Etna wines, they are exported to England, according to custom, brandied to excess to save care in their management, or, as the phrase is, to *fortify* them. The Marsala wine, well treated, is sound and good, and made in the fine climate of Sicily with French science, might still be greatly improved.

The Greek islands produce wine of various kinds, but mostly muscadines. In Cyprus the grapes are not suffered to lie too numerously on the stock. They are of a rich purple, with a thin skin. The vintage begins at the end of August. For the celebrated wine of the Commandery, the fruit is placed on covered floors called *punsi*, and spread out with care in a bed of eighteen inches thick, where the grapes remain until the seeds or grains are ready to drop from them. They are then carefully lifted with wooden shovels and carried to rooms paved with marble, or covered with a cement equally compact. These floors are made of a gentle slope. The grapes are bruised with a wooden mallet, and pressed in little presses denominated *patitisi*; the must, which is very thick, flowing into a vessel on the lower side of the floor. This vessel is emptied, when full, into small vases, and in these conveyed into baked earthen vessels with acute bases, like the ancient amphoræ. In these the wine is left forty days to ferment, in some places with the vat covered while in that state. This wine, if taken while in a state of fermentation, causes severe colic pains, to prevent which it is filtered through bags of vine ashes, but when thus treated it never attains the perfection desired. When the fermentation has ceased, the wine is shut up from the air with covers of baked earth, and has already put on a lighter color than before. These vessels are either coated internally with pitch, or varnished the instant they leave the potter's hand. If varnished, the composition consists of a boiling liquid in which turpentine and pitch are mingled with vine ashes, goat's hair, and fine sand; this effectually closes the pores, and never falls off. The art of making these vessels belongs to the remotest antiquity. They hold from twenty to thirty barrels each and in them the lees are deposited, which are called *mana*. When removed, leathern bags are adopted, pitched on the inside, and detrimental to the wine, which does not for many years lose the disagreeable flavor. The cellars, in so hot a climate as Cyprus, are all above the ground; little light is admitted, and the aspect disregarded. This famous wine was named from the Commander of the Knights Templars, to whom the district once belonged. The Commandery wine resembles the Italian wine of Chianti in color. From a red it changes to a yellowish hue the first year, fines itself as it grows old, and in nine or ten years takes nearly the same appearance as the sweet wines

of the South of Europe. The dregs are thick, and supposed to aid the fining. When brought from the country to the town and put into casks, it is always in such as have lees remaining, in which it is left for a year. Whether ullage is attended to or not, it makes no difference in regard to the excellence of the wine, for sometimes a cask is left not three-fourths filled. It is sold at the vineyard by the load of sixteen jars, each containing five Florence bottles. The wine is warranted good by the seller until the August after the vintage. It is generally exported in casks of three hundred and fifty bottles each. Only about ten thousand jars are now produced. When poured into a glass, if good in quality, the particles adhere like oil to the sides. Cold injures it; in a Northern climate it must be placed before a fire. The lees are always treasured up, and are often in color a mixture of black, red, and yellow, though generally like Spanish snuff. Those wines and the muscadines of Cyprus are different. The wines of the Greek islands are mingled with rosin to impart durability, and are very disagreeable to the taste in consequence. The wine of the Crimea, at least that called *kokour*, is fermented coarser than in Cyprus. The vats in many places are only pits dug in the ground, plastered with a composition. The Shiraz wine of Persia is made of trodden grapes, fermented in jars of glazed pottery agitated briskly; it is then bottled for sale.

The wine of Portugal, forced upon the people of England in 1703, by rendering the duty on that wine a third less than on the produce of other countries, drove out many fine wines, of which there was a great variety before, and forced an inferior article upon the public, under the absurd idea that Portugal would take English woollens in return, as if all trades were not an exchange of goods. The effect was to drive all variety in wine out of the country, and make Englishmen take an inferior article. At first the wine came in its natural state, but was afterwards sophisticated and brandied. Efforts were too soon made to control the market by limiting the supply, and rendering the wine nearly of a uniform quality. After the Portugal wine monopoly of 1756 was established, brandy was added, and increased until, in recent times, no less than from twenty to twenty-four gallons per pipe are flung into the wine during and after fermentation. In its natural state this wine is not permitted to come to England. The growth is stunted because the export is limited by a privileged company, which creates an artificial scarcity. The wine is adulterated with a mixture called *geropiga*, two-thirds must, and one-third spirits 20° above proof, with elderberry juice and sweetening matter, and is sanctioned by the English Government, though a gross adulteration, being admitted here as a spirit to carry out a fraud. This medley is used only in preparing wines for England. The pure wine is seldom allowed to be exported, although good and enduring, since by this doctoring there is an equality of class established that defies seasons or bad crops. The grapes are gathered when mature almost to shrivelling. They are from the *bastardo*, *sousao*, and *alvarelhao* vines. The fruit is trodden with the stalks, and remains during the fermentation, which continues about seventy hours, in vats

containing from ten to twenty pipes each, and while fermenting, brandy is added. The wine is racked in February, and sent to the company's or merchant's cellars in Oporto. More brandy is added to the wine intended for exportation, and again in a year, when shipped, more is thrown into a wine having in its natural state, on the average, amply sufficient alcohol to insure endurance with common care. It now carries a strong odor of brandy, and must remain a dozen years until the wine, or rather brandy-wine, is sufficiently subdued in alcohol to be drunk, when it bears little resemblance to the genuine wine, having become dull, and its freshness and aroma having disappeared. The consequence of the delay often is, that while ameliorating the extractive and coloring matter of the original, if not of the elderberry, becomes deposited, the wine tawny, and the flavor without a trace of the real unadulterated article. The perverseness of usage is become in a century so much in harmony, on the part of the consumer, with the merchant's notions of brandy being necessary to preserve a wine with sufficient alcohol by nature, that a genuine and honest port wine would now be regarded as worth little, on the plea of coldness, except to real connoisseurs. At first, in 1730, only about two gallons were added to a pipe. In 1754 the practice was styled *diabolical* of checking the fermentation in this mode of *fretting* in spirit, which it was fondly imagined immediately assimilated with the natural alcohol of the wine. The Portuguese charged the English at Oporto with commencing this base practice, and making wine seem *like liquid fire in the stomach*. It is observed by one authority that, in preparing these wines, it resembled throwing into one large vat all the red wines of a country of different growths, to produce an immense quantity of second-class wine. There are excellent wines thus mismanaged. The Collares port, Bucellas, Lisbon, and other wines made in the customary manner, bespeak that there is no fault except in the management. One wine-grower purchased elderberries a few years ago to the extent of four hundred pounds in a season; and one hundred and twenty pipes of adulterated must have in one year been landed in London from Oporto, to mingle with Portugal red wine in England, and doctor or strengthen what was too weak. Science can discover nothing worthy of record in the manipulation of the Oporto wines.

The vines of Madeira, now nearly destroyed by the *oidium*, or wine disease, were a remarkably fine class. They were planted in a volcanic soil, a mixture of red and yellow tufa, called *sabro* and *pedro molle*. A light clayey earth and volcanic cinders were intermingled. The husbandry was rude; the vines planted in trellises. The vintage took place in September, and the wine of the highest quality, called *pingo*, was that which flowed from the treading alone. The wine was pressed to the fourth pressing in a trough-press, with a lever like that of a cider press. The grapes were sorted and the *mosto*, or must, fermented in pipes. Gypsum was sprinkled on the grapes. The must was agitated during the fermentation, which exceeded forty days in duration. The wine was mellowed in stoves, kept at a temperature of 80° or 90°. A voyage to the East or West Indies was always preferable for

ripening the wine, when it could be accomplished. There was once a very agreeable cordial wine, made in Madeira, by checking the fermentation and adding brandy to the must. The *sercial* is the product of the hock grape, never drank under seven years old, and then not in perfection. There were once three kinds of malmsey, from as many different kinds of grapes, in these islands. That from the cadel grape was the best. The tinto resembled new Burgundy, but was less harsh; it was drank under three years old, at which age it lost its color, and took that of old Madeira. It had an agreeable aroma. Wines of Madeira were sometimes ripened by plunging them into a trench of fermenting horse dung. The bottles were corked, and thus the wine attained, in a few months, the maturity of a voyage at sea. This, however, may be doubted; because, at sea, not only a particular temperature, but a considerable agitation is kept up. A pipe of Madeira, attached to the beam of a steam-engine, in the warm engine-house, is said to have produced the effect desired. Madeira is, or rather was, in perfection in twenty years. The vine disease has suddenly ruined this far-famed wine, and the unfortunate people of the island that produced it. A very fine sample of this wine the Editor received from Mr. J. R. HUTTON of Liverpool—a nutty flavor, and yielded 15.69 per cent. of alcohol.

The wines of Spain are quite distinct from those of Portugal, as well as of France. Many of them are superior of their class, and of the white wines in particular; they constitute the largest quantity of any single foreign wine, red or white, entered in England for home consumption. The wines of Spain, except those of Andalusia, in which much British capital is invested, are carelessly made; but their firmness, just alcohol, resistance to what would ruin very delicate growths in the North, arising from a warm and genial climate, prevent their merits from passing unappreciated. The fine red wine of La Mancha, the Val de Penas, was, until recently, carried about only in pitched skins on the backs of mules. The great exports of wine are from Cadiz and Malaga. The sherry is made near the town of Xeres de la Frontera, nine miles from Port St. Mary's, across the harbor of Cadiz. The grapes are left on the tree until they are shrivelled by the sun's heat, and when plucked remain exposed to it some time before they are pressed. The fermentation is generally left to take care of itself, with all the scum it forms; and yet the wine is so fine that very rarely mischief occurs to it. Racked after the vintage, and constantly under the eyes of the agents or principals of foreign houses, resident on the spot, the management is carefully scrutinized. The grapes here are sprinkled with powdered gypsum, once locally termed *giesso* or *jess*. The must ferments in the cask left entirely to itself. It is racked in March. The casks are left open in all temperatures, and sometimes in the open air without ill effect. A good cellar, so named in France or the North, is not thought of moment here. While fermenting, the bungs are so open as to allow the easy escape of the carbonic gas. Ropiness, dreaded elsewhere under such treatment, is very rarely observed. The natural color of the pure wine is pale; the colored are from a

blending with a dark wine called *arropé*, made by boiling down six butts of must to one, keeping the liquid continually stirred and the surface skimmed, avoiding the accident of burning, on which account the process is slowly conducted. When thick enough, the fire is gradually withdrawn, so that the fluid may cool without any injury from chill. It is then mingled in different proportions with the pale wines, thus constituting colored and brown sherry. Nothing foreign is ever mingled with these wines, except a couple of bottles of very good brandy upon their exportation. The sherry, denominated *amontillado*, is a drier wine than the common sherry, and is often the result of accident. To this wine no addition but of its own class can be made without spoiling, not even a glass of brandy. A sample of this pure wine the Editor received from the highly respectable house of Messrs. CHILLINGWORTH and SON of London. It had a superb flavor, and only contained 11·50 per cent. of alcohol—proving it to be a pure wine. Of a hundred butts from the same vineyard, some will be *amontillado* without it being possible to discover the cause. Thus the constituent parts in *amontillado*, if supposed exactly balanced, raised the question, Why should this occur in a small portion only of a larger quantity? When it is made, the grapes are plucked a week or two before those for the other wine, but the treatment is just the same. The wines that pass for sherry in England in taverns, are generally made-up wines, or good mingled with inferior or low wines. Another species of wine which may come under the sherry denomination is that called *Manzanilla*—light, delicate, and straw-colored; it is not always liked at first. It derives its name, some say, from a village near Seville, and as others suppose, from *Manzanilla*, a small apple. Neither surmise is correct. *Manzanilla* is the camomile, and there is something of the taste of that plant in its flavor. It is delicate and will admit of no foreign mixture. The dryness shows that the glucose and vegetal extract are well balanced in its fermentation. It is produced from the *Rustan* grape. The wines of Malaga are of ancient date, and the vines are grown near sugar canes, the only spot in Europe where the latter are found. The *bastardo* grape makes the sweet wine. The must is conveyed from the press, half fermented, to the merchants' stores in sheepskins, and the wines are sent to all parts of the world unbranded, except to England. The mountain wine is made in Malaga, and one species is called wine of pears, because that fruit is steeped in it. There is also a cherry wine, called *guindas*, made there. It is much flavored with the cherries. There are many excellent wines in the interior of Spain, but made unpalatable from bad management in the fermentation, exemplifying the Spanish proverb—*To cry wine and sell vinegar*.

The dry wines of Xeres and Malaga, as well as those of Teneriffe, were formerly called *sacks*, and the sweet also. In 1598, in Hakhyt, it is stated by one who resided eight years at Teneriffe, that it produced three kinds of wine—Canary, Malvasia, and Verdone, which may all go under the denomination of *sack*. The wine of different ages is mingled in Andalusia, the newest with old of the purest quality.

The wines of Andalusia are rarely sulphured, from

fear of the taste remaining, and on account of English prejudices. Some Englishmen complained of the taste where sulphur had never been used. Here the stalks, and often not even the skins of the grapes, are suffered to ferment in the must. The wines are white, and color is not wanted. In France the stalks are left in the must according to the nature of the season; if fine they remain. In Spain the glucose abounds in the grape; and were it not for the practice of leaving the scum on the wine, and even returning it under the idea of supporting the wine, none would ever become acid. The system of large vats, so friendly to a beneficial fermentation, has not been tried there. Nor is it necessary; for in their present state they enter into the largest consumption in the English market. The better wines of Southern Spain yield nearly a fifth part of alcohol on distillation, and the quality so returned is excellent, and only inferior to the best of France. The *tintilla* wine of Rota is a red of Andalusia, generally taken as a cordial from its extreme richness. In Alicante a wine is made from the same kind of grape, which holds much tannin, precipitating a species of animal gelatin. It is of an orange-red color, rough, and somewhat bitter. In Catalonia the wines are generally good, and of the red species. Vinaroza and Benicarlo produce good red wines, much of which passes for port in England, either mingled with it or flavored, so as to secure the similitude. This wine is of a wholesome quality. The malmsey of Sitges is white. In Arragon, the wine of Carinena is the best. A muscadine named *Fuençaral*, is made near Madrid, and a fine dessert wine at Peralta in Navarre.

The wines of Spain have the ascendancy in England, perhaps from their freedom from acidity, owing in part to their treatment in the vat with gypsum, to which must be added their own natural tendency and strength, as seen on their exposure to the atmosphere under circumstances in which the wines of other countries would run rapidly into the acetous state. Wines which contain much of the gluten, are more susceptible of the acetous fermentation than those in which it is more sparingly dispensed; and the latter is the case with the wines of the Xeres district, in which little or none remains after fermentation, without half the trouble in racking and fining which is bestowed on other wines. There can be no doubt, this refers to the white wines of that part of Spain alone when the spirituous fermentation has ceased. The little brandy added, and often none at all, to the best wines of Xeres, as is evidenced in the beautiful sample of Messrs. CHILLINGWORTH above referred to, shows how well their constituent parts are adapted for preservation, compared with some ports and oftentimes their twenty gallons of artificial brandy. It is only to the meagre wines of the country—mingled with a little of the good, and called *low sherries*—that brandy is added, to render the wine more agreeable to the corrupted taste of the English public, which is thus to be satisfied with brandy and wine in a state of mixture, in place of brandy and water. The intemperate use of pure wine when indulged, is never followed by those disorders so common and fatal in the use of the favorite dull fiery wines of the generality of persons in England, particularly in the class called hepatic affections. Brisk,

lively, natural wine, is totally distinct in its action on the human frame from that of the brandy wines medicated for a perverted taste. The effect of pure wine in excess is transient; of brandied wine it need not be detailed. The Editor is convinced, from investigations and analyses, that there is no more *necessity* to add brandy to port than sulphuric acid to vinegar. If the liquid be well fermented, sound, and good, any addition is pernicious and wicked.

There is no just ground for believing that brandy will prevent acetous fermentation, although the common notion is that it will do so. It is incredible how far custom goes in effecting error, and preventing its correction, often indeed irremediably. A merchant of good sense desired to have sent him, even if smuggled out of Oporto, half a dozen pipes of port-wine without a drop of brandy. His correspondent would only send him one in reply to the order, being certain *that without brandy it would not keep*. The wine came and remained good in the cellar for years till drunk out. The Oporto merchant did not know, that for forty or fifty years after the Northern treaty of 1703, little or no brandy was put into a wine of a very full body, nor that Sir EDWARD BARRY complained in 1773 of these wines becoming too hot. It was not until the end of the last century that they were so fully deluged in artificial spirit—introduced at first under the idea of their preservation, and continued, perhaps increased, by fevered stomachs, which called for deep colored, sweet, and strong; in other words, for more elderberry, sugar, and alcohol.

Brandy in a small quantity will not stop the acetous fermentation in vinegar, for it becomes itself acetified, and makes the vinegar stronger. That one-seventeenth part alcohol should succeed in so doing, as some experimentalists aver, is met by other facts; for acetous fermentation is very easily produced in wine containing an eighth part of alcohol. It is still possible that alcohol added in a sufficient quantity may suspend or retard the fermentation, owing, perhaps, to its not mixing with the natural alcohol of the wine. Chemistry has not yet made this point clear; but it would seem that the general notion of vinous preservation through alcohol, unless in a ruinous quantity, as it is applied in port, sometimes to more than a fifth of its bulk, is very erroneous. The Editor has found port sold in some of the hotels with *thirty-five* per cent. of brandy!

The fact is, that the usage at first, from whatever cause, gave a desire for strong wine in England; and there was the advantage that the growths of bad and good years flung into large vats, and well mingled with brandy, gave a product of that middle-class wine artificially so made, which paid better than a little choice at a high price, and a good deal at a very low figure. It must be observed, too, that in most Northern countries, except France and those yet more to the South, there is a continued craving after alcoholic strength. This has been the case in all ages of the world. The Englishman has his wine medicated until spoiled with brandy; the Persians infuse poppies and similar things for the same end. There is ever a craving for increased stimulants, which, not found in the wine itself, must be added. The Greeks and Romans medicated

their wines, or rather perfumed them with various substances. The holy scriptures have left evidence of this, even in the earliest times of the Jews. The alcohol in wine placed there by nature seems to have its parts separated, and to be rendered comparatively innoxious compared to that added unnaturally; and, in the former case, will not readily intoxicate like alcohol mingled with water, milk, and similar liquids. The Jews had no knowledge of alcohol or the still, and endeavored to render their wines more stimulating by their deterioration, as is done at present another way. They had a general term for fermented liquids of all kinds—*shekhar*; but the words, *strong drink* or *mixed wine* are denounced, meaning wine with spices, and stimulating aromatic drugs. *Jahin* or *Yayin*—the *j* is pronounced as *t*—is the term for wine in general; *sobhe* is sometimes used figuratively for the same liquor, and *tirosk* for new wine. But *shekhar* means strong and medicated wine, of which honey was one ingredient, as well as spices and herbs. In the time of AUGUSTUS CÆSAR honey was mingled with his wine, and exposed to the sun, perhaps fermented in it; and as honey contains grape-sugar, it would necessarily strengthen the alcoholic principle, if there remained any gluten, for the emperor could drink no more than a pint of it at a time. Alcohol is formed by nature in every human stomach to a certain extent, according to an eminent chemist, and so far must be congenial to it. The reasonable use of natural wine is often highly advantageous. Discoveries in relation to the combination of alcohol with wine are yet to be made, but it remains certain that it is one of the vinous elementary constituents. Medical men will designate the difference between the effect of wine with its alcohol on the human economy, and the effect of alcohol combined with water. The ebriety produced by champagne in which carbonic gas and alcohol are combined, and that produced by pure claret or chambertin with port and madeira, are obvious to all who move in society where good wines are taken. The effects so lively and airy of the one, with the dull sedative state produced by the last, a blunted quiescent state not easily disturbed, but when disturbed not easily appeasable—indicate different effects from causes, no satisfactory definition of which has yet been obtained.

There has been much dispute regarding the alcoholic strength of wines. There is no reason whatever to dissent from BRANDE'S analysis of a considerable variety, made with great care, and there is little difficulty in making the test correctly enough; but the utility is only comparative, because the particular wine to which the test is applied must be taken for itself alone, according to the nature and produce of the grape for the year of the vintage, and not for a succession of years, nor for the same sorts generally; and the like holds good with all the constituent parts, and those slight traces of foreign substances, from differences of soil and plant, and little more, continually perceptible in wines. The same vines for two successive years will not bear fruit so exactly similar, as that some difference shall not be detected in the wine, and in the different proportions of its alcohol. The nature of the season in the same vineyard, and often under similar circumstances, will cause unaccountable changes. A warm year causes the

saccharine principle to be abundant, and, yielding more alcohol, gives a stronger wine, as is evidenced upon distillation. Nor is this natural effect more an impediment to classing wines by their alcoholic strength, than that of throwing in brandy, as in Portugal, during fermentation. By the wine being artificially brandied is prevented an accurate knowledge of its alcoholic strength, in the kind most commonly used in the British islands, as no two samples can be expected to show the same result. Thus it arose that the analysis of Dr. BRANDE was wrongfully censured, because it did not appear to be exactly what everybody supposed.

The Editor is of opinion that no port wine contains naturally more than fifteen per cent. of spirit—four or five per cent. are afterwards added to insure the wine keeping for years, in which time the artificial spirit becomes perfectly blended and mellowed in the wine.

The simplest method of ascertaining the amount of alcohol contained in wine is to distil the spirit from the wine, determining its specific gravity and quantity, and compare it with the quantity of wine taken; of course one of the first things to be considered, is how much wine to distil. The Editor takes generally one-third, and determines the alcoholic contents from it. If, for example, in the distillate thirty-three parts out of a hundred are composed of alcohol, the quantity of alcohol in the wine will be 11 per cent. for $\frac{33}{3} = 11$.

In the case of strong wines it is advisable to distil even more than a third, especially if a glass retort and water bath are used. Let the distillation be continued till at least half has passed over. If the density of the distillate is such as to yield twenty-five per cent. of alcohol, then $\frac{25}{2} = 12.5$ per cent. of alcohol.

In strong new wines, undecomposed sugar and vegetal extractive matter may cause the evolution of more alcohol during the insensible fermentation. It may be presumed, notwithstanding, that if the quantity of alcohol in any wine exceed twenty per cent. it has been added artificially. All bottled wines, which improve at all, become sweeter, and old wines always appear to have gained in sugar. A very generous wine of the Drôme, in France, will afford a third of its weight in the brandy of commerce; in the department of the Herault there will not be more than a fourth part; in the Côte d'Or about an eighth of what is called prime brandy; in the department of the Charente, a still, charged with two hundred and forty litres of wine, yields from twenty-four to twenty-six of spirit, or about a tenth of the volume of the wine, and a little more in quantity of the second-class spirit; in the department of the Gard, from the same quantity of wine, forty litres of prime spirit, and about the same quantity of the second class. From these products it is easy to approximate to correctness in regard to the amount of spirit in wine, and thus it is seen that one-third spirit is given in first and second brandy of the Gard, while there is often a third distillation, which is not included.

In France it is found necessary to accommodate the Northern palate, by adding ten per cent. to the wines supplied to that part of Europe.

A tale, that BRANDE had only tested adulterated

wines palmed off upon him for genuine, was as silly as spiteful. Dr. BRANDE took the wines as he found them in the hands of the merchant, in a state awaiting consumption; and no rival examination showed a greater difference than might be expected to exist on all similar trials. The reader must bear in mind that it is nearly half a century since Professor BRANDE analysed the wines referred to. The Editor has always considered the per centage of alcohol given in genuine port to be too high, and this seems to be corroborated by the fact that samples of port, vintages 1820—1834, *et cetera*, kindly forwarded to him by Messrs. CHILLINGWORTH for experimental purposes, never gave more than *eighteen per cent. of pure spirit*. The 1820 had a specific gravity of .9945, and the distillate .9740 = 18.01 of alcohol; and the 1834 had a density of 1.0163, and the distillate .9723 = 18.99 of alcohol. Extractive matter in 1820 was 5.140, and in the 1834, 5.976 per cent. There is too frequently a disposition prevalent to cavil at scientific men and their statements because they are novel, or do not chime in with preconceived notions. The nature of the combination of the natural alcohol with wines is not now understood, but its effects just noted are undeniable. This combination cannot be supposed to be any other than one of those secrets, the discovery of which science will one day lay open. Annexed are the results of BRANDE, PROUT, and others, as to the alcohol contained in the well-known wines in common usage.

PORTUGUESE WINES.	Alcohol in 100 parts.	Specific gravity.	Analyst.
Port,	25.83 ..	— ..	Brande.
Do.	24.89 ..	— ..	Do.
Do.	23.71 ..	— ..	Do.
Do.	23.39 ..	— ..	Do.
Do.	22.30 ..	— ..	Do.
Do.	21.40 ..	— ..	Do.
Do.	19.00 ..	— ..	Do.
Vinho de Ramo,	15.62 ..	— ..	Prout.
Do. average,	22.96 ..	— ..	Brande.
Do. average,	20.64 ..	0.9890 ..	Prout.
Do. weakest,	14.97 ..	— ..	Christison.
Do. strongest,	17.10 ..	— ..	Do.
Vinho de Ramo, mean of seven samples,	16.20 ..	— ..	Do.
White port,	14.97 ..	— ..	Do.
Colares,	19.75 ..	— ..	Brande.
Carcavellos,	19.20 ..	— ..	Do.
Do.	18.10 ..	— ..	Do.
Do. average,	18.65 ..	— ..	Do.
Lisbon,	18.94 ..	— ..	Do.
Do. dry,	16.14 ..	— ..	Christison.
Bucellas,	18.49 ..	— ..	Brande.
Vidonia,	19.25 ..	— ..	Do.
SPANISH.			
Sherry,	16.81 ..	— ..	Brande.
Do.	19.83 ..	— ..	Do.
Do.	18.79 ..	— ..	Do.
Do.	18.25 ..	— ..	Do.
Do.	21.34 ..	0.9752 ..	Do.
Do. average,	17.17 ..	— ..	Do.
Sherry, very old,	23.86 ..	— ..	Prout.
Do. weakest,	13.98 ..	— ..	Christison.
Do. strongest,	16.17 ..	— ..	Do.
Mean of thirteen kinds,	15.37 ..	— ..	Do.
Do. long kept and East Indian,	14.72 ..	— ..	Do.
Mean of Madre de Xeres,	16.90 ..	— ..	Do.
Amontillado,	12.63 ..	— ..	Do.
Tint,	13.30 ..	— ..	Brande.
Alba Flora,	17.26 ..	— ..	Do.
Malaga, 1663,	18.94 ..	— ..	Do.
Do.	17.26 ..	— ..	Do.

MADEIRA ISLANDS, ET CETERA.	Alcohol in 100 parts.	Specific gravity.	Analyst.
Madeira,	24.42 ..	— ..	Brande.
Do.	23.93 ..	— ..	Do.
Do.	19.24 ..	— ..	Do.
Do. average,	22.27 ..	— ..	Do.
Do. Sercial,	27.40 ..	— ..	Do.
Do. do.	15.45 ..	— ..	Christison.
East India, in cask,	16.90 ..	— ..	Do.
Do. weakest,	14.09 ..	— ..	Do.
West India, do.,	21.20 ..	0.9908 ..	Prout.
Red Madeira,	22.30 ..	— ..	Brande.
Do.	18.40 ..	— ..	Do.
Do. average,	20.51 ..	— ..	Do.
Malmsey,	16.40 ..	— ..	Do.
Do.	12.86 ..	— ..	Christison.
Teneriffe,	19.79 ..	— ..	Brande.

The analyses of BRANDE are calculated upon eighty-nine per cent. of alcohol and eleven of water; of CHRISTISON and ZIZ upon absolute alcohol.

FRENCH.	Alcohol in 100 parts.	Specific gravity.	Analyst.
Claret,	17.11 ..	— ..	Brande.
Do.	16.32 ..	— ..	Do.
Do.	14.08 ..	— ..	Do.
Do.	12.90 ..	— ..	Do.
Do. average,	15.10 ..	— ..	Do.
Do. first growth, 1811,	7.72 ..	— ..	Christison.
Do. Latour, 1825,	7.78 ..	— ..	Do.
Do. Rose,	7.61 ..	— ..	Do.
Do. ordinaire,	8.99 ..	— ..	Do.
Champagne, still,	13.80 ..	— ..	Brande.
Do. Mousseaux,	12.80 ..	— ..	Do.
Do. red,	12.56 ..	— ..	Do.
Do. pink,	11.30 ..	— ..	Do.
Do. average,	12.61 ..	— ..	Do.
Do.	12.10 ..	— ..	J. Fontenelle.
Do. Burgundy,	16.60 ..	— ..	Brande.
Do.	15.22 ..	— ..	Do.
Do.	14.53 ..	— ..	Do.
Do.	11.95 ..	— ..	Do.
Do. average,	14.57 ..	— ..	Do.
Do. 20 years in bottle,	12.16 ..	— ..	Prout.
Hermitage, white,	17.43 ..	— ..	Brande.
Do. red,	12.32 ..	— ..	Do.
Côte Roti,	12.32 ..	— ..	Do.
Roussillon,	19.06 ..	— ..	Do.
Do.	17.26 ..	— ..	Do.
Do. average,	18.13 ..	— ..	Do.
Sauterne,	14.22 ..	— ..	Do.
Nice,	14.63 ..	— ..	Do.
Barsac,	13.86 ..	— ..	Do.
Vin de Graves,	13.94 ..	— ..	Brande.
Do.	12.50 ..	— ..	Do.
Do. average,	12.08 ..	— ..	Do.
Grenache,	21.24 ..	1.053 ..	Prout.
Frontignan,	12.79 ..	— ..	Brande.
Rivesaltes,	9.31 ..	— ..	Christison.
Lunel,	15.52 ..	— ..	Brande.
Do.	18.01 ..	— ..	Fontenelle.

SICILIAN AND ITALIAN.

Marsala,	26.03 ..	— ..	Brande.
Do.	25.05 ..	— ..	Do.
Do. average,	25.09 ..	— ..	Do.
Do. 21 years old,	18.20 ..	— ..	Prout.
Lissa,	26.47 ..	— ..	Brande.
Do.	26.35 ..	— ..	Do.
Do. average,	25.41 ..	— ..	Do.
Do.	15.90 ..	0.9913 ..	Prout.
Lacryma,	19.70 ..	— ..	Brande.
Syracuse,	15.28 ..	— ..	Do.
Do.	30.00 ..	0.9911 ..	Prout.
Etna, red,	18.90 ..	— ..	Faraday.
Do. white,	18.16 ..	— ..	Do.
Do. Sinical,	19.00 ..	— ..	Do.
Do. white Falernian,	18.19 ..	— ..	Do.
Do. red,	20.00 ..	— ..	Do.
Aleatico,	16.20 ..	1.020 ..	Prout.

GERMAN.	Alcohol in 100 parts.	Specific gravity.	Analyst.
Hoeheimer,	14.37 ..	— ..	Brande.
Do.	13.0 ..	— ..	Do.
Do. old in cask,	8.88 ..	— ..	Do.
Do. average,	12.03 ..	— ..	Do.
Joannisberger, 1788, 9.38 } parts acid in 100 by weight,	8.71 ..	0.9978 ..	Prout.
Rüdesheimer, 1811, 6.22 } parts acid in 100 by weight,	10.72 ..	— ..	Do.
Do. 1800,	12.22 ..	0.9960 ..	Ziz.
Do. superior,	8.40 ..	— ..	Christison.
Do. inferior,	6.90 ..	— ..	Do.
Hambacher,	7.35 ..	— ..	Do.
Oestricher, 1801,	8.46 ..	0.9960 ..	Ziz.
Do. 1802,	10.50 ..	0.9890 ..	Do.
Do. 1804,	10.66 ..	0.9920 ..	Do.
Zornheimer, 1802,	10.11 ..	0.9790 ..	Do.
Do. 1803,	9.00 ..	0.9960 ..	Do.
Do. 1804,	8.75 ..	1.0310 ..	Do.
Bodenheimer, 1802,	13.96 ..	0.9890 ..	Do.
Rhenish, four years, under Soemmering's process, 10.58 parts acid by weight,	7.58 ..	0.9997 ..	Prout.
Do. natural state, 10.58 parts acid in 100,	7.36 ..	0.9992 ..	Do.
Do. three years under Soemmering's process, 8.4 parts acid in 100 by weight,	7.00 ..	0.9968 ..	Do.
Steinberger,	10.90 ..	1.0025 ..	Geiger.
Marcobrunner,	11.60 ..	0.9985 ..	Do.
Leibfrauenmilch,	10.60 ..	0.9939 ..	Do.
Geisenheimer,	12.60 ..	0.9945 ..	Do.

HUNGARIAN.

Tokay,	9.33 ..	1.054 ..	Brande.
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PERSIAN.

Shiraz,	15.52 ..	— ..	Do.
Do.	12.95 ..	— ..	Christison.
Do.	19.80 ..	0.9944 ..	Prout.

CAPE OF GOOD HOPE.

Cape Madeira,	22.94 ..	— ..	Brande.
Do.	20.50 ..	— ..	Do.
Do.	18.11 ..	— ..	Do.
Do. average,	29.51 ..	— ..	Do.
Cape Muscat,	18.25 ..	— ..	Do.
Constantia, white,	19.75 ..	— ..	Do.
Do. red,	18.92 ..	— ..	Do.
Do. do.	14.50 ..	1.081 ..	Prout.

REDDING has given an analysis in another form, as follows; but has not stated his authority:—

	Absolute Alcohol.	
	Ounces.	Drachms.
Port, in bottle of 26 oz., seven years in glass, ..	2	7
Do. 25½ oz. one year in bottle, two in wood, ..	2	6
Pale sherry, 25 oz., three years old,	2	4
Another specimen,	2	7
Madeira, 25½ oz., two years old,	2	5
Cape, 25 oz., one year old,	2	8
Old hock, 21 oz.,	1	0
Brandy, 24 oz.,	10	0
Rum, 24½ oz.,	9	8

MULDER, who has had great experience in the analyses of wines and spirits, states that alcohol varied as follows:—

	Per cent.	Per cent. by measure.
Port,	20.70	to 23.20
Sherry,	15.40	24.70
Madeira,	19.00	19.70
Marsala,	19.90	21.10
Claret,	9.10	11.10
Burgundy,	10.10	13.20
Rhine wine,	9.50	13.00
Moselle,	8.70	9.40
Champagne,	14.10	14.80
Brandy,	52.40	53.80

Eighteen per cent. alcohol by weight are equal to about twenty per cent. by volume.

The wines of Palestine, Syria, and Asia Minor vary much in alcoholic strength. Those analyzed by Professor HITCHCOCK of Amherst College, United States of America, contained from ten to eighteen per cent. of alcohol, or nearly as much as the European wines, except those of Oporto, Madeira, and Sicily, or the low wines of Spain that are brandied.

Of late years Australia has become rather prominent as a wine-producing country. The Editor's brother, Mr. FREDERIC MUSPRATT, who has resided there for some years, writes as follows:—

Wine has been made in Australia during the last thirty years, but has not been known in the towns till within the last ten years, owing to the great demand for it in the country. The vine flourishes more or less in all these latitudes, but the climate of New South Wales must be admitted to be the best adapted for wine-growing, and vineyards are established on the banks of the Hawkesbury, the Nepean, the Hunter, the Williams, and the Paterson, which are capable of being greatly augmented, to meet any demand there may be made for wine; and a rapidly increasing population will doubtless hasten their extension. The quantity of wine produced in 1857 was about three hundred thousand gallons.

The wines best known in Sydney and Melbourne are Irrawang, Tomago, Caewarra, Camden Park, Kinross, Kaludah, Porphyry, Tanilba, Wivenhoe, *et cetera*, and the *crû*—characteristic flavor—of the different varieties is as marked as is that of *Chateau Lafitte*, *Margaux*, or other European wines.

A Burgundy wine is best at Irrawang; a champagne at Kaludah and Caewarra; a medoc at Tomago, Kinross, and Tanilba; a hermitage at Porphyry; a muscat at Camden Park; and a Grâves at Tanilba.

The vineyards are principally worked by Germans, and the cellar-masters have learned their craft at Frankfort-on-the-Maine in Europe; so the local prejudice against colonial wine, manufactured formerly under the superintendence of squatters, who never had any experience in wine-making, is rapidly disappearing, the grape being richer in sugar than that grown on the Rhine-board. *The ordinary wine* of the country is considered generally to be superior to that of Germany. There has not been time to test, on a large scale, the capability of producing extremely fine wines, but, judging from the fact, that wine thirty years old is as rich in flavor and bouquet as wine the same age in Europe, there can be but little question as to the quality. At the Paris Exhibition of 1855, the jury, upon tasting a red wine, two years old, called it a *joli vin, beaucoup d'avenir*, and awarded it one of its highest numbers. All present expressed their surprise at the result of the examination, and highly approved of the wines. The foreman said they were perfectly astonished at the quality of the Australian wines, and were unanimous in giving them a place, for strength and flavor, between the wines of Madeira and those of the *Côte du Rhone*.

A Sydney trade-circular, in describing the wines at present in the market, says:—The wines of this colony are essentially Australian in general character. They

assimilate to the French and German wines. Some are considered by connoisseurs to resemble hock, Sauterne, claret, Burgundy, and the like, but no attempt is made to imitate these or any other wines. Of course, the vines are in great variety, but, from whatever description of grapes they are made, each vineyard has a peculiar local character, distinguishable by vinists. The Camden wines will first be noticed. These are of three sorts, namely—white, which resembles the Rhenish wine; red, which approaches Burgundy in taste; and muscat, rather like the Frontignac of the Cape, malmsey, or Madeira. Now for the Irrawang wines. The white is considered like hock or Sauterne; of the red there is at present no stock; and the sparkling Muratta is a very fair champagne. Next, the Wivenhoe wines will be referred to. These are—the white Muscat, resembling hock; red, corresponding in flavor with Rhenish wines; Madeira, which is of a Frontignac description; and Reissling. There are some wines grown at Oatlands, near Paramatta—the red resembles a claret, and the white corresponds with a light French wine. Under the head of Notes and Queries in the *Spectator*, is the following:—The samples of Australian wine at the Paris Exhibition have earned special commendation. When the horticulturists of that colony shall have succeeded in extending the cultivation of the vine over the land of the dreary *Encalyptus*, one may imagine that it is destined to the nurture of a British BACCHUS, and may look forward to the importation of Australian wines; and upon its arid soil, even upon the chasm of pools that its rivers present in the summer, would be exhibited the same miracle which is to be seen in the South of Europe, the juicy grape growing upon a parched soil, and for a season would be clothed with the loveliest foliage under the sun. Fancy the change of character that must come over the British stock habitually living in such scenes, under such a sun, with such a diet. It will be an experiment somewhat such as the world might have witnessed had the Saxon been planted in Italy. These queries are curious, as indicating the notions of the untravelled; but parties are daily getting more accurate knowledge as to the actual capabilities of the British Colonies.

The vineyards in the neighborhood of Adelaide, South Australia, are rapidly extending, and on the banks of the Murray and Murrumbidgee; the wines that are grown there will bear comparison with those of other lands. The only drawback to a rapid increase in the wines made in Australia lies in the dearthness of labor; but as all the farmers along the thousands of miles of river banks are all planting their small vineyards—which may be tended by their wives and children—and as merchants, who will buy the juice and await its ripening, are establishing themselves at convenient places, there is every prospect of the trade becoming greatly enlarged.

In the ripening of wines Australia possesses an advantage over Europe. As there is no winter there, so is there no check to the fermentation after the juice has been removed from the vats to the casks. This check to the fermentation in Europe is the cause of much wine *fouling*, and is the mother of many of the

so called *sicknesses in wines*. This is a source of great anxiety to many of the large European *vignerons*. On account of the hot winds in Australia, the vines are pruned low; and as this method, combined with a hot sun, causes more *must* to be in the grape than is usual in Europe, it is found that the fermenting juice will, as a rule, bear a large quantity of *stalk*; the consequence is, that the elements of bouquet are much more prominent than with wines of the same strength in Europe.

The foregoing remarks are well worthy of attention. Good and sound wines doubtless have been made in Australia; but the Editor is not so certain whether the English will ever admit any wine produced in the colonies to be equal in that beautiful aroma—which science has not yet been able positively to assert what it is—and flavor belonging to the first-class wines of Europe—Johannisberg, Sauterne, Rudesheimer, Liebfraumilch, *et cetera*.

In 1852, specimens furnished to Baron LIEBIG will explain the result of an attempt at wine-making in that colony. This wine, principally from the grape called the pineau noir and gris, carried a specific gravity of 0.992, and gave 16.20 per cent. of alcohol; 0.505 of free acid; 3.265 of dry residue; and 0.498 of incombustible ashy constituents. Another species of white wine grown at Irrawang had a specific gravity of 0.94; gave out thirteen per cent. of alcohol; 0.66 of free acid; 3.313 of dry residue, chiefly saccharine; and 0.563 per cent. of ashy constituents—proportions met with in some of the European wines, particularly the German. LIEBIG also analyzed other wines of Australia, and among them one obtained from the white muscat grape, which gave 19.53 per cent. of alcohol and 0.64 of free acid.

The wines of South America have not been analyzed. They are scarcely known in Europe. There is, however, a red wine made at Chili which is much liked by Frenchmen, and is considered a very fine *vin ordinaire*; instances being known of French men-of-war putting in to Chili and stocking their vessels with hogsheads of it.

The difference in the intoxicating effect of wine, and brandy and water, it has been asserted does not exist. Professor BECK, taking brandy at 53.39 of alcohol, calculated strong Madeira at 48.26; weaker Madeira, 36.14; port, average, 42.33; Bucellas, 35.21; sherry, 33.75; Sauterne, 24.34; claret, 21.38. He is of opinion that the difference between wine and brandy and water is more fanciful than real. New wine is more intoxicating than old, although the latter is more spirituous; and, according to SOEMMERING, loses of its aqueous parts by age. BRANDE, with good reason, supposes that when brandy and water are allowed a sufficient time for combination, the intoxicating power may not be more than that of wine containing an equivalent of brandy. Thus the effect of brandy and water arises from their imperfect union. On the other hand, it is certain, that the evil effects of the two, when taken in excess, upon the animal system are very different. Fine pale cognac—HENNESSY or RENAULT'S—with water, is often prescribed for invalids, and with great success. The Editor is of opinion that such a beverage taken constantly is less injurious than heavy, and especially drugged wines.

In some places in the North of Europe wine has been exposed to severe frost, under the idea of imparting strength to it, by drawing off the unfrozen portion. In the Augustan age, when the Euxine sea used to be frozen over, the wine in the casks, it is said, was cut with hatchets. Mr. PARKES experimented on wine exposed to 22° below the freezing point. He could discover no difference in taste between the fluid frozen and unfrozen, and thought the unfrozen the more rapid of the two. Of five hundred and sixty grains of port wine, five hundred and forty remained liquid; and of sherry two hundred and eighty-five grains were frozen, and one thousand and fifty-six remained in a fluid state—a result not in accordance with the experience of the colder wine countries of Europe.

The various matters discoverable in wine are not all found in the same growths. Less or more in some, and none at all in other kinds, with ever varying quantities, render analysis only good in relation to single specimens, and of no service in laying down a general rule for all. Thus water, sugar, alcohol, gum, extractive and nitrogenous matter, or albumen; the bitartrate of potassa, sulphate of potassa, chlorides of potassium and sodium, and in red wine coloring matter, and tannin from the stalks; carbonic acid in sparkling wine, and a perfume or bouquet, a species of ether—*enanthic*, *acetic*, *et cetera*—found in the fermentation, and citric acid—a mere trace of the latter—have been found in wine. Malic and gallic acid were thought at one time, with tartar and sugar, adding the gluten, to be almost the entire of the principles discoverable, and that all wines were the same in this respect; but science has undeceived the world upon this point. The amount of sugar in some sweet wines is full thirty per cent. according to PROUST. White wines are more perfect than red, and will endure longer; perhaps arising from the absence of the acid taken up by gypsum in the making, which cannot be used in red wines. The color of the red wines sometimes approaches to black from intensity. Indeed, a powerful wine in France carries the name of the Black wine of Cahors, generally used for strengthening weak-bodied or light-colored wines. Port wine of the vintage 1812, and that of 1820—CHILLINGWORTH—are nearly black, although upwards of forty years old. From pink to black in red exist, and from water to a deep golden hue in white wines, and even a green color in the wines of Cotnar. Amber and brown in different shades are to be met with, but no merit in regard to the quality of the wine attaches to the hue, however agreeable one more than another may be to the vision. Perhaps the clarets—so named from the French *clair*et, which, however, attaches to a different species—hold the middle place in regard to color, between the light red and black. The coloring matter in red wines may be obtained by an exposure of the bottle to the sun's rays, when it will fall in flakes; the taste of the wine remains unaltered. Before adding lime water the coloring matter is precipitated with the insoluble salt formed by the wine and acid of the wine in union. The finer wines are generally those in which the color is most attended to by the maker, and the rivalry in this respect is considerable. It is a matter in which preju-

dice operates. Many people cannot be persuaded that a pure red wine, of a light color, may be far superior as a wine in every good quality to one deeply colored, even when perhaps, as in port wine, it is aided by the elderberry.

When red wines lose color on the Continent they are said to be *rancio*, rusty; in England tawny. The coloring matter deepens on the deposit of tartar, and the tawny hue arises from age. Heat, too, will injure the color, which is thus not necessary to the flavor of the wine, being no way dependent upon it. Carbonate of potassa, sometimes formed in wine, injures both the color and flavor. It arises from the decomposition of the tartar, and in France is called the *tornure*. A little tartaric acid being added, the potassa forms cream of tartar, depositing crystals.

Wines grow darker as they ameliorate up to a certain point, but this is not uniformly the case. The alcohol in the wine, diminishing by evaporation, has no relation to this change; indeed, it is probable, that the aqueous portion evaporates rather than the spirituous. The specific gravity of wine increases under those circumstances. Many affirm that the alcohol in bottled wine increases by age; MULDER asserts that such a statement is thoroughly false, the formation of alcohol in the bottles being impossible. SOEMMERING discovered, that there were substances which permitted the aqueous portion of wine to escape more freely than the alcoholic. Equal parts of alcohol and water were placed in a glass vessel, and the mouth closed with a piece of bladder.—See ALCOHOL. It was observed, that under the circumstances more water was lost than alcohol, but when the temperature was raised to 62° it passed through the bladder unchanged. From this, and other experiments, SOEMMERING took the idea of ameliorating wine by exposing it to a similar process. He, in consequence, covered a glass vessel full of wine with a bladder, and suffered it to remain eighty-one days aside in a warm dry room. During that time one-half had evaporated, and the residue had acquired a more spirituous, mellow, and agreeable flavor. The color was deepened, a film had formed over the wine, and a deposit of crystals had taken place at the bottom of the glass. The proportion of alcohol had doubled from 4.0 to 8.0. A repetition of the experiment gave the same result, and thus a more rapid mode of ameliorating wine was discovered, than keeping it in wood, to effect the disengagement of the alcohol and water by time. Hence the transportation of wines to a tropical climate and home again, exposing the wine to aqueous evaporation, easily accounted for the beneficial effect, and the same with heat artificially applied. Wines thus exposed, too, deposit rapidly. Thus it is a common trick with port wine-mixers to place the bottles in water, carry it to the boiling point, and then, taking them out and placing them in the cellar, *the crust so admired by the ignorant in port wine is immediately formed*. It has been advanced, in consequence of the foregoing discovery, that the amelioration of wines in the wood is effected mainly by the disengagement of some of their water—the alcohol being retained, or a smaller proportion of alcohol than water being evaporated, the rest of the wine becomes more

concentrated—and that for this purpose vessels are most desirable which will retain the alcoholic and permit the aqueous particles to escape. Wine is observed to evaporate more rapidly in chestnut casks than in those of oak or similar close-grained timber. To such an extent is this evaporation carried in chestnut casks, that the French have prohibited the exportation of brandy in any but what are made of oak. Hence it may be conjectured, that the larger the surface of the liquor exposed the more rapid will be the evaporation; and that as the fermentation is quickened by the larger bulk in action, so it is with vinous amelioration. There is probably a limit here, which it would be very desirable to ascertain, but to which discovery no approximation has yet taken place. The Germans of late years, as they have discovered that, beyond the point of maturity in wine, the long keeping once thought of so much importance is not really of any great moment, seem also to have discovered that tuns of a moderate capacity are fully as advantageous as the gigantic vessels, by their fathers deemed of so much moment, for mellowing their Rhine wines.

Wine is continually sophisticated and adulterated, especially such as is of a coarse nature, having no obvious standard of taste. Of such wines port is, from the common usage, and the different flavors imparted to the wines of that name, the most abused. It is clear that a wine of any given species, if pure, will differ very little more in flavor in any season than the strength or weakness of the must will occasion. The main characteristics of the wine will be present. In a first-class Burgundy wine, for example, it will always be possible to distinguish that the wine is the growth of the country assigned, and no other wines will be drank in its place that are not of the same order. This would be the case with all sound good growths, and with the wines of Oporto as well, had they not been continually deprived of their natural character by mingling, coloring, and brandy adulteration. A house—IRELAND and Company of Bristol—was renowned for its excellent Bristol port wine, and a handsome fortune realized. All at once, on the breaking out of the French revolutionary war, Bristol ports were no longer to be had, and IRELAND and Company wound up their affairs, because they could no more obtain the wines of the South of France, for which they were celebrated as port-wine merchants, not a cask of their wines having ever been in Portugal. Now, such a deception could not be practised with Burgundy, champagne, or the finer wines of France.

The Editor has repeatedly had *English-made port* sent to him, but the imitation in no instance deceived him. The *taste* was sufficient to detect the imposition.

The mingling of inferior wines with superior, or with brandy, is not the sophistication for which the chemical professor is so much required to confer a boon upon the public, as in detecting extraneous substances of no vinous character at all. To brandy intermixed with wine, and which never blends with it as the natural alcohol of the wine does, are owing, in many cases, the liver complaints of the wine drinkers in England—a disease rare in wine countries.

The alcohol in wine may be ascertained by adding

one part of a concentrated solution of subacetate of lead to eight of wine by measurement. A precipitate is thus formed: agitate the mixture for a few minutes; pour the whole upon a filter; and then collect the fluid. This fluid consists of the spirit and water, with a portion of the lead. Now add by little and little *pure*, warm, dry subcarbonate of potassa—not the salt of tartar, and subcarbonate of potassa of commerce—which has been freed by heat from water. This must be done until the last portion remains undissolved. The spirit in the fluid being thus separated by the potassa abstracting all the water, the former will be found a stratum upon the salt. The experiment should be made in a glass tube, from half an inch to two inches in diameter, graduated into a hundred parts; and thus the quantity of spirit may be read off at sight.

To detect elderberry coloring in port and other red wines, acetate of lead is the simplest test. With pure red wine it throws down a greenish-grey precipitate. A deep blue precipitate is the result of elderberries, logwood, and bilberries. Brazil wood and red sanders are thrown down red. Lime water destroys the color imparted by beet.

WATSON in his chemical essays, as to his assertion that lead has been used in wine, is contradicted by the best French chemists, who have never been able to find a trace of its usage, and assert that it cannot be of any service. In England, among the fabricators and amenders of base wines, sugar of lead and litharge have been ignorantly applied for cleansing white wines rapidly, according to their own statements. Ignorance and vice generally travel abreast. Thus to keep wines from turning, some one of the vulgar receipts has proved a very harmless one—Put in fair water a pound of lead which has been melted; then into the cask, pretty warm, and stop it close! Oyster-shell lime has been used for the same purpose, an ounce to two gallons of the wine. Cochineal, to the extent of half an ounce dissolved in wine or brandy, is one means used to improve color; and for port wine the compound called *geropiga* made in Portugal, and imported into England openly, as a *liqueur* solely for sophisticating port wine. Port and claret are rendered rough by baking two quarts of sloes in a gentle oven, or over a slow fire, until their moisture is given out. The fruit is squeezed, and a pint of the liquid is applied to thirty or forty gallons of the wine.

Substances native, such as genuine must, wine, alcohol, or sirup—that is, boiled wine—can alone be tolerated in mixing. All besides is more or less a fraud. The object of mixing litharge, potassa, and tartrate of potassa, is to arrest bad flavor and temper sharpness in new wine. Some substances for color, sugar and honey to sweeten, spices to improve the flavor, and perry and water to increase the volume, are complained of in France. There is a commission there of able chemists, who examine samples of wine with great care. First, as to litharge—a poison—no one instance of its use has ever been detected. In 1824 a petition was presented to the French chamber of deputies, making such a charge against the wine merchants generally, that the public were alarmed, and an inquiry was instituted. The result was, that no single instance

of the employment of litharge could be substantiated—that, chemically speaking, litharge was a substance which, from experiment, contributed more to the deterioration than the preservation of the wine, and the merchants had no interest in its use. The petition was rejected as without foundation. In analyses of the wine for fifty-five years, the French council of health never met with the traces of such a substance in wine. They only stated that they had to complain, that too much water and often perry had been mingled to increase the volume of the wine. Sirup of dried raisins had been used with colored water, and fermented and sold to imitate the wines consumed in cabarets, but never any deleterious substances, under countless analyses. M. JULLEN experimented upon this substance in 1824. In a litre of musk in a state of acetous fermentation, one gramme and a half of powdered litharge was mingled and agitated several times for twenty-four hours, and then suffered to rest. The wine was tasted two days afterwards, and found as acid as at first, and unchanged in color. It was then filtered, and sulphuric acid being added, the white precipitate of the sulphate of lead was scarcely perceptible; but the sulphide of potassium, in another part of the liquid, caused a precipitate of the color of the lees of the wine. The result of four analyses was, that litharge did not deprive wine of its acidity, and contributed more to its decomposition than preservation; that in any considerable quantity it destroyed it, and that in a small quantity it remained in the wine in a state to be recognized with facility. If used in domestic wines, the same effect would follow. It was probable that the tartar of the wine had been mistaken for it. After all the scientific researches of foreigners into the nature of wine, they have not succeeded in detecting the quantity of perry, water, and not insalubrious ingredients, added by the dishonest dealer.

Frauds in blending wine, often too common, are not managed with substances foreign to the grape. The rinsings of brandy and rum casks, Cape wines, cider, coloring matter, and tartar, or anything which will form a basis with Benecarlos, Figueras, red Cape, mountain, tartar, gum-dragon, cider, for port; and for coloring it red sanders infused for fourteen days in spirit of wine. Port is also made with that wine, twelve gallons; spirit of wine, six; brandy, three; rough fine cider, forty-two. A strong decoction of Brazil wood and alum imitate the favorite crust. Sherry is imitated, but the low-priced wine mingled with Cape answers the end. The notion that lead helps bad wine is current in England. But little faith is to be placed in such reports, since it has not the effect ascribed to it. Sulphide of hydrogen gas will detect lead in wine, turning it deep brown or black. Alum, sometimes used for astringency, or for the purpose of brightening the color, or of clarifying newly made wine, may be detected by first decoloring the wine—if red—by means of animal charcoal, previously washed with hydrochloric acid, filtering, and evaporating the liquid to about one-third of its volume in a porcelain or platinum capsule, and refiltering. If a precipitate has been formed while concentrating; if potassa, soda, or

chloride of ammonium produces when poured into the filtrate, a white precipitate soluble with the aid of heat in excess of alkali; if carbonate of potassa or soda produces a white deposit; if nitrate of baryta or or chloride of barium produces also a white precipitate insoluble in acid, *alum is present*; or as NORMANDY further adds, a given portion of the wine may be evaporated to dryness and ignited, the residue treated with a little hydrochloric acid, evaporated to dryness and re-treated with dilute hydrochloric acid. If now the addition of caustic potassa produces a white gelatinous precipitate soluble in excess of alkali, but which is reprecipitated by chloride of ammonium, then alum is present.

Not to follow these deceptions further—the field it may be inferred is a wide one for the investigation of science, by researches into the defects of wine itself, and pointing out proper remedies—the inequality in must of the product of the grape, from so many causes, requires to be obviated; but no rule can yet be laid down by which existing evils can be certainly avoided. Among the curious facts in relation to pure wines are the character of their deposits, so varied in form and density, according to the growth of the vine and temperature of the year when the vintage occurred. Some are oily, others muddy, adhering to the side of the bottle; and some are very light, so that on the least movement they mingle with the wine. Oftentimes the same wines will make a deposit in two different forms in the same bottle, one adhering to the sides or uniting in a mass at the bottom of the wine, the other suspended in the liquor. One species of deposit resembles litharge, and no doubt caused the report of its usage. In champagne wine the deposit is called *depot-pierre*, a precipitate in the form of very fine sand, or little scaly crystals, which are the tartar naturally deposited. All wine residuums contain more or less of this substance, but it is often so enveloped in the oily or muddy parts of the precipitate that it is not apparent. It is heavier than other deposits, and when mingled with the wine does not communicate any bad taste, alters its clearness very little, and when shaking the liquor ceases it falls to the bottom. This deposit is found in the better wines, and those having it preserve their excellence a long time, and are less subject to disarrangements than the wines the residue of which floats in the liquid. In order to investigate the nature of this substance, it is dried and placed upon burning charcoal. In consuming it emits an odor of burnt tartar, and on keeping up the fire, leaves a white residue which is found to be potassa.

The choicest wines keep the longest in bottle, and deposit there so much that, in order to have the wine perfectly limpid, it is necessary to decant them with great care. It is useless to place them in different bottles for no other reason but to secure transparency, as they will soon begin to deposit anew. Unless they are to be removed to a distance, or there is a fear of their acquiring a bad taste, they should remain untouched. This operation, when necessary, is to be performed with great care. Small glass or tinned siphons have been tried for delicate French wines, but not with the desired success. Crape or gauze has its inconveniences. An

instrument called a *cannelle-aérifère*, invented by M. JULLIEN, is used for the purpose in France, as well as for chemical transfusions. For champagne more particularly it is well adapted. Wine is sometimes placed in demijohns, which hold from thirty to sixty bottles each, by which means it is well preserved; but the inconvenience of stirring up the deposit is in no way lessened on attempting to transfer their contents.

The disproportionate allowance of brandy thrown into wine is after all the great evil encountered in the wines destined for British consumption, and this is always to be detected by science. All wines of the highest class are deemed too weak and thin. The merchant imagines that it prevents acetous fermentation, and he knows that it blends all qualities into that which is most plentiful. Dr. McCULLOCH denied that it suspends acetification; Mr. CADET says, that if administered to the one-seventieth of the entire value it will do so. Alcohol is not separated by the action of heat, since it has been effected at 56°; but, however, this may be, wine to which brandy has been artificially added, affects the nervous system to a degree far greater than wine in the natural state, and chemistry has not yet been successful in discovering any theory which will account for it. The following tables show the importations of wine and the amount for home consumption for the years mentioned in the respective columns:—

TABLE OF WINE IMPORTATIONS.

Years.	Tuns. French.	Tuns. Portuguese.
1675	7,495	20
1676	9,645	83
1677	6,789	176
1678	7,212	199

French war—wine prohibited.

Years.	Tuns.	Tuns.
1679	3	1,013
1680	1	1,003
1681	..	1,718
1682	..	13,860
1683	..	16,772
1684	..	11,611
1685	..	12,885

French again admitted.

Years.	Tuns.	Tuns.
1686	12,760	286
1687	15,518	327
1688	14,218	448
1689	11,109	579

Here the French imports again interrupted. From 1697 inclusive, the returns were more exact and given in gallons, *videlicet*, together, French, Spanish, Portuguese, and Rhenish.

Years.	Tuns.	Hhds.	Galls.	Years.	Tuns.	Hhds.	Galls.
1697	13,086	3	43	1707	12,962	0	16
1698	12,974	2	15	1708	14,380	0	50
1699	21,553	3	25	1709	13,338	1	48
1700	23,502	0	10	1710	15,869	0	56
1701	21,443	2	23	1711	15,481	2	14
1702	15,725	1	62	1712	12,677	1	27
1703	11,092	2	42	1713	15,937	1	8
1704	13,811	1	57	1714	18,747	1	57
1705	12,070	1	17	1715	21,751	0	9
1706	10,973	2	31	1716	18,834	3	7

Years.	Tuns.	Hhds.	Galls.	Years.	Tuns.	Hhds.	Galls.
1717	22,260	3	58	1771	16,874	2	12
1718	23,875	1	48	1772	15,597	2	42
1719	20,510	2	13	1773	16,431	3	20
1720	19,141	0	44	1774	17,992	1	20
1721	25,263	0	45	1775	17,736	0	13
1722	25,470	0	42	1776	16,734	0	36
1723	22,415	1	1	1777	18,217	2	60
1724	23,075	3	8	1778	16,343	0	51
1725	24,722	3	35	1779	12,760	2	10
1726	19,334	0	24	1780	20,514	2	39
1727	21,064	3	61	1781	13,311	3	20
1728	30,045	2	32	1782	9,791	0	39
1729	25,672	3	50	1783	13,624	1	51
1730	19,823	3	31	1784	14,499	0	56
1731	24,239	1	58	1785	16,287	0	58½
1732	21,384	0	11	1786	16,242	3	53
1733	21,420	1	57	1787	23,324	3	33
1734	21,264	1	47	1788	25,560	3	52
1735	24,416	1	28	1789	26,299	2	60
1736	20,763	0	10	1790	29,144	3	13
1737	26,605	1	38	1791	33,155	1	33
1738	22,171	2	1	1792	35,525	3	51
1739	18,594	3	28	1793	22,788	3	40
1740	15,198	3	60	1794	30,259	2	2
1741	17,178	1	3	1795	35,608	3	54
1742	16,715	3	58	1796	23,693	1	37
1743	17,655	0	34	1797	15,904	2	30
1744	10,276	2	60	1798	23,287	3	49
1745	16,034	1	34	1799	33,419	3	7
1746	12,205	1	11	1800	32,332	1	26
1747	14,560	2	32	1801	38,893	1	21
1748	15,135	1	16	1802	30,407	0	53
1749	21,555	0	35	1803	37,913	1	62
1750	15,456	2	11	1804	19,419	3	2
1751	14,788	0	2	1805	33,463	0	55
1752	13,708	2	52	1806	35,910	0	55
1753	18,857	0	20	1807	39,789	3	29
1754	14,982	3	50	1808	47,143	3	49
1755	16,544	2	22	1809	49,762	3	17
1756	12,264	2	18	1810	47,058	3	25
1757	14,050	2	30	1811	20,787	1	4
1758	15,896	1	54	1812	35,082	1	17½
1759	15,405	2	19	1813	..	..	..
1760	15,427	3	47	1814	31,465	2	36
1761	14,602	3	46	1815	30,874	0	20½
1762	16,097	0	1	1816	18,218	0	57½
1763	17,082	3	21	1817	27,073	0	1½
1764	17,300	1	42	1818	35,763	2	9½
1765	18,132	1	4	1819	23,407	0	33½
1766	18,472	0	14	1820	22,781	1	55½
1767	17,087	3	5	1821	24,125	0	2½
1768	18,580	0	58	1822	27,454	2	25
1769	18,371	2	30				
1770	16,724	0	40				

The Methuen treaty to favor Portugal at the expense of France was signed in 1703—the duty on French wine to be one-third more than on that of Portugal. A tun of wine is two pipes, four hogsheads, or two hundred and fifty gallons old measure, or two hundred and thirty-one cubic inches. From the year 1785 the returns include all sorts and quantities of wine, however small. In 1813 the records were destroyed by fire at the Custom House.

About this time the returns were made in imperial gallons, the old measures being abolished.

Years.	Imperial Gallons.	Years.	Imperial Gallons.	Years.	Imperial Gallons.
1823	6,676,355	1835	9,039,551	1847	7,938,067
1824	6,637,506	1836	9,406,083	1848	7,536,730
1825	10,892,033	1837	8,033,480	1849	7,970,067
1826	7,586,937	1838	8,518,484	1850	9,304,312
1827	7,950,961	1839	9,909,056	1851	9,008,428
1828	9,637,951	1840	9,311,247	1852	6,793,304
1829	7,618,196	1841	7,708,502	1853	11,029,567
1830	6,879,588	1842	7,216,113	1854	10,875,855
1831	7,116,870	1843	6,807,053	1855	8,946,766
1832	6,018,480	1844	8,584,586	1856	9,474,694
1833	7,443,841	1845	9,469,776	1857	10,336,845
1834	9,766,116	1846	7,711,309	1858	5,791,656

TABLE OF WINE CONSUMPTION.

Wine consumption and proportion to population. Down to the year 1787 the importation and consumption were nearly equal.

Years.	Imperial Gallons.	Years.	Imperial Gallons.	Years.	Imperial Gallons.
1787	4,521,941	1811	5,629,722	1835	6,420,342
1788	6,650,644	1812	5,024,530	1836	6,809,212
1789	5,959,098	1813	4,565,477	1837	6,391,531
1790	6,601,038	1814	5,330,774	1838	6,990,271
1791	7,573,790	1815	4,624,105	1839	7,000,486
1792	7,851,707	1816	4,057,038	1840	6,553,922
1793	6,610,701	1817	5,142,829	1841	6,184,960
1794	6,811,374	1818	5,635,216	1842	4,815,222
1795	8,238,438	1819	4,615,212	1843	6,068,987
1796	5,776,260	1820	4,586,495	1844	6,838,684
1797	3,569,261	1821	4,686,885	1845	6,736,131
1798	5,265,768	1822	4,606,999	1846	6,740,316
1799	6,138,164	1823	4,845,060	1847	6,053,847
1800	7,294,752	1824	5,030,091	1848	6,136,547
1801	6,876,710	1825	8,009,542	1849	6,251,862
1802	7,113,416	1826	6,058,443	1850	6,437,222
1803	8,226,464	1827	6,826,361	1851	6,280,653
1804	5,457,691	1828	7,162,376	1852	6,346,061
1805	4,622,701	1829	6,217,652	1853	6,813,830
1806	5,825,178	1830	6,434,445	1854	6,775,858
1807	6,271,346	1831	6,212,264	1855	6,873,601
1808	6,331,875	1832	6,965,542	1856	7,367,874
1809	5,894,177	1833	6,207,770	1857	7,042,042
1810	6,521,293	1834	6,480,544	1858	6,697,146

The wine consumption, with a population of about eight or nine millions in 1787, augmented to nearly twenty millions of souls in 1851, showed little increase, in consequence of the duties on several classes of wines reaching fully to 500 per cent. That the means of purchase increased with the population, is shown by the augmented value of property assessed in 1803 = £115,351,952, and in 1843 = £181,322,202.—*James on the Wine Duties*, 1855. If, with eight or nine millions of souls, we consumed seven millions of imperial gallons, with twenty millions of population we should have consumed double that quantity, in place of no increase having taken place—spirit having been substituted.

	Imperial Gallons.	Population.
1787 to 1792	39,158,218	8,000,000
1793 to 1798	36,871,802	8,500,000
1799 to 1804	41,107,197	10,812,000
1805 to 1810	35,466,570	..
1811 to 1816	29,231,636	13,296,177
1817 to 1822	29,273,636	14,072,331
1823 to 1830 (8 years)	50,583,970	16,000,000
1831 to 1836	37,495,674	16,255,605
1837 to 1842	37,936,392	18,664,761
1843 to 1848	38,574,512	..
1849 to 1854	38,909,486	20,919,531

The consumption of wine was three and a half bottles per head from 1785 to 1794. It fell to three bottles from 1794 to 1814; and from 1814 to 1820 to two bottles. After that one and three-tenths bottle per head.

From 1786 to 1794 the Portuguese wine consumed in Great Britain, principally port, was 75·67 per cent., because there were only two-thirds of the duty paid upon the wines of Portugal that were paid on other wines. The duties were equalized in 1831, and from that time to 1854 the consumption of port diminished, until, in 1854, it was only 36·69 of the whole consumption. Spanish wines, only 16·67 in the first period, rose to 38·34 per cent.; French wines that were only 3·26 per cent., had risen in 1854 to 8·12.

Table of the proportions of different wines consumed in England, for which the Editor is indebted to Mr.

JAMES, author of the *Wine Duties considered Financially and Socially, et cetera*, 1855:—

TABLE OF PROPORTIONAL CONSUMPTION.

Years.	Colonial. Per cent.	Spanish Per cent.	Portuguese. Per cent.	French. Per cent.	Sicilian. Per cent.	Madeira. Per cent.
1849	3·87	39·16	42·36	5·03	7·11	1·14
1850	3·82	38·36	43·73	5·29	6·61	1·09
1851	3·74	40·33	40·02	7·12	6·28	1·10
1852	3·82	41·08	39·23	7·05	6·12	1·1
1853	3·92	39·58	38·87	7·79	7·55	1·02
1854	3·75	38·33	36·67	8·15	11·32	0·06
1855	3·95	40·42	35·16	7·99	10·82	0·05
1856	4·02	39·81	34·03	8·33	10·43	0·57
1857	6·05	39·43	32·72	8·83	10·62	0·05
1858	10·89	39·67	28·69	8·54	10·33	0·05

Proportion of White to Red Wines consumed.

Years.	White.	Red.
1854	52·065	47·935
1855	54·32	45·68
1856	54·31	45·69
1857	54·85	45·15
1858	59·21	40·79

Cape import at half duty.

Cape consumption.

Imperial Gallons.	Imperial Gallons.
361,605	261,564
492,087	352,330
787,753	456,214
654,118	726,314

DECREASE IN IMPORTATION, 1858, COMPARED WITH THE PREVIOUS YEAR.

Total.	Pipes.	Decrease. Pipes.
French imports	1,742	504
Portuguese imports	14,240	3,332
Spanish imports	20,078	1,114
Sicilian imports	1,900	114
Madeira and Canary	192	52
From Holland	79	32
Other places	2,339	401
British Possessions	1,427	..
Total	41,997	5,549
		2,950 { Colonial increase at half-duty deducted.
		2,599 Decrease.
		58 { Decrease mixed in bond.
Total	2,657 Pipes decreased.	

The Cape wines at half duty increased in ten years, from 3·87 to 10·89. Spanish were stationary, or with a small increase. Portuguese decreased from 42·36 to 28·69. Other wines, except Madeira, increased.

In the monetary provisions of the government for 1860, the duties were reduced upon all wines of all countries and of our own colonies from five shillings and sixpence and five per cent., to take place on January 1, 1861, on wines of the lowest alcoholic strength, or not above 18°. These to be admitted at one shilling per gallon. The wines above this alcoholic strength at two shillings, or wines "approaching 40° of proof spirit. This reduction to commence at first by a fall of duty to three shillings per gallon, from the existing five shillings and sixpence $\frac{2}{20}$.

The grocers' home made wines, free of duty, aided to supersede foreign wines in consumption, and thus injured the exchange of goods with the foreigner;

these wines or compounds having been sold at little more than the duty only on foreign wines.

The average product of wine in France is nine hundred millions of gallons; and in Paris two hundred and sixteen bottles per head are annually consumed; in Hamburg twenty-nine per head. The following table is the most authentic extant, and there is reason to think much within the real limit of the produce of the wines of Europe:—

	Gallons.
France	900,000,000
Hungary and Austria	500,000,000
Spain	220,000,000
Italy	195,000,000
German States, Prussia, Luxemburg, &c.	45,000,000
Portugal—total product	10,500,000
Sicily	3,000,000
The Azores	575,000
The Canaries	1,875,000
Cape of Good Hope 14,000 leagues } of 60 gallons	840,000
Cyprus, Commandery, Muscadines, &c.	30,000
Servia, Wallachia, &c.	170,000
Total	1,876,990,000

Greece produces four millions six hundred and forty thousand oke; Asia Minor, Syria, Palestine, Persia, and the East produce wine, as well as some parts of Southern Russia.

The following tables, from *Redding on Wines*, contain a selection out of a number of the fine growths, of the names and character of the wines produced in the principal countries in Europe. To extend the list would be useless. In France alone, there are six classes of red wine, seven of white, and five of *vins de liqueur*. There are four hundred and sixty-three red wines, two hundred and forty-three white, and nine *de liqueur*. The champagne wines alone reckon six degrees in quality:—

WINES OF THE FIRST CLASS.

FRANCE, SPAIN, HUNGARY, GERMANY, SICILY, NAPLES, AND CAPE OF GOOD HOPE.

Wines.	Country.	Place.	Character.
Romanée Conti.....	France	Côte d'Or	The first and most delicate red wines in the world, full of rich perfume, of exquisite bouquet and fine purple color; light, yet with body and spirit sufficient to render them pleasant and healthful in use.
Chambertin.....	"	"	
Richebourg.....	"	"	
Clos Vougeot.....	"	"	
Romanée St. Vivant.....	"	"	
La Tache.....	"	"	
St. Georges.....	"	"	
Corton.....	"	"	Burgundies, closely resembling the above growths in aroma, and all their other qualities.
First growths of Prémaux...	"	"	
Musigny.....	"	"	
Clos du Tart.....	"	"	
St. Jean.....	"	"	
Perrière.....	"	"	
Veroilles.....	"	"	
Morgeot.....	"	"	White, highly esteemed.
Mont Racht.....	"	"	
Lafitte.....	"	Gironde	Fine color and perfume, light, less warm than Burgundy, with a taste of the violet, and a rich purple hue.
Latour.....	"	"	
Château Margaux.....	"	"	Wines of the Rhône, darker in color than the preceding. Red Hermitage the most noted of these, of good body, and a fine flavor of the raspberry.
Haut Brion.....	"	"	
Beaume.....	"	La Drôme	
Muret.....	"	"	
Bessas, Burges, Landes.....	"	"	
Méal and Gréneux.....	"	"	
Racoule, Guionière.....	"	"	
Sillery.....	"	Marne	White, still, dry; of an amber color; generally iced for drinking.
Ay.....	"	"	
Mareuil.....	"	"	Fine effervescing wine, bright in color, slightly frothing.
Hautvilliers.....	"	"	
Piery.....	"	"	The best of the white wines of Champagne, being all of the first quality, but differing a little in color and effervescence.
Dizy.....	"	"	
Eprenay—Closet.....	"	"	Fine white wines of excellent quality, lightish brown in color, aroma most agreeable, and some of rather sweet taste.
St. Bris.....	"	Gironde	
Carbonnieux.....	"	"	
Pontac.....	"	"	
Sauterne.....	"	"	
Barsac.....	"	"	
Preignac and Beaumes.....	"	"	
Château Grillet.....	"	La Loire	Description resembles the preceding.
Hermitage.....	"	Rhône	
Rivesaltes.....	"	Pyrénées Orientales	Full of body, spirit, and perfume. The white is the finest of all white wines.
Colmar, Olwiller, Kaiserberg.....	"	Haut Rhin	
Kientzheim, Ammerschwir.....	"	"	A rich muscadine.
Hermitage de Paille.....	"	"	
Amontillado Sherry.....	Spain	Rhône	Straw wines, rich and luscious.
Schloss Johannisberger.....	Germany	Andalusia	
Lacryma Christi.....	Naples	The Rhine	A dry delicate wine.
Syracuse.....	Sicily	Naples	
Tokay Essence, and its first growths, called Tarzal, Szeghi, Zadany, Tolesva, also Erdo-Benye, Zambor, Tallya, Mada.....	Hungary	Syracuse	Ditto.
		County of Zemplin	
Cotnar.....	Moldavia	Cotnar	A fine, luscious, sweet red wine.
The Commandery.....	Cyprus	Com. D.	
Constantia.....	Africa	Cape of Good Hope	Remarkably fine red muscat.
Lagrimas.....	Spain	Malaga	

SECOND CLASS.—FRENCH.

Wines.	Place.	Character.
Verzy, Verzenay, Mailly, St. Basle, Bouzy, St. Thierry.....	Marne	Red wines of Champagne.
Vosne, Nuits, Chambolle, Volnay, Pomard, Beaune, Morey, Savigny, Meursault.....	Côte d'Or	
Olivotes, Pitoy, Perrière, Préaux .. Chainette, Migrenne.....	Yonne	Excellent red Burgundies, very little inferior to first growths.
	"	
		Good wines.

SECOND CLASS.—FRENCH.—(Continued.)

Wines.	Place.	Character.
Moulin à Vent, Torins, Chénas.....	{ Saone et Loire, Rhône Rhône }	Red.
Hermitage, second growths.....	"	Red.
Côte Rôtie.....	"	Red.
Rozan, Gorze, Léoville, Larose, Branne-Mouton, Pichon-Longue- ville, Calon.....	Gironde	Red.
Côteau Brûlé.....	Vaucluse	Red.
Jurançon, Gan.....	Basses Pyrénées	Red.
Roussillon, Bagnols, Cosperon, Col- lioure, Torémila, Terrats, Mas- deu.....	Pyrénées Orientales	Red.
Cramants, Avize, Oger, Menil.....	Marne	White Champagne wines, of good quality.
La Perrière, Combotte, Goutted d'Or, Genevrière, Charmes et Meursalt }	Côte d'Or	White Burgundies, of high repute in France.
Guebwillers, Turkeim, Wolxheim, Molsheim, and Rangen, in Belfort }	Haut Rhin Bas Rhin	Dry, white, and <i>vins de paille</i> , of good repute.
Arbois, Pupillin, Château Chalons..	Jura	Good wine, <i>mousseux</i> and still.
Coudrieu.....	Rhône	{ A white wine, which keeps long, of fine <i>sève</i> and perfume.
Langon, Cerons, Podensac.....	Gironde	White wines, capable of endurance.
Montbazillac, Teaulet, Raulis, }	Dordogne	Good white wines of the country.
Suma, Sancé.....	Lot et Garonne	Generous white wines, of good body.
Buzet, Amazon, Vianne.....	Ardèche	{ Delicate <i>mousseux</i> and <i>non mousseux</i> , of agree- able flavor.
St. Peray, St. Jean.....	Basses Pyrénées	White, with an agreeable perfume of the truffle.
Jurançon.....	Herault	Sweet, rich, and luscious; white.
Frontignan and Lunel Mazet.....	Pyrénées Orientales	Red, styled <i>de Grenache</i> , rich and sweet.
Bagnols, Collioure, Rodez.....	"	Sweet, <i>vins de liqueur</i> .
Maccabeo of Salces.....		

THIRD CLASS.—FRENCH.

Wines.	Place.	Character.
Hautvilliers, Mareuil, Dizy, Pierry, }	Marne	{ Red Champagne wines of the second quality; light and agreeable.
Epernay, Taisy, Ludes, Chigny, Villiers-Allerand, Cumières.... }	Aube	Resembling the preceding.
Ricey, Avirey, Baguex la Posse....	Côte d'Or	Good Burgundies of the third quality.
Gevrey, Chassagne, Aloxe.	Yonne	Ditto.
Savigny sous Beaune, Blagny, }	Saone et Loire	Ditto.
Santenay, Chénôve.....	Puy de Dome	Not wines of note; red.
Clarion, Bonvin.....		{ Resembling red Hermitage; a little less full and fine, might be called Hermitage of the third quality.
Fleury, Romanèche.	Drome	Red wines, very middling of the class.
Chapelle Guinchay.....	Isère	Resembling Cote Rotie.
Chantergues, Montjuset.....	Rhone	{ Pouillac, St. Estephe, good light red wines; Castelneau mediocre; the other growths agreeable.
Crozes, Mercuroil, Gervant.....	Gironde.	Resembling St. Emilion; keeping well.
Seyssuel, Revantin.....	Dordogne	Red; light colored, with a harsh taste.
Verinay.....	Landes	{ Red wines, grown on the banks of the Rhone; will not keep good more than six years.
Pouillac, Margaux, Pessac, St. }	Gard	Good red wines; keep well.
Estephe, St. Julien, Castelneau de Medoc, Cantenac, Talence, }	Vaucluse	Champagne; light and agreeable, white.
Merignac, Canon.....	Aube	Tolerable wine; not exported.
Farcies, Terrasse, Campreal.....	Côte d'Or	{ In considerable esteem in Paris as wines of the table. They are all white.
Cape Breton, Soustons.....	Yonne	Much the same as the preceding.
Chuzelan, Tavel, St. Genies, Virac. }	Saone et Loire	White.
Ledenon, St. Laurent des Arbres }	Jura	White; of middling quality.
Chateaufneuf.....	Gironde	White; consumed in the country.
Riceys.....	Loire	{ Second growths of those famous and rich white wines.
Rougeot de Meursalt.....	Herault	Rich luscious sweet wines, prepared in the department of Herault, and very little ex- ported; also muscadines.
Vauvillan, Grises, Valmure, Grenouille, Vaudesir, Bourger- eau, Mont de Milieu et Chablis. }	"	Rich sweet wines, boiled wines, and malmseys, of good quality.
Pouilly and Fuissé.....	Bouches du Rhone	
Etoile, Quintignil.....		
Pujois, Ilats, Landiras, Virelade }		
St. Croix du Mont, Loupiac.... }		
St. Michel sous Condrieu.....		
Frontignan and Lunel.....		
Vins de Picardan of Marseillan and Pommerols. Vins de Ca- labria, de Malaga.....		
Roquevaire, Cassis, Ciotat. Vins Cnits.....		

SECOND AND THIRD CLASSES.—GERMAN.

RHINE AND MOSELLE.

Wines.	Place.	Character.
Johannisberger	Johannisberg	{ Grown near the Schloss Johannisberger, in the list of first growths already given. A very fine growth.
Steinberger	Rheingau	
Rüdesheimer { Berg	Rheingau, six leagues from Mayence, facing Bingen; on the hill and slope behind the houses.	Lighter than Johannisberger; fine bouquet. A highly prized wine.
{ Hinterhäuser		
Laubenheimer	Mayence district	Lighter than Johannisberger, but delicate.
Kösterich	"	Ditto.
Niersteiner	"	A good wine, with fine flavor and body.
Oestricher	Worms	Ditto.
Liebfrauenmilch	The Rhine	Hence the word hoch. The first growth is the prime hoch wine of the importer. Light, agreeable—12·08, average of spirit. Some kinds, when new, contain as much as 14·37, according to BRANDE.
Zornheimer		Choice wine, of fine flavor.
Hochheimer	{ Spire, on the } { River Mayn }	Light, agreeable, good bouquet.
Graefenberger	Rheingau	An excellent wine.
Gaubischeimer	{ Near Mayence, } { the palatinate }	Ditto.
Deidesheimer	"	An excellent wine, light and delicate.
Oppenheimer	"	Ditto.
Bodenheimer	"	Of first quality.
Nackenheim	"	Ditto.
Braunberger	{ Moselle, Treves } { district }	Ditto.
Scharzberger	"	Ditto.
Graach	"	Ditto.
Zettingen	"	Ditto.
Wehlen	"	Ditto.
Piesport	"	Ditto.
Montagne Vert	"	Second quality.
Causel and Valdrach	"	Moselle, noted for diuretic qualities.
Rinsport	{ Moselle, Witlich } { canton }	Secondary Moselle.
Bacharach	Near Mayence	Wine once in high repute.
Becherbach	Becherbach canton	Secondary Moselle.
Walporzheimer	Upon the Ahr	Called wine of the Ahr.
Rutz	On the Moselle	Considered one of the Moselle wines.
Steeg	Near Bacharach	A light Rhine wine.
Montzingen	"	Inferior light Rhine wine.
Bodendorf	Near Bonn	A secondary wine.
Affenbourg Hamen	Near Coblenz	Ditto, a Rhine wine.
Strang	Near Neider Breisig	Ditto.
Elzenburger	"	Ditto.
Alzenburger	"	Ditto.
Lutz	Near Treiss	Ditto.
Maas and Huhn	Niedar Heimbach	Ditto.
Stugerboeg	Rhine	Ditto.
Engelhohe	On the Nahe	Called wine of the Nahe; secondary wines.
Neiderborg	"	Ditto.
Leinenborn	"	Ditto.
Bangert	"	Ditto.
Rosenhech	"	Ditto.
Rensberger	Tarbach	Secondary Moselle.
Wurzgarten	Tarben	Ditto.
Amfuhr	{ Burg, left bank } { of the Rhine }	Ditto.
Rothenberger	Geisenheim	Soft, delicate, prime wine.
Scharlach	Mt. Scharlachberg	Fine flavored; rich aroma.
Roth	{ Near Hochheim, } { Spire district }	Hoch of good quality.
Königsbach	"	Ditto.
Weinheim	"	Ditto.
Forst	"	Ditto.
Ungstein	"	Ditto.
Schierstein and Narden	Wishaden	Tolerable wines.
Epstein	Near Frankfort	Middling wines.
Phillipsech	"	Ditto.
Reichenberger and Wildenstein	Erbach	Inferior Rhine wine in quality.
Fënerbach and Laufen	{ Near Fribourg, } { at Badenweiler }	These are considered the best wines of Baden.
Heidelberger and Kleingenberger ..	Baden	Good wines of the country.
Richenau Island	Lake of Constance	Ditto.

SECOND AND THIRD CLASSES.—GERMAN.—(Continued.)

RHINE AND MOSELLE.

Wines.	Place.	Character.
Meresberg and Überlingen.....	Near the Lake	Good wines of the country.
Cretzingen.....	Baden	Ditto.
Berghausen and Stellingen	"	Ditto.
Beringfield and Zeil.....	Bavaria	} Inferior wine.
Lindau and Ravensburg.....	"	
Schweinfurt.....	"	} Excellent wine, Rhenish character.
Liest.....	Württemberg	
Stein.....	"	Ditto, of a very dear price.
La Harpe.....	"	Inferior, but often sold for Stein.
Escherndorf and Schalsberg.....	"	Inferior to Stein.
Bischofsheim.....	{ Near Hanau, } Frankfort	A tolerable wine, resembling Rhenish.
Calmus.....	{ Trieffenstein, } near	} A <i>vin de liqueur</i> .
Guben.....	Aschaffenburg }	
Meissen.....	Saxony	Very poor wines.
Franconia.....	Franconia	A <i>vin de paille</i> ; aromatic.
Assmannshäuser.....	{ Rheingau, near } Rüdesheim }	{ Equal to the second class of Burgundy; excellent body.
Bessingheimer.....	{ Lauffen, } Württemberg }	{ Well tasted, good bouquet; called wine of the Neckar.
Altenahr.....	{ Rhine country, } left bank }	Inferior wines.
Mayschof.....	"	Ditto.
Rech.....	"	Ditto.
Ahrweiler.....	"	Ditto.
Bruch.....	"	Ditto.
Creutzberger.....	"	Ditto.
Hoënnungen.....	"	Ditto.
Kesseling.....	"	Ditto.
Dernau.....	"	Ditto.
Blischert.....	Lintz	A tolerably good wine.
Neuwied Blischert.....	Hesse Darmstadt	Ditto.
Wangen.....	Bavaria	Poor, though esteemed in the country.
Naumbourg.....	Saxony	{ Like fourth class Burgundy; styled <i>vins agrelés</i> .
The wine of Blood, Sang des Suisses	Bale	{ A good wine, called also the Hospital and Cemetery of St. James.
Erlach.....	Berne	} Remarkable for durability.
Valteline.....	{ Made in the } Valteline }	
Boudry and Cortaillods.....	Neufchâtel	Equal to third class Burgundy.
Cully.....	{ Near Lausanne, } and Vevay }	Like Rhenish.
Désalés.....	{ Between } Lausanne and }	} Dry wines.
La Cote.....	Coppet	
Bernang.....	St. Gall	} Tolerable of the country.
Frangy and Monnetier.....	Geneva	
La Marque.....	Martigny	{ Red and white, and muscadine of tolerable quality.
Coquempin.....	Grisons	
Chiavenna.....		Aromatic, white, from red grapes.

SECOND AND THIRD CLASSES.

PORTUGUESE.

Wines.	Place.	Character.
Carcavellos, or Lisbon.....	{ Between Oëiras } and Carcavellos }	Sweetish, white, well known in England.
Bucellas.....	Near Lisbon	{ A fiery wine, from brandy being mixed with it; something like Barsac when pure.
Vinho de Termos.....	Estremadura	
Setuval.....	"	A light ordinary wine of the country.
Lamego.....	Near Coimbra	Two kinds, dry and muscadine; both good.
Alenquer, Monção.....	Estremadura	An inferior kind of Bordeaux.
Santorin.....	Near Lisbon	As the former, but somewhat better in quality.
Barra a Barra.....	Near Lavadrio	An ordinary wine.
Colares.....	Near Cintra	A good wine.
Pezo da Regoa, Abasas, Villarinho } des Freires, Gorvaens, Alvacoës, } do Corgo, Hormida, Guials, Con- } velinhas, Galafura, Lavradrio... }	Mostly on the Douro	{ Port wines of the Douro, of the first and second qualities, denominated Feitoria and Ramo.

SECOND AND THIRD CLASSES.

ITALIAN AND SICILIAN.

Wines.	Place.	Character.
Lacryma Christi	Naples, Mt. Vesuvius	Red rich muscadine, of a fine flavor and perfume.
Syracuse	Sicily	Luscious red muscadine.
Reggio	Naples	Resembling Burgundy.
Baia	"	Ordinary wine.
Mascoli	Sicily, Mt. Etna	{ The best red wines in the island, of excellent body, like the secondary Rhone growths; rare in the island.
Mascoli Sciarra		
Mascoli Macchia		
Mascoli San Giovanni		
Catania	"	Pitchy taste, ordinary <i>wines</i> .
Tormina and Faro	"	Tolerably good.
Ovièto	Roman States	Excellent durable red wines.
Asti	Piedmont	Ditto.
Bianillo and Aleatico	Elba	Good wine of the second class.
Bischillato	"	A durable wine, exports well.
Procanico	"	A <i>mousseux</i> wine.
Chianti	Tuscany	A good wine.
Aleatico	"	{ Resembling the Tinto of Alicante in flavor and bouquet.
Carmignano, Antella, Artimino, } Tizzana, Mentali, Lamporecchio, } Monte Spertoli, Poncina, Glogoli }	"	Good wines of the country.
Val di Marini	"	Ditto.
Naples muscadine	{ Mt. Vesuvius } Lake Averno } Maria de Capona }	A delicate fine colored wine.
Vino Greco	"	An excellent muscadine.
Carigliano	Naples	Muscadine, flavor of fennel.
Bari and Tarento	"	Muscadine and common.
Reggio	"	<i>Vin de liqueur</i> .
Baia	"	Good ordinary wine.
Gierace	Near Reggio	Between light French wine and <i>vin cuit</i> .
Asprino	Campagna	A <i>vin de mousseux</i> .
Fundi	Kingdom of Naples	Good ordinary wine.
Val di Mazara { Mazara } Veterano } Corigliani } Termini } Girgenti }	Sicily	Of tolerable quality.
Messina, Milazzo, Avola, Vittoria ..	"	Ditto.
Lipari and Stromboli	Lipari Isles	Ordinary wines, and superior muscadine.
Imola	Near Bologna	<i>Vin cuit</i> and <i>mousseux</i> .
Terni	Near Spoleto	Good wines.
Farnese	Near Castri	Good muscadine.
Ovièto (white)	Roman States	Muscadine, not durable.
Monte Fiascone	{ Near the Lago } Bolsena }	{ A strong muscadine, finely perfumed and flavored; of great strength.
Albano	Roman States	Ditto, excellent.
Moscatoello	"	{ <i>Vins de liqueur</i> , of greater or less merit; not bearing exportation.
Aleatico		
Vino Santo		
Vernaccia		
Riccia	"	Good wine, but a small quantity made.
Buti	Plain of Pisa	Weak wine.
Monte Pulciano	Tuscany	The most esteemed of the Tuscan muscadines.
Montalcino, Rimeneze, Pont-Ecole } and Santo Stephano }	"	Good muscadines.
Vermut	Elba	A cordial wine, prepared with wormwood, &c.
Rio	"	Good muscadine.
Vino Morto	The Veronese	Deficient in spirit and strength.
Vino Santo	"	Good red and white wines.
Bellagio	Lake of Como	Wines of color and spirit.
Labusca	Mantua	An agreeable wine.
Pavia	Pavia	Both dry and <i>mousseux</i> , but very inferior wines.
Monte di Brianza	Milan	Good flavored wines.
Panocchia, Vigalto, Traversetolo, } Casola, Avola, Azano }	Parma	Ordinary wines of the country.
Val Irdone, Bottola, Ponté d'Al- lolio, Verdetto, Sala del Christo } Creta }	Placentia	Ditto.
Santo Pretasso, Frescale, Caselle, } Lassurascio, Rugarlo, Castellina, } Salso, Maggiore, Villa-Chiara, } Claretto, Pazole }	District of Borgo Placentia	{ Inferior wines, some of them <i>vins de liqueur</i> , having a disagreeable taste of honey.
Ratrera and Sapolo	Modena	Ordinary wine, for home consumption.
Vin Piccolit	Friuli	Resembling Tokay.

SECOND AND THIRD CLASSES.
HUNGARIAN, AUSTRIAN, AND SCLAVONIAN.

Wines.	Place	Character.
Tokay, Essence, and Ausbruch....	{ Near Mt. Tokay, Hungary }	See wines of first class.
Tokay, Maslas.....	"	A secondary Tokay.
Gyängyäsch.....	{ Mount Matra, Upper Hungary }	Wines, both red and white, much esteemed.
Ödenbourg.....	Lower Hungary	Ditto.
Meneser.....	District of Arad	Red, much esteemed for spirit and sweetness.
Meneser-Ausbruch.....	"	{ Like Tokay, preferred by some; rich, aromatic, sweet, not cloying.
Erlon.....	Upper Hungary	Good red and white wines, and an Ausbruch.
Rusth.....	Lower Hungary	Similar to Ödenbourg.
St. Gyorgy.....	Near Presburg	{ A white wine of excellent quality, somewhat in aroma like Tokay.
Ofen.....	Near Pesth	Good wine of the country.
Carlowitz.....	{ On the Danube, in Slavonia }	Resembles Cote Rotie.
Buda.....	{ Near the ancient capital }	Like Burgundy.
Sexard.....	{ Between Buda and Esseh }	{ Resembles Languedoc, a good red wine of the country.
Gros Warden.....	{ Near Transylvania, the fortress }	Ditto.
Schiller.....	In Sirmian	Strong and sweet, of a red color.
Wermuth { Palunia.....	"	Wines prepared with spices and wormwood.
Troptwermuth.....	"	Scarcely different from Meneser.
Glodova, Menos, Gyordk, Paulis...	Menes	Excellent wine, resembling Burgundy.
Modeon.....	Near Presburg	Ditto.
Katschdorf, Grunau, Obernusdorf...	"	
Neustoad, Zschelhæ, Kosrad.....	Near Buda	
Wersitz.....	In the Bannat	{ Wines like Burgundy and Bordeaux.
Jobbagy, Etsey, Sætvesch.....	Bannat of Tameswar	Good red wine.
Weisskirchen.....	"	Ditto.
Zips, Arva, Liplow.....	Croatia	White wine.
Buokwetz.....	"	Ditto; same quality.
Vinitza, Toeplitz.....	Transylvania	Wine of the country, Ausbruch.
Birthalman.....	Sebenico, Dalmatia	A wine highly characterized; not the <i>liqueur</i> .
Marachina.....	Moldavia	Green in color, and strong as brandy.
Cotnar.....	Wallachia	Light, rivalling Tokay.
Piatra.....	Ragusa	Good country wine.
Gravosa.....	Slavonia	Good red wine.
Semlin.....	"	{ Both red, and of agreeable flavor, and much spirit.
Syrmia and Posega.....	"	Red wines, which will not keep.
Podskalchi.....	{ Circle of Lentmeritz, Bohemia }	Ditto, like Burgundy.
Melnick.....	Circle of Bunzlow	Good wines, equal to Hungarian.
Poleschowitz.....	Moravia	Ordinary wine.
Mount Calenberg.....	Austria	
Hoefflein, Kloster Newbourg, Unter Kutzendorf, Kaplenburg, Misdorf, Salnendorf, and Lichtenstein.....	"	{ Wines of little note, generally of a green hue, and drank young.
Giberwein.....	{ Southerly, near Vienna }	{ A wine that will keep, though of no extraordinary quality.
Spitz.....	"	Good wine.
Luttenberg.....	Lower Styria	Good wines, red and white.
Radskersbourg, Arnfels, Windisch, Gonowitz, Kerchenberg.....	"	Of the next rank to the foregoing.
Sansal, Leitschach, Pickerne, Stadlberg, Pulsgau, Sauritsch, Raen, Rast, Peittersberg, Wiesel.....	"	Good wines of the country.
Moettling, Weinitz.....	Carinthia	Resembling good Italian wines.
Freyenthurn, Wipach, Tsche.....	"	Ditto.
Proseco Antignana, St. Serf Trieste	Istria	Red and white, sparkling and well flavored.
Berchetz.....	An Adriatic island	Red wine, deep colored and sweet.
St. Patronio, Petit Tokai, St. Thomas, &c.....	{ At Capod'Istria, Pirano, and Cittanova }	Good <i>vins de liqueur</i> .
Corregliano.....	Istria	A good wine, consumed at Venice.
Izeszgard.....	In the Tolna district	A superior red wine.

SECOND AND THIRD CLASSES.—SPANISH.

Wines.	Place.	Character.
Val de Peñas	New Castile	Good body, deeper than Bordeaux in color.
Manzanares	Manzanares	An inferior Val de Peñas.
Ciudad Real	New Castile	A tolerable red wine.
Albacete	"	Ditto.
Vino Tinto, Alicant	Valentia	Yellowish red color, when old called Fondellol.
Mataro	Catalonia	Good bodied and generous.
Torre, Beni Carlos, Santo Domingo, } Segorbe, Perales, Vineroz..... }	Valentia	{ Wines of good body, some of the most esteemed red growths of the country; color deep.
Hospital	Arragon	{ Excellent flavor and body, from the Garnacho grape.
Carignena	"	A vino tinto from the same fruit.
Tinto Olivencia	Estremadura	Excellent red wine, the best in Spain.
Tinto di Rota, or Tintilla	Andalusia	A sweet reddish cordial wine.
Ribidavia	Gallicia	An ordinary red wine.
Chacoli	Biscay	A very harsh austere wine.
Guindre	Malaga	Dark, flavored with cherries.
Tinto di Malaga	"	Seldom exported, a good wine.
Aleyor	{ Minorca, near } Mount Taurus }	A red wine, consumed on the island.
Palma	Majorca	A full-bodied wine.
Cordova	Andalusia	
Mirando de Ebro	Old Castile	{ Good red wines of the country.
Carbezon	Valladolid	
Terra del Campo	Old Castile	
Velez Malaga	Malaga	A luscious sweet wine.
Malaga	"	A luscious sweet wine, with a burnt taste.
Pedro Ximenes	"	A luscious sweet wine, fine and delicate.
Malaga Xeres	"	Resembling sherry, dry.
Xeres vino seco, pale and brown....	Xeres de la Frontera	Pale and brown sherry.
Abocado	"	A second growth sherry.
Huesca	"	A yellowish-white wine.
Paxarete	{ Frontera and } St. Lucar }	A sweet wine, of light amber color.
Moguer	Niebla, Andalusia	{ Used to lower the sherries at Xeres, of which it is an inferior species.
Negro Rancio	Rota	A sweet wine, of a yellow color.
Montilla	Cordova	A dry wine, of good bouquet and flavor.
Borja	{ Arragon and } Tarragona }	A luscious wine.
San Lucar di Barameda	Andalusia	A light red muscadine.
Manzanilla	"	Dry white, of inferior quality; a <i>vin du pays</i> .
Zalonge and Carlon	"	Ditto.
Yepes	New Castile	A well-flavored wine.
Fuenceral	"	A <i>vin de liqueur</i> .
Sitges and the Priory	Catalonia	Malmseys of two qualities.
Peralta and Tudela	Navarre	{ White dessert wines. Peralta is a Rancio when aged.
Pollentia	Majorca	A <i>vin de liqueur</i> .
Alba Flora	Minorca	A dry kind of Rhenish.
Vidonia	The Canaries	A wine resembling Madeira, of inferior quality.
Verdona	"	A green wine, not now made.
Palma	"	A rich Malmsey, having a taste of the pine apple.

MADEIRA AND THE AZORES.

Wines.	Place.	Character.
Malvasia, or Malmsey	Madeira	Rich and sweet.
Madeira	"	A durable, dry wine.
Sercial	"	Ditto, of excellent quality.
Muscatel	"	Not exported; a good wine.
Tinto	"	{ A red wine, changing in twenty years to rich old Madeira in color.
Figaa do Pereiro	"	{ Of inferior kind to the above.
Santo Antonio	"	
Vino Passado	Pico, in the Azores	A species of Malmsey, of light quality; keeps ill.
Vino Seco	"	A dry wine, light, not durable.

DOMESTIC WINES.—The grape ripens too seldom in England to be applied with advantage to the making of wine. The warmth of September is not sufficient to mature the grape; though up to some time in August, and generally to the end of that month, the vine may progress favorably. There are many fruits, however,

from which very palatable household wines can be made, and from which dull wines are continually manufactured, when those more lively can be introduced from the produce of the orchards, gardens, and fields of England. The mode of making these wines is generally not well understood; if it were, the wines would be much more palatable. Yeast, resorted to for the purpose of fermentation, often imparts a nauseous after-taste to the wine, which would ferment well enough in the natural way. There is nothing unwholesome in these wines, if properly made; and to this end the wine of the grape, and its mode of management, should be clearly comprehended, that its principles may be made applicable to domestic wine manufacture. The malic acid in the wines of English fruit often causes a trifling inconvenience to the *primæ viæ*, which acid may easily be exterminated in making the wine. The wine of the grape should be the model after which all wine of the garden-growth should be fermented—general principles should be first mastered. Suppose the gooseberry be taken as the fruit, it contains centesimally:—

	Unripe.	Ripe.
Green coloring matter,.....	0.03	—
Sugar,	0.52	6.24
Gum,	1.36	0.78
Albumen,	1.07	0.87
Malic acid,	1.80	2.41
Citric acid,	0.12	0.30
Lime,	0.24	0.29
Lignin, with seeds,	8.45	8.01
Water,	86.41	81.10
	100.00	100.00

The above are all the requisites for making wine, and some that are to be dispensed with; a deficiency in tartar is often noticed, but this can be supplied artificially. The excess of malic acid, on the other hand, is injurious; but as in making white wines in the South of Spain, this acid is got rid of by sprinkling powdered gypsum over the grapes, which takes it up, the same means should be adopted when making domestic wines in England.

Sugar is the first constituent in wine-making, and as it does not abound in some garden-fruits in England, it must be added. Cane-sugar, it has been seen, differs from grape-sugar in its proportional parts, but it is converted into grape-sugar by the process of fermentation. It is a sugar which goes slower into fermentation than that of the grape, and the alcohol in the wine always bears a proportion to the pre-existent sugar. This sugar uniformly contains a portion of a vegetal extractive matter, unless it is separated from it by art. The natural sugar of some plants also contains, some more, others less, of this sweet vegetal matter. If there is much of it in the sugar, the wine will be dry and perfect, because all the sugar will have been changed into alcohol. The mucilage, or vegetal extractive matter, like the gluten of wheat or albumen, contains azote, the gas of which has been noticed in grape wine making. This matter, found too in yeast, thus acts in exciting fermentation. Most garden fruits possess it; and it is this sweet principle combined with that in sugar, which operates the conversion with other wine, as with the grape. Water is another constituent. As to

the other substances, except tartar, they rather concern the curious in chemistry than the maker of family wines, for some can only be detected by the close scrutiny of the experienced chemist. Little color can be communicated to any of our domestic wines, if the elderberry, currant, blackberry, and black cherry be excepted; but this is a matter of little moment in that which should rather be adopted to please the palate than the eye. If astringency or roughness be in request, that loss may be innocently supplied by the application of catechu. The damson and sloe alone possess it naturally.

The substances necessary to vinous fermentation, the sugar and its sweet principle, the natural vegetal extract, the tartaric acid—in place of which latter the malic acid is often found, which should be dispensed with, and tartar added artificially—and water; these in certain preparations, and in their differences, are the essentials in this class of wines. Sugar is the most important, and its decomposition gives out the alcohol, on which the strength of the wine depends; therefore its quality is of great importance. When the sweet principle and sugar—for they are in union—have disappeared in fermentation, and there is no more vegetal extractive matter belonging to the fruit in the liquid, the wine is a dry wine, and is in its perfect state. If the sugar be in excess, the result is wine and sugar; vulgarly, a sweet wine. If the vegetal extract be in excess, and the fermentation too prolonged, acetic acid will be the product.

The want of attention to the foregoing points often renders the making of dry wines a failure. No yeast should ever be used. If the vegetal extractive matter be wanting, the lees of other wine may be tried; but this is seldom needful, with due care. During fermentation the leaven or ferment is insoluble, and rises to the surface, or falls to the bottom. On restoring this to the surface, the fermentation may be prolonged at pleasure, until the necessary dryness be gained. To attain a sweet wine, the fermentation should be stayed by separating the wine from the ferment, and fining it with isinglass or white of egg. Thus the ferment is separated, and the operation suspended; it may be renewed by restoring the separated matter; if not, a sweet wine remains. It cannot run into acetous fermentation if its leaven be expended; but still there is hazard, and some care necessary, in thus renewing the operation.

Of these acids, sometimes found in fruits—the tartaric, malic, and oxalic—only the first two have any share in the fermentation. Tartar abounds in the grape, and to that its superiority is ascribed. It is wanting in our domestic fruits, or very scantily bestowed. Malic acid is predominant in apples and pears, and they give liquors very different from wine. Crude tartar is best added to the must for domestic wines, not the purified salt.

Care should be taken not to carry on fermentation in new wooden vessels, nor to place wine in them without due preparation. The vegetal extract in the wood will infallibly set the fluid in fermentation, as is well known to the French wine-grower.

The end of the fermentation is the production of the alcohol; and the chemical action involved is well

understood, although the primary force of the ferment is not, nor can it be, so well comprehended. In this respect Nature eludes the efforts of the chemist and physiologist to define correctly her workings, or submit a true definition of the affinities which are continually set in motion by natural force. As regards fermentation, it is true that only the salient points of the chemical changes are understood, but they are sufficient to govern the industry of the fermentation of liquids of every kind, provided all that chemistry has revealed be known to the operator. In domestic wines no just rule has been regarded. Most of the directions are based upon false principles, and display extraordinary ignorance, according to Dr. McCULLOCH, who has written so well upon the subject; and if not clear to the family makers of such wines, and too scientific for the common concoctors of them, his work still is not the less worthy because the stolid do not perceive its merits.

BRANDE made analyses of the strength of some of the domestic wines, which are appended. The alcoholic strength was per cent. at eighty-nine alcohol and eleven water.

Wines.	Per cent.	Wines.	Per cent.
Grape,	18.11	Orange,	11.26
Raisin,	26.40	Elder,	8.79
Do.	25.27	Mead,	7.32
Do.	23.20	Cider,	9.87
Do. average, ..	25.12	Do.	5.21
Currant,	20.55	Do. average, ..	7.54
Gooseberry, ..	11.84	Perry, average, ..	7.26

Before going into the practical part of the subject, the warning against the use of yeast must be repeated. It is a vile substance when in contact with anything vinous, imparting a base flavor, and is to be altogether shunned. The regulation of the temperature, too, is to be sedulously regarded, that the fermentative process may not proceed too rapidly. The bulk of the must to be fermented, and its exact quality must be well considered; the addition of flavoring substances, and finally, the proper vessels adopted for the different operations.

The fruits most commonly employed for making domestic wines are the elderberry, cherry, raspberry, sloe, damson, quince, strawberry, mulberry, gooseberry, lemon, orange, and two or three kinds of currants. Of these several do not retain their flavor, and are to be rejected on that account. The flavor of the strawberry is not communicated to the wine, nor of the quince or raspberry. These might be infused to advantage nearly at the close of the fermentation of some tasteless must, and thus their flavor be sustained in the wine. The blackberry and mulberry should, as in the instance of grape-wine, be allowed to go into fermentation, skins and all, for the sake of the color. The damson and sloe make a good rough wine, but care must be taken to proportion the sugar to the fruit as to quantity, and by protracting the fermentation, to make a dry wine. By a due admixture of elderberries or currants with sloes and damsons, wines like inferior ports are often easily produced. The proportions vary according to the season. The elderberry may be made to yield an excellent red wine. It possesses enough of the extractive principle to impart a very rich tint, and even a

fine deep color. Tartar should be introduced into the must; and, besides, this berry requires much sugar, as the saccharine principle is scanty.

The gooseberry is known as giving a species of champagne to the list of domestic wines, which are made to effervesce; but, in order to answer, the gooseberries are used in an unripe state. The effervescing property always results from the use of unripe fruit, and will be readily produced by mixing ripe and unripe grapes together; and it is the same with the gooseberry. In general the flavor is bad, and to avoid it, as it is imparted by the ripe fruit, the more unripe should be prepared. This wine should be made with the expressed juice of the fruit alone, and nothing else should be fermented, the skins not being suffered in the must. By this means any disagreeable or peculiar taste is avoided, and the wine, if nearly tasteless, is brisk, pleasant, and perfectly free from any bad flavor. To make this wine, three pounds of sugar, and four of fruit, are allowed to eight pounds of water. Five pounds of fruit would be better, to avoid sweetness, though in complete fermentation; the wine would then be amply strong. No brandy should be added to effervescing wines. Care should be taken in bottling, and the same attention bestowed upon genuine champagne should be bestowed on this imitation wine, which will readily repay the extra trouble. This wine arrives at perfection only in the cellar. Wine made from ripe gooseberries is good for little; but if attempted, the skins must be carefully excluded.

In such wines too little fruit in proportion is used. In currant wines the fruit is always stinted, there being sufficient extractive matter and natural acid to insure, if rightly arranged, a very perfect fermentation. These wines are made too sweet, and pall upon the palate. The proportion adopted is in all cases to be increased as regards the fruit, and the skins to be excluded from the must. The recipes, so manifold, handed about for domestic wines, continually show that the true principles of making such wines are not recognized, although laid down so lucidly by Dr. McCULLOCH. British champagne is directed to be made by crushing the fruit with a mallet, and a gallon of fruit is to be put to a gallon of water; then brandy is added, and sugar of the species often to be avoided; and brandy is added again in bottling. McCULLOCH recommends boiling the fruit, in some cases, previous to fermentation. The black currant acquires, by boiling, an agreeable flavor. The success of the plan is remarkable; the more so as, in its natural state and unboiled, it is harsh. The wine made from it much resembles sweet Cape wine. The same improvement takes place in regard to the red and white currant. The boiling should not be protracted. It is always best to boil about a third of the quantity used, and to apply the rest in the natural state. The boiling must not be continued too long, because it tends to precipitate the ferment.

The dried raisin is largely used in making domestic wines; and it naturally must be analogous in some respect to certain foreign wines, because for making them the grapes are not used until they are shrivelled in the sun. Thick, sweet grape-wines are made this way. The process adopted in making raisin-wine in

England has not shown any approach, with the same materials, to the wines made of dry raisins, or such as are called *straw wines*, or some of those of Malaga. In the mode actually adopted here, whether for domestic use, or for the deceptive objects of wine-dealers to mingle with foreign wines, from two to seven pounds of raisins are employed to a gallon of water, common clayed sugar or molasses from half a pound to three or four pounds, and oftentimes from four to six pounds of tartar in the crude state are added. Yeast is not used; still the wine is never well-tasted, and to obviate that, as the bad taste may arise from the skins, cold water is used. It is necessary to apportion the sugar to the tartar. From two to four per cent. of crude tartar is a sufficient addition, giving more when the fruit is sweetest. In regard to the sugar, two pounds to the gallon of the other ingredients will produce a light wine like the white wine of Bordeaux. Three pounds will give the body of hermitage, and four that of Muscat or of Cape Madeira, before their respective doses of brandy were added to them. The sugar added must be apportioned to the quantity in the fruit. If the wine is to be a sweet wine, not less than four pounds to the gallon must be used. The water added must not be out of all proportion to the fruit—which last rarely forms a fourth of the entire fluid—and four pounds to eight of water, and three or four of sugar, supposing no regard is had to the state of the fruit in respect to its ripeness. The vegetal extractive matter in such a case is deficient, as well as the native acid, and this acts injuriously upon the fermentation, and renders it inefficient; the must, consisting of an overplus of sugar and water, cannot thus form wine. Let the principle wanted be increased, and the wine will put on the true character—the dilution of the acid, if the fruit be ripe; and if it be unripe, then the acid and extract being in excess, the operation must fail of fulfilling expectation.

Flavor may be easily imparted to all those wines which want it. Elderflowers, mignonette, clove pinks, for example—or sweet briar, wormwood, ginger, cloves, orris, and the like—will impart, either of them, or perhaps some in combination, a flavor agreeable to the taste of the maker. They are suspended in a bag from the bung-hole during the first stage of fermentation. To please the eye, elderberries, or mulberries, will supply color, or what the French call *vin de fismes*—a color liquor, made near Rheims of a small bitter cherry used for the same purpose, a few drops being sufficient to color a bottle. In Holland, tounsel is used for the same purpose—the *crotum tinctorium* of Linnaeus. It is naturally of a blue color, but on coming into contact with an acid it immediately takes a red hue. In France it is said that color derived from woods, as Brazil or logwood, do not long resist the acid of the wines; and, therefore, they find it better to darken the light hue of wines by mingling deep-colored wine with them. This, however, need not deter from the use of such means to suit the eye in domestic wines of English fruit. Bitterness may be obtained by the use of burnt sugar, as well as yellow tints. Cognac brandy for the English market is thus colored in France, where the people use the pale spirit.

All vinous operations require great care and sound

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judgment. In fining home-made wines, the same management is necessary as in treating the grape-juice with a similar object. The imitation wines made in the household must first be considered in regard to the model immediately in view. If the object be a sweet wine, of which the fermentation is incomplete from the want of sugar in the must, or if its suspension be by design as before described, the operation to be followed is clear.

If the wine be designed to sparkle or effervesce, the cause and mode of acting has been shown; and that briskness is not much in accordance with sweetness. Though generally made of the gooseberry, any other fruit in a proper state of immaturity will answer as well. The use of carbonate of potassa or soda must be avoided, because the gas is almost all disengaged in the first glass on pouring out, before the wine can be drunk, nor has it anything like the effect of carbonic acid gas in the wine. It also deteriorates the taste, and destroys the native acid, replacing it with an alkali.

The Rhenish wines have never been successfully imitated, and for the paramount reason, that their constituent parts are so accurately balanced that they would require great judgment, and much care, in the process; the fermentation must be perfect, and exact proportions be carefully kept in the ingredients. Even then their preservation would require great attention. Fining, racking, and sulphuring, must be had recourse to by hands often not adepts in their use. The dry wines of some strength, imitative of Sherry and Madeira, may be made strong enough without the addition of brandy, which, however, may be added to them by the operator, if he sees it requisite.

Dr. M'CULLOCH recommended that wine should be made from grapes grown in England. The grapes may not ripen in some years, and in an agricultural view it is profitless; but wine is continually made by cottagers in Sussex from the grapes grown in front of their houses, and some species ripen a full month before others. The white muscadine, the two varieties of the chasselas, the black Hamburg, and others, are of this class. But to make domestic wine from the grape in England, does not demand that the grape should reach the maturity required for its wines, as the term is generally understood. A crop of grapes is certain, if not always a ripe crop. A compound artificial must can be made from the admixture of sugar with the extractive and other matter of the fruit, which, undergoing a regular fermentation, forms a perfect wine, as applicable to the grape as the gooseberry. The experiment has been tried and found successful, and domestic wines made this way declared excellent. Three pounds, or less, of sugar to the gallon, with the hardest grapes, produce a wine of the strength of red hermitage, not void of flavor, but the reverse. Dr. M'CULLOCH mentions the proportions he found needful, both of sugar, water, and other substances necessary for the purpose. He kept some of the wines twenty years, and found them as little liable to destruction as the wines of France.

The want of judgment, the haste, the non-comprehension of the chemical principles upon which wine is made from domestic fruits, the want sometimes of a clean palate on the part of the maker, and the aban-

donment of a nice operation to the hands of servants and old housewives, have caused great mistakes in the manipulation of these wines. Dry wines of the first quality do not require that maturity of the grape which is so necessary to those which are sweet. In the first case sugar can be added; but the customary notion of the ignorant in this, as in other cases, often prevails, and the neglect of the green grape for the green gooseberry is a striking proof of it. Nor is this all; for it has been proved by chemical examination, that the tendrils, shoots, and even the leaves of the vine themselves, possess exactly the same qualities as the crude fruit. Experiments were in consequence instituted in France, to try if they would not answer for the purpose, and they were satisfactory; but there, where the fruit was to be had in any state, the matter naturally terminated; while in England it was different. The success of the attempt was decisive, on adopting the management had recourse to in treating wine from other unripe fruit. Only young or half-green vine leaves are selected, together with the tendrils. The old leaves are not proper. The month of June is the right season to pluck them. The vines for the purpose may be planted anywhere, and suffered to run up unpruned. Close imitations of the sparkling wines of Champagne and of St. Peray have been made this way, and none were made that were not as good as the ordinary sweet wines of the Cape. If the wine is too sweet from want of the vegetable extract in a sufficient quantity, a fresh infusion will reinstate the fermentation. The wine of a defective year in goodness, may be renewed the next season. The leaves should be infused sometime before they are used, yielding their virtues more readily to hot than cold water without any material difference in the result. Half a pound of crude tartar, or more, within a pound, to two gallons of must, is useful. The expense of the sugar here is nearly the whole incurred, and a single vine will supply a family, as the leaves are successive.

A few specific directions under the scientific authority before mentioned:—The cask measure being supposed ten gallons, will illustrate the foregoing principles; those adapted to the lands of the vine being kept in view as guides, where any difficulty may occur. In a tub or vat carefully cleaned, that has a capacity for fifteen or twenty gallons, forty pounds of the gooseberry of the green Bath kind are introduced, avoiding any that are ripe. Reject the unsound, and remove the blossom and fruit-stalk, or their remains. The small berries may be separated by a sieve. The fruit is to be bruised into the vat by a pressure sufficient to break the skins, without fracturing the seeds or compressing it too much. Four gallons of water are then poured in upon the fruit, and the whole is carefully stirred and compressed with the hand, until the juice and pulp are separated from the solid matter. The materials must rest for ten or twenty-four hours, and then be strained through a coarse bag with as much force as can be easily applied. A gallon of fresh water is to be added to the mash, to remove any soluble matter remaining. From twenty-five to thirty pounds of white sugar are to be dissolved in the must

or juice thus obtained, and the mass of fluid increased by more water to ten gallons and a-half. This difference in the weight of the sugar is to balance any in the quality of the fruit, the discovery of which difference must depend upon the judgment of the operator. Old haphazard receipts gave forty pounds of sugar, which of course make a sweet wine, continually failing in effervescence on that account. The must is next to be placed in a tub or vat, over which a blanket is thrown, and a board over that, and the whole kept in a temperature between 55° and 60°, to remain from twelve to twenty-four hours, according to the state of the fermentative process. It is then to be drawn off into a cask until the fluid nearly reaches the bung-hole, so that the scum which ascends to the surface may overflow, and be thrown out. As the fermentation goes on, and the bulk of the liquid diminishes in the cask, the superfluous must made for that purpose must be poured in, so as to keep the liquid always near the bung-hole. When the fermentation diminishes still more, which may be judged of by the reduction of the hissing sound, the bung is driven in, and a hole bored on one side of it, into which a wooden peg is put, and in a day or two taken out, in order that the gas within may have vent. It is then restored and reopened to let the gas again escape, until, there being no longer any danger from the expansion, it is tightened for good. The wine is to be kept over the next winter season, in a cool cellar, and on a clear sharp day about the beginning of March, if fine, it is bottled; if not fine, or to insure its fineness, if doubted, at the end of December it is decanted into a fresh clean cask, to free it from the lees, which, if the wine be too sweet, instead of drawing it off, should then be stirred up in it, increasing the temperature to renew the fermentation. When drawn off, it is fined with isinglass; and if not clear, the operation is repeated in dry, clear, cold weather as before, and bottled in March, and not later. Such a wine is brisk like champagne, and similar in quality, but stronger, differing in little but the flavor. Sometimes the wine will be still, like sillery, or sweet, without close attention to the process; at other times it will be dry. If sweet and still, it may be remanufactured the next season by renewing the fermentation, and repeating, under the addition of fresh juice or must, the former treatment. If it be dry, it remains so, and may be drawn off into a sulphured cask, and then fined and bottled. Any peculiar and not agreeable taste, during the first year, will go off by age. Such wines are best when drunk at five or six years old. In making the foregoing wine, the mode in managing grape-wine—fermenting the husks or skins as well as the juice with the sugar—may, on the other hand, be adopted in the earlier stage of the operation. The rapidity of the fermentation in this way is much increased; the wine, stronger and less sweet, will gain more flavor. Crude tartar, to the extent of six ounces to the ten gallons, is sometimes added. Sweetness with briskness, though the latter quality is hazarded, may be had by using sugar to a greater extent under forty pounds. Brisk domestic wines are not durable nor strong, and must be drank very early from want of the capacity for keeping. Effervescence without sweetness

is obtained by increasing the fruit, as in the proportion of fifty pounds of fruit to thirty of sugar.

The wine made from unripe currants, under the same general process as the former, requires that the stalks be separated with care. The must of this fruit is much easier to manage than that of the gooseberry, and it is far better calculated for brisk wine, and less likely to carry a bad flavor.

Nothing but the pure must is introduced into the cask—not a particle of the mash. If, in the fermenting in the vat, the scum, crest, or head, called the *chapeau* by the French, be tainted with sourness or mustiness, it must be at once removed; and when the fermentation of the mash does not take place with the must, the latter may be at once introduced into the cask.

Mature gooseberries and currants are made to produce dry and sweet wines by the foregoing modes. In sweet wines the fruit should not be above forty pounds; if in dry, it should be carried to sixty. The sugar should be full thirty pounds, unless a strong wine is desired, when forty pounds must be employed.

Wines from elderberries are made with the same proportions of ingredients as the former kinds, and in the same manner. If boiled fruit is taken—an operation which relates almost wholly to the black currant—the fruit must only be brought to the boiling point of the water, and the burning of it at the bottom of the vessel must be guarded against. Wine from the mature grape in this country it is not worth while to manufacture, as too few grapes ripen to make it any other than an object of curiosity, and the mode of treatment of them, described in the preceding pages, contains all that is necessary upon the subject.

It is probably due to M'CULLOCH that it was ever known that domestic wines could be made from immature grapes, vine tendrils, the young leaves, and the thinnings of the branches in places where vines are grown under shelter, in different stages towards maturity, no matter how different in species. No part of the vine need be feared as communicating a bad flavor. If the immature grapes be those grown in the open air, they should be taken just at their first tendency to ripen. The proportions and treatment are similar to those recommended for the gooseberry, but the husks may always be fermented in the vat with the must. Except in not breaking the seeds, no care need be taken about not bruising the fruit. The fermentation will be slow; but no obnoxious yeast is to be employed. Patience is necessary, but the operation will not ultimately be less effectual. Elevation of the temperature will excite it, if languid; as will also agitation of the cask, or omitting to replenish the fluid at the bung, so that the scum may remain upon the liquor.

The wine made from the young leaves, tendrils, and even young shoots, may be taken at any period from vines cultivated for this object, from which fruit is not expected. If the claret vine—*Clairrette rouge de l'Herault*—be cultivated for the purpose, the wine will be of a red color. The leaves should be young, and sixty or eighty pounds should be introduced into a vat. In the vicinity of a large town they should be first washed, to clear them of sooty particles from the impure atmosphere. Seven or eight gallons of boiling water

should then be poured upon them, and left to infuse for twenty-four hours. The water being poured off, the leaves are pressed in a press of considerable power, washed with an additional gallon of water, and again pressed. Sugar, from twenty-five to thirty pounds, is then to be added to the mixed liquors, and the whole made up to ten gallons and a half, when the same process is to be pursued as in the case of gooseberry wine. The water soon cools down to the usual temperature, it being used hot in order more effectually to extract the soluble part of the plant or fruit. These proportions are for brisk wines, which, if mismanaged, will fail of due effect. In the case of sweet wines of the same substances, from thirty-five to forty pounds of sugar must be used. As soon as the first fermentation has subsided, the wine is racked into a sulphured cask and fined. If it tend to a renewal of the fermentation, it must be racked and fined again, and even a third time. When perfected, the wine may remain in the cask as long as is desired. For dry wines the proportion of fruit to the sugar is to be the largest of all. The bung must be left open, and the fermentation, if sluggish, must be increased by heat and agitation. If the wine continues too sweet, it may be bunged down until the next spring without fining, and then the fermentation must be renewed by adding fresh must. As soon as it has become sufficiently dry, it must be fined into a sulphured cask, and again fined before bottling. The dry and sweet wines of this kind should be kept five years to be in their highest perfection. The brisk wines are drank after being six months in bottle, and are good to their third year. If they lose their briskness, they become dry, something like the Moselle or Rhine, and will keep indefinitely.

Wines, if they can be so called, are also made of dried substances, as ginger. They are composed of sugar and water, fermented with yeast and flavored with ginger. These are rather drinks than wine. The last are made by fermenting substances which possess little or none of their own extractive vegetal matter. Three pounds of moist sugar, a gallon of water to two ounces of bruised ginger are boiled, skimmed, and set to ferment with a yeast toast, flavored with a lemon to each gallon, or a little balm, and then bunged up. In about two months it is fit for drinking, having been fined with isinglass.

Mead, a very ancient domestic wine of honey, is made with sixty gallons of pure soft water, and seven gallons and a half of clarified honey, of which mellitose—see SUGAR, Vol. II. p. 966—is the sweet principle. In a copper of thirty gallons capacity, having mixed the honey and water, boil it down to one-fourth, then let it off, and boil the other moiety in the same manner; and when thus reduced fill up the copper with what was boiled first, and continue ebullition and filling up until the copper will contain half the liquor, all the rest having evaporated. The liquor must not be skimmed, but the scum must be well mingled with the liquor while seething, by means of a jet. When this is done it is drawn off into under-backs by a tap in the copper, and the fluid falls to the temperature of new milk. Then it is turned up and fermented in the vessel, where it forms a thick head. When it has

ceased to ferment it is closed from the air, and bottled at the end of six months, having been well worked and kept in the same cellar temperature as it had before. Aromatic flavors are often added by mixing elder or rosemary, marjoram flowers, and the like; or cinnamon, cloves, or other spices, during the process.

Raisin wine was manufactured light and dry in England of a superior kind, by Mr. AIKIN, secretary to the Society of Arts in 1829. Dr. M'CULLOCH censured the mode in which it is generally attempted to be made, and noticed the failure which is naturally to be expected from the use of molasses, coarse sugar, and the nauseous yeast of beer, which can never be rendered vinous. He would have the native acid neutralized, and with all domestic wines use crude tartar. Mr. AIKIN's wine was produced from Muscatel raisins. These, it is obvious, being sweet and dry, were not very different from some of the shrivelled and dried-up grapes with which wines are made in the South of Europe, as in the example of straw wines, for which the grapes are kept on the vine till shrivelled, and then further dried upon straw, giving a thick must, scanty in proportion to the produce, in a state of the grape so over-mature. Muscatel raisins are imported in boxes of twenty pounds weight. The fruit kept in the warehouse or shop unsold for above a year, is less approved by purchasers than when new, the rich pulp becoming mixed with the saccharine concretions. The extractive matter or gluten in the raisin is more than sufficient to ferment its sugar, and only from one-tenth to a third of the weight of the raisins is added. Cane sugar should be avoided in the unrefined state; if used it should be loaf. Sugar from honey or starch would be best, as unrefined sugar of the cane taints the wine. The raisins, without the stems, are chopped fine on a board, in the mode adopted with minced meat. Three pounds of raisins and one pound of sugar, were used to an ale gallon of water. The next process is mashing or maceration. If the former mode is adopted, the chopped raisins are placed in a tub, and hot water, a quart to four pounds of fruit, poured over them—the water not heated above 120°—to extract the mucilage. The whole is then stirred with the hand, no lumps being left, and placed in a sieve over a tub a short time to drain; this operation is repeated a second time throughout. The clamminess of the mass is by this extracted. The water for a third mash is poured on at 160°. The liquor now begins to be acidulous, with little sweetness. Three-fourths of the mash being made and tasted, to discover if it be sufficiently astringent, the stems or stalks, in part or all, are used, according as more or less astringency is intended. Hot water is poured upon the must, and the whole is well pressed by the hand. The three first mashes are now thrown into the tun, and the sugar, with as much of the last mash as will bring the must to its due proportion of one ale gallon to three pounds of fruit and one of sugar. The operation so far requires four or five hours; the temperature of the must is about 70°. The liquor soon ferments according to the atmospheric temperature and its treatment, but generally within thirty-six hours. The scum is either duly removed, or suffered to remain till the wine is drawn off. If the fermentation is languid, the cover is kept on the tun

and the scum stirred into the liquor; if too rapid, the cover is taken off and the scum removed as it rises. The must is thus become vinous, and is transferred to carboys, or stone-ware barrels, holding six or seven gallons. Safety tubes of glass are placed in the bungs, and on the second day an inch of quicksilver in the tube, to exclude the air. The bungs are covered with a cement consisting of wax and rosin. Carbonic gas bubbles through the quicksilver for some weeks, when it ceases. The wine should remain for the summer in the carboys, or barrels, if the latter be used. The wine thus made in April should be bottled in March, or if made in October, be bottled in September. The wine is not fined, for a light dry wine the inventor thought would be injured by being deprived of its tannin. After a year in bottle the wine had a bouquet like elderflower. As the wine is not fined it is decanted with care to keep it clear. It is of a pale yellow color, but in a short time deepens to the tint of Bucellas, having a flavor something like prussic acid at uncorking, which disappears. If, in place of mashing, maceration is applied, putting the chopped raisins and sugar into cold water, a higher colored wine is obtained, the fermentation is slower, and it is destitute of the elderflower bouquet, acquiring a taste from the husks of the raisins; but often this second mode of treatment answers well. It is sometimes twenty days under fermentation. Tartar is often added in making this kind of wine, but it often fails to be good—generally from the use of molasses, cane-sugar, and yeast.

Makers of domestic wines, it must be repeated, fail from not, before commencing their attempts, becoming perfectly acquainted with the mode of making foreign grape-wine, and the principles upon which it is done, which are applicable to all domestic wines, almost without exception. They are scarcely ever what they are capable of being made. In the evidence on the wine duties, before a Committee of the House of Commons, Mr. A. WALKER and Mr. J. FRITH were examined. They deal in wine, home-made, of all kinds, and some bearing foreign names. The wholesale price by the hogshead was five shillings per gallon. They make sixty-five thousand gallons, of which ten thousand are British port and sherry. It is estimated that six hundred thousand gallons of these wines are made. Port is imitated from the black cherry; champagne from French grapes; port, partly too with French grapes and raisins; and Cape or Pontac, with bottoms of Oporto and Spanish wines. Spirit is added to them all. Some champagne, home-made, is from rhubarb and gooseberry. It is averred that any light wine may be made to pass for home-made champagne, by means of sirup and carbonic gas, applied as if to aerated waters. However this may be in practice, Dr. M'CULLOCH so well explained the process of making these wines, that success is sure wherever the guide he has left is followed; and if the domestic manufacturer be not successful, it is not for want of the soundness of the principle, but of the practical action arising from its knowledge.

WINE MEASURES.—The imperial gallon wine measure which superseded the old contains ten lbs. avoirdupois of distilled water, or 277·274 cubic inches. The old wine gallon was equal to two hundred and thirty-one

cubic inches, the ratio being nearly as six to five, or more correctly as one to 0·833111. The imperial

wine-pint is 34·65925. The old English wine measures were:—

Tun.	Pipes.	Puncheons.	Hogsheads.	Tierces.	Barrels.	Rundlets.	Gallons.	Quarts.	Pints.	Quarterns.	Cubic Inches.
1	2	3	4	6	8	14	252	1008	2016	8064	58212·
	1	1½	2	3	4	7½	126	504	1008	4032	29106·
		1	1½	2	2½	5½	84	336	672	2688	19404·
			1	1½	2	3½	63	252	504	2016	14553·
				1	1½	2½	42	168	336	1344	9702·
					1	1½	31½	126	252	1008	7276·5
						1	18	72	144	576	4158·
							1	4	8	32	231·
								1	2	8	57·75
									1	4	28·875
										1	7·219

Wine measures differ greatly in the European wine-making countries, and give much perplexity in conducting operations of any kind in regard to them. Thus a tun is two pipes; three puncheons, four hogsheads; six tierces, two hundred and fifty-two old English gallons; and one thousand and eight quarts, two thousand and sixteen pints. The following are some of the more common measures:—

	Old Gallons.	New Gallons.
Tun,.....	252	210
Pipe of Port,.....	138	115
Do. Carcavellos, Lisbon, Bucellas,.....	140	117
Do. Madeira,.....	110	92
Do. Sicilian, Marsala,.....	112	93
Do. Vidonia, Teneriffe,.....	120	100
Butt Mountain, }.....	126	105
Do. Malaga, }.....		
Do. Sherry,.....	120	100
Hogshead, Claret,.....	57	46
Do. Tent,.....	63	52
Ohm Rhenish,.....	36	30
Do. Aix-la-Chapelle,.....	—	35
Do. Cologne,.....	—	41
Do. Heidelberg,.....	—	29
Do. Cassel,.....	—	43
Do. Frankfort,.....	—	39

The French measures are the litre and hectolitre. The first contains 61·0280264 cubic inches; the second, 3·531714693 feet English; or the litre is equal to 2·113 pints old English wine measure, and the hectolitre to 26·4 old English gallons, or to 22·01 gallons imperial, and the litre to 4·5432. Therefore, 100 imperial gallons are 454·3200 litres. A pipe of port contains 522·3680 litres; a butt of sherry, 490·6656; a hogshead of claret, 208·9872, and an ohm of Rhenish 136·2960. In France, let the name of the cask or measure be what it may, the stranger asking the number of litres, is at once answered—the litre being the legal standard.

FRENCH WINE MEASURES WITH OLD ENGLISH.

Litres.	Cubic Inches.	Imperial pints.	Old wine pints.	Oz. of water, troy.
1 =	61·028	1·7608	2·11353	31·104
2 =	122·056	3·5216	4·22706	64·208
3 =	183·084	5·2822	6·34059	96·312
4 =	244·112	7·0430	8·45412	128·416
5 =	305·140	8·8038	10·56765	160·520
6 =	366·168	10·5646	12·68118	192·624
7 =	427·196	12·3253	14·79471	224·728
8 =	488·224	14·0861	16·90824	256·832
9 =	549·252	15·8469	19·02177	288·936

In some countries a troublesome variety prevails in measures of the same name. In Sweden, the ohm is 139·019 litres, or 30·543 gallons imperial; at Strasburg it is only 46·093 litres, or 10·146 gallons.

The measures for wine in Spain are commonly arrobas, of which sixteen make a mayo; twenty-seven mayos, a pipe; thirty pipes, a bottle—the last equal to one hundred and twenty-seven and a half old English gallons, or one hundred and six imperial. But the measures of the same name differ in different provinces. The arroba of Valencia contains 11·786 litres; of Malaga, 15·850; of Spain and the Canaries generally, 16·073. The cantaro of Alicante is 11·554 litres, or about three gallons, and the tonelada is one hundred cantaros; that of Arragon, 10·313; of Oviedo, 19·236. The carga of Barcelona is 123·756; the gerra of Minorca, 12·063; the mayo of Galicia, 161·991; the quartin of Majorca, 27·131 litres, or 7·168 old gallons.

In Portugal, the almude is 25·480 litres; of Lisbon, 16·541; of Oporto, twenty-one make a pipe; at Lisbon, thirty-one, or one hundred and forty old English gallons. At Figueras the almude is 4·75 English imperial gallons; at Viana, 5·5. All these are in use in Portugal; besides which, they have potes, canadas, quartillos, basils, and toneladas; this last two hundred and thirty-one imperial gallons.

In Germany the ohm varies, at Hanover and Hamburg it is thirty-two imperial gallons; on the Rhine only twenty; at Ratisbon the bergeimer—about nineteen imperial gallons, and the same at Munich—seven and a half only; at Vienna it is ten and a half imperial gallons. The ohm at Basil, in Sweden, Dantzic, and Strasburg is a different measure from the German ohm. The ohm at the Cape of Good Hope is thirty one and two-thirds; the eimer of Leipzig, twenty and a half old English gallons, and at Dresden eighteen only; at Antwerp the aum or ohm is forty-two old English gallons.

The Russian wine-measure is the vedro of 2·705 imperial gallons; three vedros make an anker; six ankers, an oxhant; two oxhants, a pipe, or 75·320 imperial gallons.

The Hungarian measures are, the antheil of 11·125 imperial gallons; the great and little eimer—the first equal to 16·140 imperial gallons, and the second to 12·515.

The other European wine measures are of little moment comparatively. In Italy they are numerous. The oke in Greece is two pounds, three ounces, five drachms, avoirdupois; and the alma of Constantinople, 1·150 imperial gallons.

Mr. CYRUS REDDING kindly tendered some valuable matter, which the Editor has incorporated in the preceding details.

ZINC.—*Zinc*, French; *Zink*, German.—It is only from the middle of the sixteenth century that zinc has been known as a metal. Its ores were known from a very early date, and were spoken of under various names; but the first account which is recorded of the term *zinc* being used in reference to the educt from the calamine or cadmia of the period, is that of ALBERTUS MAGNUS; and the first who characterized it as a distinct metal was PARACELSUS, about the year 1530. For a long time afterwards, however, the knowledge of this substance was almost entirely confined to alchemists, who prized it highly on account of the property which it was thought to possess of transmuting copper into the more precious metals. It was owing to this imaginary property that the metal was long termed *counterfey* or *counterfeht* by the Germans. The present name seems to be derived from the word *zinken* or *zacken*, the German for nails or spikes, because, in preparing brass, a portion of the ore, on being sub-

mitted to a preparatory roasting, often assumed such forms. The synonym *SPELTER*, which is now so much used in commercial language, is derived from the terms *spiauter*, *spialter*, *et cetera*—terms which were introduced along with the first portions of this metal imported from India.

That the ores of zinc were known to the ancient Greeks and Romans, is attested by the accounts which DIOSCORIDES, STRABO, and PLINY give of one of them, or perhaps of several of them under one generic name; and likewise by the fact that in the time of these writers or at a later period, articles are known to have been produced in a kind of brass or bronze, the analyses of which clearly indicate the presence of zinc in greater or less proportion. The following analyses of different varieties of brass, dating from about the beginning of the Christian era, are given by PHILLIPS as demonstrating this fact indisputably:—

		Copper.	Tin.	Iron.	Zinc.	Lead.
Large brass of the Cassia family, B.C. 20	....	82.26	....	0.35	17.31	....
Large brass of Nero family, A.D. 60	....	81.07	1.05	....	17.81	....
Titus,	" 79	83.04	....	0.50	15.84	....
Hadrian,	" 120	85.37	1.14	0.74	10.85	1.73
Faustina, jun.,	" 165	79.14	4.97	0.23	6.27	9.18

Of many other bronze articles analyzed by PHILLIPS, none of them, known to have been produced anterior to the year 20 before CHRIST, were found to contain zinc as a constituent, tin being the material employed instead of that metal. The earth which was used in those early days for the purpose of forming an alloy with copper was termed *cadmia*; but it is evident that by this substance was not meant an oxide or silicious oxide of zinc, as at the present day, but any mineral, whether oxide or carbonate, that contained a large proportion of that metal, notwithstanding there being other metallic compounds associated with it. The alloy so prepared was known as *aurichalcum*, which was then recognized as a purer copper than the ordinary metal, and hence was more esteemed. The dross or oxidized portion sublimed from or remaining in the furnace after the alloy was drawn off, was likewise known by the general term *CADMIA*, but was distinguished by some particular designation, according to its color, form, or consistency. In later times this compound was distinguished at Rammelsberg as furnace calamine—*ofenbruch*—when it was discovered that it could be employed instead of native calamine in the manufacture of brass. Another substance called *TUTIA*, which seems to have been analogous to *cadmia*, or at least to have been a compound also rich in oxide of zinc, is spoken of in writings of the eleventh and subsequent centuries as having been employed for the manufacture of brass. ZOZIMUS, who is supposed to have written about the fifth century, states, that to make brass, cyprus copper must be melted and pounded *tutia* strewn upon it. According to ALBERTUS MAGNUS, the celebrated alchemist HERMES taught the method of making copper of a gold color by introducing pounded *tutia* into the melted metal; and ALBERTUS leaves no doubt of the nature of this *tutia*, for he states that it is not a native mineral, but an

admixture produced in the furnace when copper ore is melted—thus showing that evidently it was a sublimed oxide of zinc mixed with other ingredients, and analogous to the furnace calamine or *ofenbruch* of a later period. The discovery that this sublimate could be substituted for native calamine in the production of brass, is said to have originated with ERASMUS EBENEZER, a German, towards the middle or first quarter of the sixteenth century. The discovery was greatly esteemed, as up to that period the refuse matter from the furnaces of Rammelsberg were cast aside as useless. Doubtless the period intervening from the time of ALBERTUS MAGNUS to that of PARACELSUS gradually developed facts resulting in a more comprehensive knowledge of *cadmia*, *tutia*, and the other substances containing oxide of zinc, and leading as a natural consequence to the isolation of the metal. Indeed, the former of these writers distinguished the principle in the earth which was used to convert copper into brass as *marcasita aurea*, a term which might be qualified as meaning the metal of this earth, though properly it was understood at the period as a mercurial ore, probably a sulphide of mercury. This *marcasita*, of which MAGNUS speaks as superior to the other ores of zinc, was found at Goslar; but that of which PARACELSUS wrote was stated to be produced at Carinthia. By AGRICOLA, however, who wrote about the year 1550, reference is made to the Goslar product alone, which he designates as *liquor candidus* or *counterfey*; and FABRICIUS, who died in 1571, conjectures that *stibium* is what the miners call *cincum*, a compound that could be melted but not hammered.

From these different statements it will be seen that the knowledge of zinc, even for a long time after its recognition as a distinct metal, was exceedingly meagre; and in point of fact very few of the chemists of that period could obtain even samples of

it, owing, as it is alleged, to the great hopes entertained of it as an alchemical agent, and the consequent prohibition by Duke JULIUS to sell it or make it generally known. However this may be, the first certain account of its production at Goslar was given in 1617 by LÖHNEYSS, whose note in reference to it runs thus:—When the people at the melting-house are employed in melting, there is formed under the furnace, in the crevices of the walls, under the stones where it is not well plastered, a metal which is called zinc or *counterfeht*, and when the walls are scraped the metal falls down into a trough to receive it. This metal has a great resemblance to tin, but it is harder and less malleable, and rings like a small bell. It is not much valued, and the servants and workmen collect it only when they are promised drink-money. They, however, scrape off more of it at one time than at another; for sometimes they collect two pounds, but at others not above two ounces. This metal by itself is of no use, as, like bismuth, it is not malleable; but when mixed with tin, it renders the latter harder and more beautiful, like English tin. This zinc or bismuth is in great request among the alchemists.

BECKMANN KENKELL is accounted to have been the first who procured it directly from calamine in 1741. After him LAWSON is stated to have succeeded in extracting it from the ore, though no account of his researches exist. VON SWAB, a Swede, obtained it by distillation from calamine in 1742; and almost contemporary with him MARGGRAF likewise discovered a process for the same purpose in 1746. It is stated by WATSON in his chemical essays, that in 1743 a manufactory for the production of this metal was established at Bristol, by CHAMPION, and was carried on by his successor, EMERSON, who established another in the neighborhood. It appears, however, that the wants of Europeans, as regards this metal, were supplied from China and India, through the Dutch, and probably the Portuguese, the imported articles bearing the title *tutenague*, or Indian tin. RAYNAL records that the Dutch East India Company purchased annually at Palimbang a million and a half pounds of this metal; and the Danish Company at Copenhagen, in 1781, as much as one hundred and fifty-three thousand nine hundred and fifty-three pounds. It appears, however, that between the above date and 1820 the production of zinc must have greatly increased, as it is recorded that at the latter date spelter or zinc was imported into England from Silesia, to be again exported to India to supply the place of the *tutenague*, formerly imported from China. The Silesian zinc was analogous in composition to the Chinese product, as will be seen by the subjoined figures:—

	Zinc.	Lead.	Iron.	Sulphur.	Sand.
Silesian zinc,	98.32	1.40	—	0.18	0.10
Chinese <i>tutenague</i> , 97.63	0.33	1.90	0.14	—	—

The quantity exported from England to India almost balanced the total amount of her imports, until about 1830, when the quantity retained for home consumption began to be increased annually, so that in 1851 the amount thus utilized reached eleven thousand two hundred and sixty-two tons, while the quantity imported in the same year amounted to eighteen

thousand six hundred and twenty-six tons, whereas the exports to India remained nearly the same. At present Silesia is the great seat of the manufacture of zinc, containing the largest works of the kind in the world, and producing as much as fifty-three per cent. of the total yield of all countries. Belgium, including more especially the works of the *Vieille Montagne* Company of Liege, ranks next, and produces about thirty-three per cent.; Poland and Cracow furnishes ten and a quarter per cent., and England the remainder.

The application of zinc within the last twelve years has been very much extended, not only for use in brass foundries, but in several other departments, such as in galvanizing iron for light roofing and for fencing, and in fact for all the lighter kinds of iron which have to be exposed to the air; for the base of electro-plated articles, for paint, and various other applications.

OCCURRENCE OF ZINC.—This metal is never found in the native or virgin state, but always combined with oxygen, sulphur, and salt radicals. Ores of zinc are met with in almost every country, though not to such an extent in many of them as to render them particularly important in a metallurgical point of view. The most remarkable deposits of these ores hitherto discovered are those in New Jersey in the United States, where almost every variety of the natural combinations of zinc are met with. They exist in considerable quantities in Siberia and on the continent of Europe, more especially in Silesia, Hungary, Carinthia, Saxony, Belgium, Sweden, and France; also in England and Scotland, and some parts of Ireland. The most famous localities where the deposits occur will be mentioned presently in specifying the particular ores of zinc.

ORES OF ZINC.—The most important ores of zinc, not only as containing more of the metallic element, but also as affording greater facilities for its extraction, are the oxide, carbonate, sulphide, and silicates.

OXIDE OF ZINC—SPARTALITE—red oxide of zinc, zinc oxide ferri-fere; zinc erze; zinkit.—Generally this ore is met with in the amorphous state, but it is occasionally found crystallized in forms of the rhombohedral system, the crystals appearing colorless or yellowish-red, according to the purity of the compound; their lustre is adamantine, appearing translucent on the edges, having a cleavage parallel to the base and one of the sides, a conchoidal fracture, and a specific gravity equal to 5.43 to 5.52. Crystallized oxide of zinc is infusible before the blowpipe, though it phosphoresces strongly; with borax and phosphorous salt the presence of manganese is indicated in it, while that of zinc is shown by the green color produced in the assay, when it is moistened with nitrate of cobalt solution, and subsequently heated to strong redness. The powdered crystals, as well as the amorphous substance, dissolves readily without effervescence in nitric acid. Its composition is—

	Whitney.		Hayes.	Berthier.
Oxide of zinc,	94.45	96.19	93.48	88.0
Oxide of manganese, trace	—	3.70	5.50	—
Franklinite,	4.49	—	—	12.0
Oxide of iron,	—	0.10	0.80	—
Loss by ignition, &c.	1.06	0.01	0.22	—
	100.00	100.00	100.00	100.0

CARBONATE OF ZINC—*calamine*; *zinc carbonaté*, *Galmei-Smithsonite*; *zinc spar*.—This is by far the most important ore of zinc, and that from which the metal is chiefly extracted; it is more diffused than any other, and offers, like the oxide, peculiar facilities for smelting. Calamine is usually found in a crystallized state, in concretioned and compact masses, and in pseudomorphic forms. The crystallized variety when pure has a vitreous, inclining to a pearly lustre; is colorless, white, grey, green, or brown, according to its freedom from extraneous matters. Its crystalline form is that of the rhombohedron, with a cleavage parallel to its faces.

Its fracture is uneven or imperfectly conchoidal; its streak white, and its specific gravity 4.34 to 4.45. The ore is infusible before the blowpipe, but affords a white sublimate of oxide of zinc when it is heated on the charcoal, and which is yellowish while hot, and becomes white on cooling. By moistening the assay with a solution of nitrate of cobalt, and then heating, the green color peculiar to zinc under such treatment makes its appearance. It is readily soluble in acids with the evolution of carbonic acid, and in an excess of caustic potassa. The following analyses of a few samples of the mineral indicate its composition:—

	Smithson.		Karsten.			Berthier.
	1	2	3	4	5	6
Oxide of zinc,	64.8	65.2	57.76	64.53	64.36	60.7
Carbonic acid,	35.2	34.8	35.62	35.47	35.14	35.0
Protoxide of manganese, ..	—	—	6.62	—	—	—
Oxide of lead,	—	—	—	—	0.50	—
Oxide of iron,	—	—	—	—	—	4.3
	100.0	100.0	100.00	100.00	100.00	100.0

Samples 1 and 2 in the preceding table represent calamine from Somersetshire and Derbyshire; 3 is from Nertschinsk, 4 from Altenberg, 5 from Brilon, and 6 from Taina in Siberia.

Annexed are a few analyses of other samples of

calamine more manganiferous than the foregoing. Number 1 specimen represents the calamine in yellowish white crystals from Altenberg; No. 2, light green crystals from Nirm; No. 3, dark green crystals; and No. 4, calamine from Nertschinsk:—

	Monheim.			Kobell
	1	2	3	4
Carbonate of oxide of zinc,	84.92	85.78	74.42	96.00
Carbonate of protoxide of iron,	1.58	2.24	3.20	2.03
Carbonate of protoxide of manganese,	6.80	7.62	14.98	—
Carbonate of oxide of lead,	—	—	—	1.12
Carbonate of lime,	1.58	0.98	1.68	—
Carbonate of magnesia,	2.84	4.44	3.88	—
Silicate of oxide of zinc,	1.85	—	—	—
Silica,	—	0.09	0.20	—
Volatile matter,	—	—	0.56	—
Loss,	0.43	—	1.08	0.85
	100.00	101.15	100.00	100.00

Very frequently the silicated oxide of zinc and the carbonate are confounded under the title calamine. Two principal classes of calamine are recognized, namely, ordinary white calamine, which may be a carbonate or a silicate of the oxide, containing but a very small proportion of ferruginous matters, and the *red*, which differs from the foregoing, but only by its containing more hydrated sesquioxide of iron or its salts.

The following are analyses of red calamine by JOHN:—

	From Radipikar.	From Benthon.
Oxide of zinc,	39.00	35.00
Carbonic acid and water, ...	15.00	{ 24.37
Oxides of iron, manganese, } lime, and silica,	46.00	{ 10.63
	100.00	100.00

Calamine, as well as *blende*, is found in two geological formations—the one is the carboniferous or mountain limestone, in which it occurs in veins accompanying galena; and the other the magnesian limestone formation of English geologists, the Alpine limestone of the French, and the *Zechstein* of the Germans, in which it is disseminated in small veins forming a network in the mass, not more than a few inches in thickness, except where several intersect, when it sometimes increases to

as many feet. Explorations for lead and zinc are carried on in England, wherever the mountain or metalliferous limestone exists; but the principal seats of operation are in the neighborhood of Alston Moor in Cumberland, of Castleton and Matlock in Derbyshire, and in Flintshire in Wales. In the magnesian limestone the explorations for calamine are prosecuted chiefly on the flanks of the Mendip hills, near Bristol; and the mineral is excavated by means of numerous small shafts and levels. Calamine usually occurs in beds and veins, associated with Smithsonite galena, blende, and other minerals, in the crystalline slates, transition rocks, the coal formations, the muschel kalk, and oolite formations. It is found at Altenberg and Nirm, near Aix-la-Chapelle; at Iserlohn and Brilon in Westphalia; near Tarnowitz in Silesia; at Raibel and Bleiberg in Carinthia; in the Banat; at Miedziana Gora in Poland; Dognazka, Rezbanya, and Saska, in Hungary; at Kuesiana in Servia; Tschairski in the Altai; Nertschinsk and Nischn Tagilsk in Siberia; Chessy in France; in Belgium; in several places in the United States, especially in Jefferson County, and many other localities.

SILICATE OF OXIDE OF ZINC—*Smithsonite*, Phillips; *zinc oxidé silicifère*, Hany; *zink-glas*, Hausmann; *galmei*, Haidinger.—Two varieties of this mineral exist;

the one anhydrous and the other hydrated. Anhydrous oxide of zinc is found crystallized in regular hexahedral prisms of a green or grey color; translucent, sometimes transparent, with a vitreous lustre on the surfaces of the fracture, which is somewhat conchoidal and uneven. Its streak is white. Before the blowpipe it is infusible, and is only reduced when mixed with charcoal, and submitted to a very high temperature; heated with soda on charcoal, it affords a sublimate of oxide of zinc; with a solution of nitrate of cobalt it affords the characteristic green color of zinc; it is decomposed by mineral acids, yielding a jelly of silicic acid. It is composed of—

Oxide of zinc,.....	71.32
Oxide of lead,.....	2.66
Oxide of iron,.....	0.67
Silicic acid,.....	25.35
	100.00

HYDRATED SILICATE OF ZINC—*Electric calamine.*

—Silicates of zinc, especially this variety, were long confounded with calamine or carbonate of zinc, notwithstanding the great difference which exists between the two minerals. Electric calamine occurs in stalactitic, mammillated, botroidal, and massive forms, as well as in crystals of the right rhombic system. Its usual color is white, but in this respect it varies to shades of yellow, brown, green; its lustre is vitreous, and its streak white; it is phosphorescent when rubbed, and becomes electric by heat; its streak is white; it has an uneven fracture, and a specific gravity of 3.3 to 3.6. When heated on the mattress it yields water and turns white. It swells on charcoal before the blowpipe, and shines with a green light, but does not fuse, excepting a little on the edges; in other respects it comports itself like the anhydrous compound. The pure silicate is composed of—

Oxide of zinc,.....	67.07
Silicic acid,.....	25.48
Water,.....	7.45
	100.00

corresponding to the formula $\text{ZnO}, 2 \text{SiO}_2 \text{HO}$. In most cases, however, this mineral is associated with various extraneous matters, as shown in the annexed analyses—

	Berzelius. 1	Berthier. 2	Smithson. 3	Thomson. 4
Oxide of zinc,.....	66.84	66.0	64.5	68.3
Silica,.....	24.89	25.0	25.5	25.0
Oxides of lead and tin,.....	0.28	—	—	—
Water,.....	74.45	9.0	10.0	4.4
Carbonic acid,....	0.54	—	—	—
Loss,.....	—	—	—	3.3
	100.00	100.0	100.0	101.0

	Lowe.		Arfvedson.	Henry.	Berthier.	Lecanu.	Kersten.	Jackson.		Berthier.	Sebecher.
	1	2	3	4	5	6	7	8	9	10	11
Zinc,.....	61.40	62.62	66.34	66.46	63.0	55.0	64.22	63.62	52.0	61.5	53.17
Iron,.....	1.29	2.20	—	—	3.4	8.6	1.32	3.10	10.0	4.0	11.79
Cadmium,.....	1.50	1.78	—	trace	—	—	trace	0.60	3.2	—	—
Antimony, lead, and oxygen,....	—	—	—	—	—	—	0.72	—	—	—	—
Manganese,.....	—	—	—	—	—	—	—	—	1.3	—	0.74
Sulphur,.....	33.15	32.72	33.66	32.22	33.6	36.2	32.10	33.22	32.6	33.0	35.73
Water,.....	—	—	—	—	—	—	0.80	(earthy matters 1.5)		—	—
Loss,.....	2.66	0.68	—	1.32	—	0.2	0.84	—	0.9	—	—
	100.00	100.00	100.00	100.00	100.0	100.0	100.00	100.54	100.0	100.0	101.43

Numbers 1 and 2 in the foregoing table were from Limburg, 3 from Breigau, 4 from Rezbanya, and 5 from Leadhills.

This mineral is generally associated with calamine in veins containing iron and lead ores and blende; it is found in most of the localities already mentioned as containing calamine. Considerable quantities of it are mined at Bleyberg and Raibel in Carinthia; in Brisgau, Hungary; and at Tarnowitz in Silesia; it is also found in Poland, Galicia, Baden, in the Tyrol, and in Banat; at Alcares in Spain; at Altenberg, near Aix-la-Chapelle; at Moresnet, near Liege; near Goslar in the Hartz; at Matlock, Derbyshire; in the Mendip Hills and Flintshire in England; at the Wanlock-head; and the Leadhills in Scotland, and several other localities.

SULPHIDE OF ZINC—*Blende; zinc sulfuré; zinc-blende.*—Blende occurs in a variety of conditions—massive and crystallized in octa- and dodecahedrons and other allied forms, derived from the cubic system, its color varying between black, brown, red, yellow, and green. The crystallized variety is translucent, transparent, and opaque; it has an adamantine lustre, a conchoidal fracture, and a cleavage parallel to several of its faces; it gives a white, shading off to a reddish-brown, streak, according to its purity; it is brittle, and has a specific gravity of 4.0 to 4.1. By friction some varieties are rendered electric. Heated alone it decrepitates violently; it is infusible, excepting slightly on the edges in the blowpipe flame; but it gives, under a strong oxidizing flame, a sublimated areola of oxide of zinc round the assay; with carbonate of soda on charcoal it is reduced. When treated with nitric acid the base is dissolved, and the sulphur left in proportion to the strength of the acid employed. When pure, sulphide of zinc consists of equivalent proportions of its constituents, corresponding to the formula ZnS , and is composed centesimally of—

Zinc,.....	67.03
Sulphur,.....	32.97
	100.00

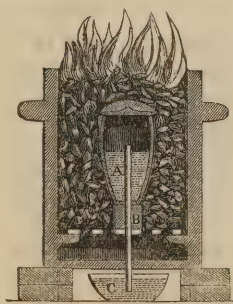
Generally, it contains several impurities, such as sulphides of iron, of lead, of cadmium, and of antimony; the first of these is more frequently met with in the dark, and the second in the reddish striated kind. The following are analyses of a few samples of blende from different localities; namely, those marked 1, 2, and 3, from Przibram; 4, a transparent variety from New Jersey; 5, from Bagnères de Luchon; 6, from Chérones, in the department of Charente; 7, from Raibel in Carinthia; 8, from Eaton; 9, from Shelburne in New Hampshire; 10, from England; and 11, from Christiania:—

Blende is found, as before stated, in the metalliferous mountain and magnesian limestone, especially in England, in veins and beds associated with lead, iron, and copper ores. In Cornwall its presence is observed in the older transition rocks, and chiefly accompanying copper pyrites. The variety so found, from the large quantity of sulphide of iron, is mostly of a black color—hence the miners term this mineral *black jack*. The ore is found in more or less abundance in Hungary, Transylvania, Bohemia, Carinthia, and the Hartz; large quantities of it are obtained in Cumberland, Derbyshire, and Cornwall, in England; Flintshire, in Wales; in Perthshire, the Leadhills, and the coal fields round Edinburgh and Lanarkshire, in Scotland.

SULPHATE OF ZINC.—*Goslarite, zinkvitriol, white vitriol, aluminate of zinc, gahnite spinelle, zincifère*, and a few other minerals of zinc exist; but their importance in relation to their abundance, or for their application in the metallurgy of zinc, is not so great as to require a description here.

PREPARATION OF ZINC.—To obtain perfectly pure zinc is a task of some difficulty, so much so that the commercial article is never met with in a pure state, but rather with variable quantities of arsenic, cadmium, tin, lead, manganese, iron, cobalt, and nickel. In order to obtain perfectly pure metal, the purest commercial zinc should be dissolved in dilute sulphuric acid, filtered from any residue, and the foreign metals thrown down by immersing plates of zinc in the liquid till no further deposit takes place. After separating the precipitated metals, which may be tin, lead, copper, cadmium, antimony, and a trace of arsenic, the solution is treated with carbonate of soda, and the carbonate of zinc, which falls after filtration and thorough washing, is dried, heated to redness to expel carbonic acid, mixed with charcoal or lampblack, and introduced into a crucible as represented in Fig. 623, placed in a furnace,

Fig. 623.



and the metal reduced and recovered by the method known as distillation *per descensum*. In this figure, the crucible wherein the mixture of carbonate and charcoal is placed, is shown by A; it rests upon a disc of clay, B, which, together with the bottom of the crucible, is perforated for the purpose of passing a clay tube through both, one end of which opens at the top of the crucible near the cover, and the other dips into a cup of water, C, placed beneath the grate and ash-pit. The crucible being fixed, with its charge and its cover closely luted with clay, is placed in the furnace and heated to whiteness, when the reduced particles of the metal pass off in vapor, which finds an outlet in the lower opening of the tube, and condenses in the cup of water in grains. The zinc obtained in this way will be very pure, but to obtain it in absolute purity, it is necessary to have recourse to electrolysis from a solution of zinc which has undergone the above-

mentioned purifying operation, and from which the iron, manganese, and other bodies which may be deposited on the electrode, are separated by treatment with an excess of caustic potassa, subsequent precipitation of the zinc as carbonate, washing, and re-solution. The distillation of zinc being always conducted at a white heat, a repetition of the distillation, however often repeated, is not sufficient to separate many impurities of a metallic nature, which greatly injure its properties, and prevent its applications in many operations of a chemical and manufacturing nature. The substances with which it is most liable to be contaminated when prepared in this way, are lead, tin, antimony, cadmium, and arsenic, as these metals evaporate with the zinc and alloy themselves with it. A simple process adopted to free zinc from several of the preceding metals consists in incorporating some sulphur alone or mixed with grease in the melted metal, and stirring the whole rapidly with a wooden slip. The foreign metals are by this operation converted into sulphides, but traces of them are still retained in the melted zinc. Another method is to granulate the zinc by melting it in a crucible, and pouring it while fluid into a tub of water, then mixing the powder with a quarter of its weight of nitre, and introducing the mixture into a crucible, taking care that a portion of the salt rests beneath and upon the metal. The crucible is then heated in a furnace till vivid combustion ensues, after which it is taken from the fire, the slag removed from the surface, and the melted metal poured into water. Arsenic and iron are thus removed.

PROPERTIES OF ZINC.—When pure, this metal has a bluish white color, somewhat similar to lead or aluminium, and a strong metallic lustre. It crystallizes in long regular hexagonal prisms, according to NAGGERATH, but others give the crystalline form as cubic prisms. NICKLES asserts that zinc distilled in an atmosphere of hydrogen forms well-defined pentagonal dodecahedrons on cooling. When freshly fractured, its crystalline texture is lamellar, the plates sometimes appearing of considerable size. At ordinary temperatures it is brittle, of a moderate hardness, and difficult to file, but when heated between 212° and 300° it acquires a considerable degree of malleability, so that it can be drawn into wire or rolled into thin bands and sheets. Mr. FORD of Coalbrook Dale, who, according to GRAY, was the first person in England who employed the metal in casting fire-engine cylinders, states that, by the mere warmth of the hand, the strips of metal which were as brittle as glass at the ordinary temperature, could be wound round the finger like slips of paper. If the heat be raised to 400° or 410° its ductility is destroyed, and it becomes so brittle as to be reduced to powder in a mortar by ordinary grinding processes. Zinc emits a peculiar odor when rubbed. Its density, according to the mean of several experiments of BRISSON, KARSTEN, PLAYFAIR, and JOULE, is 6.89; the melted metal after cooling gave JOULE only 6.54. It fuses at 705° according to GUYTON MORVEAU, but DANIELL gives the fusing point 774°; at white heat it boils, emitting vapors which burn in the air or in oxygen gas with a very brilliant white light, producing oxide of zinc, which

condenses in filamentous flocks on a cold surface held over the flame, or on the walls of the crucible in which the combustion is effected; this is the *philosophical wool*, the *flowers of zinc*, or *pompholyx* of the old chemists. At a red heat zinc decomposes water, setting free the hydrogen of the vapor; the same effect is produced at ordinary temperatures under the influence of weak acids, and with considerably greater energy than by heat alone. In the latter behavior a remarkable difference is manifested when pure and commercial zinc are submitted to the action of the same acid, the former dissolving so slowly that it requires the action to be continued for a period of eight days to produce the same effect as that which is effected upon the latter in a space of one hour. This behavior was made the subject of a careful investigation by DE LA RIVE, who found that the action of the acid is increased by the presence of certain proportions of many metals. By alloying nine parts of pure zinc with one part of the several metals mentioned below, and employing dilute sulphuric acid, he found that the effect of the acid, measured by the volume of hydrogen disengaged in equal times, stood in the relation of the annexed numbers:—

	Gas disengaged.
Commercial zinc and alloys of zinc and iron, ..	100
Alloy of zinc and copper,	43
Alloy of zinc and lead,	15
Alloy of zinc and tin,	12
Distilled zinc,	5

One twentieth of the quantity of iron alloyed with zinc is sufficient to produce an effect equal to that of commercial zinc, and even a spiral of platinum round a bar of zinc was found to increase the action of the acid considerably. On the other hand, he observed that the acid which effected the most rapid solution of the metal, was a mixture of thirty-three parts of sulphuric acid and one hundred of water. The consideration that the zinc, on being alloyed with any metal, constitutes a kind of battery within itself, and the knowledge that the above acid is the one which possesses the greatest power of conducting electricity, led M. DE LA RIVE to the conclusion that the greater or less energy with which a plate or bar of zinc decomposes water, is dependent upon the galvanic effect of the metals associated with the zinc and of the acid body employed.

Zinc abstracts oxygen from a great number of acids containing this element. Boiling solutions of potassa and soda likewise oxidize it with disengagement of hydrogen, the oxide of zinc formed dissolving in the alkali, and forming probably the radical of an alkaline salt. Exposure to dry air, however long continued, is insufficient to tarnish bright metallic zinc; but when moisture is present it readily undergoes oxidation, a whitish coating forming upon it; this, however, retards to a great degree its further corrosion by atmospheric influences, so that it resists exposure very well; and hence, its very extended use in roofing and other applications where iron would soon become oxidized and worn away. Zinc forms an extended class of salts with acids, many of which are of some importance in many departments of art and manufactures as well as in medicine, and the metal itself has of late years been applied to a great many important uses. Zinc has the

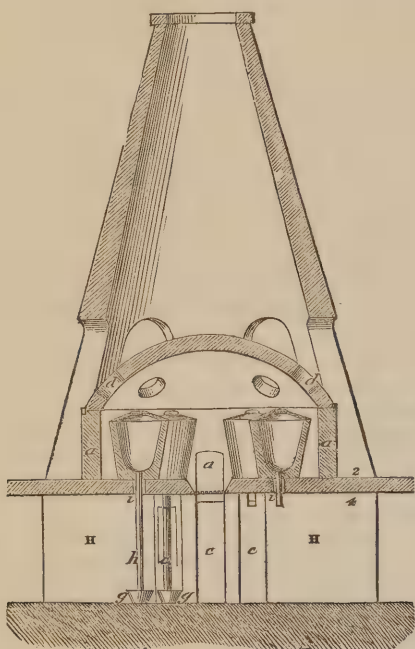
atomic or combining number 32; and its symbol, or chemical formula, is Zn.

METALLURGY OF ZINC.—The principal places for the production and manufacture of zinc are, in England, Swansea, Carlisle, Bristol, Birmingham, and the neighborhood of Sheffield; Flintshire in Wales; Upper Silesia in Germany; and Vieille Montagne in Belgium. The latter establishment has considerably increased during the last twelve years, but it has not attained the magnitude of the Silesian works, which are the largest of the kind in the world.

ENGLISH PROCESS.—The ores which are principally employed at Bristol and Birmingham, are those from the Mendip Hills and from Flintshire, while the Sheffield furnaces derive their stock from Alston Moor in Cumberland, and from Derbyshire. A large quantity of blende is likewise obtained from Cornwall, which is submitted to a preparatory roasting. The ore is sorted, and any blende which may be mixed with it is separated from the calamine; the latter is sometimes ground under head rollers, and roasted in a reverberatory furnace, to expel all its moisture and carbonic acid. This preparatory roasting is not universally practised, however, as some smelters merely break it up into fragments about the size of a pigeon's egg, and in this state mix it with its bulk of coal or slack, and submit it to the reduction process. Blende is always roasted before reducing it to metal, for which purpose it is sorted and broken up into small pieces of about half a cubic inch, and introduced into a reverberatory furnace, where it is roasted during ten to twelve hours without intermission. The furnace is ten feet long, eight feet wide, a half foot between the bed and the roof in the middle, and one foot and a half at the bridge. A continual rabbling is given to the ore, which is spread on the bed to the depth of four or five inches. During the period of the roasting, the ore suffers a loss of twenty per cent. from the sulphur expelled. Four tons of coal are said to be consumed during each operation. The charge for reduction is then compounded of one part of calcined blende, one part of roasted calamine, and two parts of charcoal. In the English system, the furnaces shown in the annexed figures are employed; their peculiar feature is their being adapted to the practice of the system of distillation *per descensum*. They consist, as shown in Fig. 624, of an inner cupola, A A, enclosing a double row of crucibles, G G, the whole enclosed by a hovel or conical brickwork chimney, D, similar to that of a glass furnace or pottery kiln. A number of openings, B B, are constructed in the cupola corresponding to the number of pots in the furnace, and which serves to charge and secure the pots in their places when necessary. For the convenience of the workmen the outer cone has doors, C C, before each pot. A fire, F, runs across the centre of the hearth and heats the row of four pots on either side, the smoke and gases passing off by the apertures, B B, and outwards at the mouth of the cone, D. The ash from the grate falls into the pit, E, at either side of which, and beneath the pots, is a gallery, H, where a number of dishes or other vessels are placed for collecting the zinc, conducted to them by iron pipes, having one end inserted into the aperture in the bottom of the pot, while the other

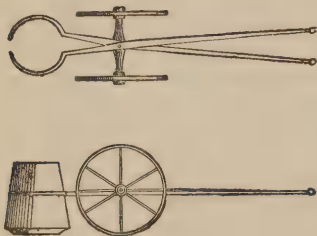
dips into the dish already mentioned. To charge the furnace, the crucibles, which are previously heated to redness in a reverberatory furnace, are carried by a pair of large iron pincers, slung in chains, and supported on a kind of over-head railway—Figs. 624, 625—much in the same way as glass-pots are inserted

Fig. 624.



and withdrawn from the furnace. They are then introduced by means of an aperture in the side of the dome, and placed in their position beneath the apertures in the top, so as to rest on each side of the wall

Fig. 625.



of the furrow opening into the chamber, H. The charge for each pot or crucible is composed of equal bulks of ore and slack when calamine either crude or roasted is used, or if a mixture of calcined blende and calamine be employed; these, in the proportions already stated, are introduced through the apertures in the dome, the outlet in the bottom of the pot being secured by a plug of wood. The fire is then urged till the contents of the pots are brought to a full red heat, approaching to whiteness, and when the vapors arising from the ore are observed to burn

with a white light, the covers are placed upon the several pots and well luted, the pipes are likewise inserted in the bottom, and the distillation is allowed to proceed, the temperature being always maintained at a high white heat. To prevent the materials in the pot from falling through, the end of the pipe is plugged with wood, but as it becomes charred, it offers sufficient space for the metal, in its passage downwards, to percolate through it without allowing any grosser matters to descend. Any metal condensed in the pipes is removed by introducing, from time to time, a small iron rod or wire, which clears it away; if this operation be neglected, the outlets are apt to get clogged up, and the tension of the enclosed gases will endanger the explosion of the covers. Usually the period occupied in a single distillation is about sixty-six hours, or five distillations in fourteen days, in which from eight to ten tons of ore are worked off, with a consumption of twenty to twenty-five tons of coal. The metal obtained amounts to thirty-five or forty per cent. of the calcined ore employed. When no more metal is condensed, the refuse matter in the pots is discharged by removing the pipe in the bottom and the cover, and then raking it out through the bottom aperture; after this operation the latter is plugged, to prepare the retort for receiving another charge. Each pot serves to distil about forty charges before it gets broken; when this happens, the fragments are withdrawn through an opening made in the surrounding brickwork, and the place of the broken pot is supplied by another annealed at a red heat in a reverberatory, as mentioned above. The collected product of the distillation, which is chiefly in drops and fine metallic powder mixed with some oxide of zinc, is melted in a large iron pot set in brickwork, and heated by a fire beneath it, when the lighter oxide and other impurities form a scum on the surface of the bath of melted metal; the former is skimmed off, and the latter cast into bars or cakes, in which state it is sent to market.

PROCESS PRACTISED AT VIELLE MONTAGNE.—The mineral wrought at this establishment is a mixture of calamine and oxide of zinc, which is of a very compact and crystalline nature, intermixed with a gangue of clay in amorphous masses. As a preparatory operation, the mineral substance, as taken from the mine, is exposed to the air for the purpose of allowing the gangue to disintegrate, with the view of rendering its separation more easy and complete in the preparatory process to which it is submitted. There are two varieties of the carbonate treated, one of a reddish color, containing a considerable amount of iron; the other white and more compact. The ore is placed in heaps, and turned over from time to time to permit the air to pass through it more freely. After a period, varying from three to twelve months, the heap is picked, and the fragments of pure ore of the size of pigeons' eggs are selected from the rest. The refuse matter is then screened, and the coarser portions again picked out by hand; finally, the reduced fragments are washed upon the inclined plane, and the chief part of the clay is thus removed. There is a considerable difference between the periods required to disintegrate the two varieties of the mineral: by a

three months' exposure the red kind is sufficiently decomposed to part with the most of its impurities, whereas the white variety takes from nine to twelve months to effect the same change; in the former the loss averages fifteen per cent., whilst in the latter it often amounts to fifty. The selected ore is then calcined, sometimes in a reverberatory, but more frequently in a conical kiln, somewhat similar in form to that in which lime is burned, and which has the advantage of being continuous in its operation. Fig. 626 represents this kiln: it is heated by two lateral fires inclosed within an arch, the products of combus-

Fig. 626.



tion from which are draughted into the interior from a channel or flue by twenty different apertures, *o, o, o*, at various points of elevation. The bottom of the kiln inclines towards the drawing doors, *A, A*, owing to the two cast-iron plates of which it is composed, *f, f*, being laid together at an angle of 45°, and hence the descending body of calcined ore falls in almost equal portions towards each of the rectangular outlets already mentioned. Coal is preferred for heating in this case, owing to the high temperature necessary to calcine the mass of ore which is introduced at regular intervals at the top. After drawing out the roasted ore it is ground under headstones, and sifted, so that its fineness is insured; it is then mixed with its proper quantity of combustible matter, which may be charcoal or fine coal, and introduced into the retorts for smelting. These retorts consist of cylinders of refractory clay, closed at the end which is inserted into the furnace, and open at that one which protrudes; to this end is adapted another cylinder of sheet-iron of a conical form, for the purpose of condensing the metallic vapor, and this in turn has a third pipe of the same form, but much smaller, appended to it. These several parts are seen in Fig. 627, *A* being the retort, *B* the condenser, and *C* the outer cone;

Fig. 627.



the first is three feet eight inches in length, and six inches in diameter, the second is sixteen inches in length, and the third about the same, only that both taper, so that the aperture of the apex of *C* is not greater than three-fourths to one inch in diameter. These are placed in a peculiar kind of furnace represented in elevated section in Figs. 628 and 629, the

latter in the line *A B* of the former. The stack consists of four distinct furnaces, each in the form of a semi-cylindrical chamber, eight feet eight inches from the highest point of the arched roof to the floor, the back of the chamber being constructed so as to recede slightly from the bottom or floor upwards, as shown by *b d*, in Fig. 629, and the front, *a c*, being left open for the convenience of introducing the retorts. The fire which heats the chamber and its complement of retorts is shown at *F*, and is placed beneath the level of the floor of the smelting house, the combustible gases and other products passing upwards through four apertures in the grate, shown at *e, e, e, e*, and thence by a double flue, *G, G*, finding an exit overhead into the chimney, *C*. The latter forms one massive construction, embracing the four outlets, each closed by a damper. In each of the chamber furnaces forty-two retorts, *G, G*, are heated; these being placed in rows one above the other, as shown in the drawing, the posterior end resting upon a ledge made for the purpose in the masonry or brickwork. In the front the distillatory cylinders are supported by plates of cast-iron, so fixed at each side of the face of the furnace as to allow the cylinders to slope downwards from the back to the front. Before placing the retorts in this furnace, a brisk fire is maintained in it for some time, so as to bring the interior to a bright red or white heat, the face of the furnace being built up with bricks or fragments of broken retorts. When this condition has been attained, the cylinders, which should be previously heated to redness in a reverberatory, are fixed in their places one by one, the interstices between each retort at the front being closed up with fire-clay. At first, a small quantity of the mixture of ore and coal is submitted to reduction in the cylinders, the condensing cone and adapter attached and luted, and any metal given out collected in the manner presently to be indicated. These preliminary charges are successively increased for a period of three or four days, or until the furnace is found to be in a proper working condition. At this period the charge attains its mean, and consists of one thousand one hundred pounds of the roasted, ground, and sifted calamine, intimately mixed with five hundred and fifty pounds of bituminous coal in fine powder, for the forty-two retorts. This is introduced into the clay cylinders by means of a long half-cylindrical shovel attached to a long iron handle, commencing with the lower retorts, and proceeding to the higher ones in succession. When all are filled, the flue, which is usually stopped by having the damper down, is

opened, and an increased firing resorted to. As the contents of the retorts attain a strong red heat approaching to whiteness, they evolve a considerable amount of carbonic oxide, which burns at the mouth of the cylinders with a bluish flame; after a while the appearance of

the flame becomes more brilliant, and of a greenish white, showing that portions of the zinc vapor have been volatilized. As soon as this symptom is observed, the iron condensing tubes are attached to the open end of the retorts, the joining is well luted with refractory clay, and finally the adapters being fixed upon the condensers and luted likewise, the distillation and recovery

of the zinc are proceeded with. Every attention is now given to equalize the heat in the interior of the furnace, in order that the upper retorts may be worked off equally well with the lower ones; but this result can

seldom be exactly attained, and to compensate for this defect the more easily reducible ores are charged into the upper retorts, and the more refractory into the lower ones, where the heat is greatest. At intervals

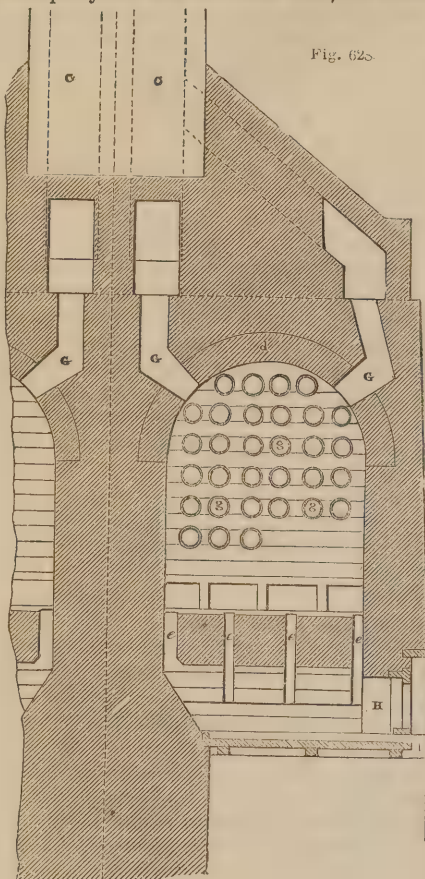


Fig. 625

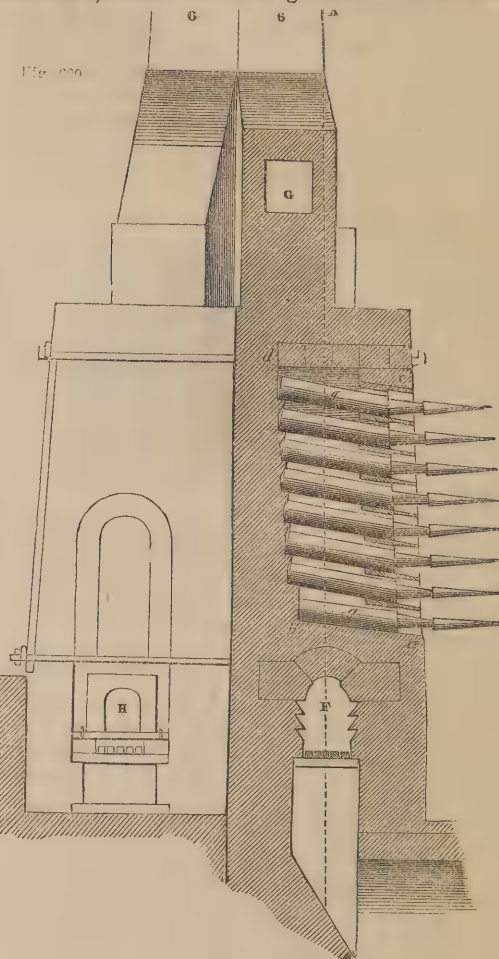


Fig. 626

of two hours after the distillation commences, the outer adapter is removed by means of tongs, and the oxide of zinc, or *cadmia*, collected in it is removed, to be again submitted to the retorts in a succeeding charge. An assistant then holds a large iron ladle, called a *poëlon*, under the mouth of the condenser pipe, and the smelter rakes out the fluid zinc at the bottom of it, as well as the drops of metal attached to the sides and other parts. After carefully separating the oxide of zinc which covers the metal thus abstracted, the latter is cast into ingots, weighing from seventy-five to eighty-five pounds. The adapters are then replaced and secured as before, and after two hours the zinc produced is again removed in the manner stated.

A charge of ore commenced at six in the morning, and worked in this way, is found to be exhausted of its reducible metal at five in the afternoon, so that two charges are worked in the twenty-four hours. When one operation is finished, the adapters, con-

densers, and retorts are thoroughly cleansed and scraped out before the next charge is introduced; and the oxide resulting from every operation and collected from the adapters and skimmings, is worked up as part of the ore of the preceding charge. The argillaceous residue cleared out of the retorts after the distillation has ended, is found to contain as much as ten per cent. of zinc; but being in the form of silicate of oxide, it resists the action of the charcoal and remains intact. About thirty per cent. of the calamine submitted to reduction is obtained in the form of metal. The distilling campaign lasts two months, during which time the fires are maintained at their greatest activity consistent with the work to be accomplished. At the end of this period, the necessity for repairs and replacing old retorts compels a cessation of the smelting for the time required to effect the necessary renovation.

Process for the Smelting of Zinc Ores in Upper Silesia.—The ores of zinc worked in this district

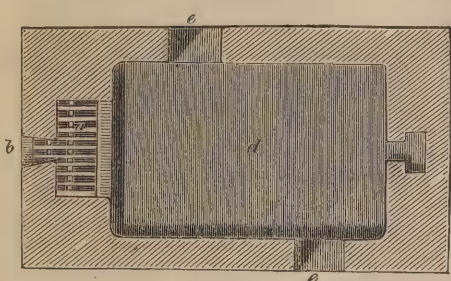
are principally a carbonate mixed with some oxide, having a calcareous and argillaceous gangue; and as

Fig. 630.



the latter ingredients would materially impede the reduction of the principal compound, the oxide of zinc,

Fig. 631.



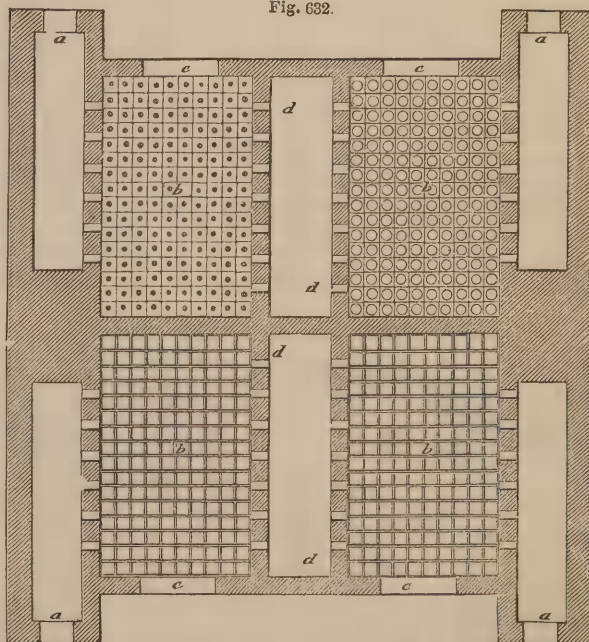
they are as far as possible removed by processes of disintegration and washing analogous to those already mentioned in connection with the Belgian method.

As in the English and last mentioned smelting establishments, the purified calamine is here submitted to a preparatory calcination for the purpose of expelling the water and carbonic acid. The furnace used for this purpose is shown in Figs. 630 and 631. It consists of an ordinary reverberatory, of which *a* is the fire-grate, *b* the doors by which the fuel is introduced, *c* the fire-bridge, *d* the interior of the furnace, the bed of which is constructed of ordinary bricks, *e e* the working doors by which the charge is rabbled and worked during the calcination, *f* the flue leading to the chimney, and *g* the superior aperture whereby the ore is charged upon the bed of the furnace. The latter is lighted in the usual way, and as soon as the interior attains a strong red heat, from thirty to thirty-five hundredweight of ore are introduced at *g*, the workmen spreading it out upon the sole with rakes at the working doors; this done all the openings are closed, and the roasting is allowed to proceed uninterruptedly, with the exception of an hourly rabbling for the purpose of exposing a fresh surface of ore to the flame, till the whole of the moisture and carbonic acid is expelled. The completion of the work is judged of by the apparent heat of the interior of the

furnace, the facility with which the ore falls to powder, and its change of color, which in case of the red calamine being operated upon should be brownish, and of the white calamine brownish-red. When these appearances are observed the charge is drawn, and a second, which had been placed on the platform in the interval between the charging and drawing of the roasted ore, introduced in its stead, the largest fragments from the last operation being ground and added to the fresh ore to be recalcined. Four charges are thus treated in the twenty-four hours, making a total of nearly six and a half tons of ore, which yield about seventy-two hundredweight of calcined calamine, with a consumption on an average of twenty-three bushels of fuel.

The Carinthian Process.—Here the furnaces are worked on the same principle as the English ones, but the details are different:—Figs. 632 and 633 show a plan and sectional elevation of the Carinthian furnace. As at the *Vieille Montagne* smelting works, four furnaces are connected in one block with one chimney; they consist of rectangular chambers arched over at the top, *b b b b*, heated by fires, *a a a*, from which the heated gases and flame enter by openings, *a' a'*, to the space occupied by the retorts. Above the sole of the retort chamber, *b*, is placed a trellace work of iron, in the squares of which the vertical retorts, *p p*, are fixed by means of a clay conductor, *n*, which receives the zinc separated in the vertical cylinder. *c c c c* are the side doors affording ingress for placing the conductors and retorts in position for operations, *et cetera*; *d d*, outlets for the waste gases from the furnace into the flues, *e e e e*, leading to the chimney, *h*. Beneath the conductors, *n n*, is placed a flooring of plate-iron, *r r*,

Fig. 632.



resting on cross supports, as well for receiving the zinc which falls in the course of the distillation as for excluding the atmosphere, and thereby preventing

the reoxidation of the metal. Each of the distilling compartments admits of erecting one hundred and sixty-four vertical retorts with their conductors, but the four ranges more distant from the heat contain only

Fig. 633.

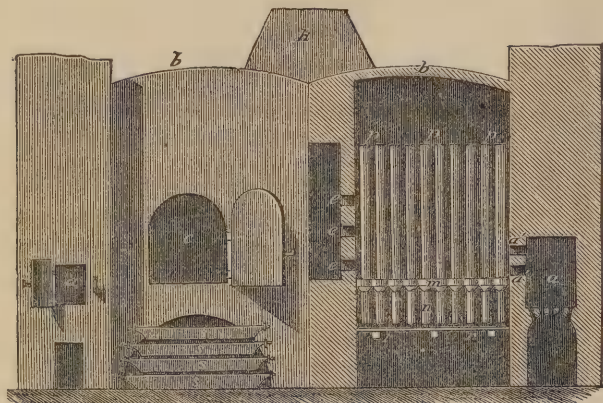
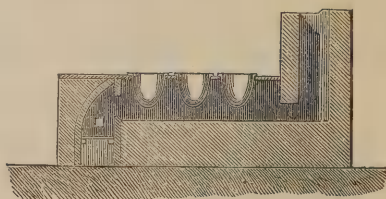


Fig. 634.



Fig. 635.



empty cylinders in process of being baked by the waste heat; and even for those within the range of a distilling temperature a different mixture is made for the charging according as the cylinders are nearer to or more distant from the fire. This mixture has the following composition:—

	For the four ranges nearest the fire.	For the other two ranges.
Roasted calamine,.....	1820 lbs.	520 lbs.
Wood charcoal, ground,.....	504 lbs.	224 lbs.
Common salt,.....	36 lbs.	16 lbs.
Water charged with 1-200ths of potassa, 280 lbs.		70 lbs.

The four first ranges contain sixty-four cylinders, whereas the following two contain but twenty; the remaining spaces being left free for the passage of the products of combustion. Two adjoining furnaces are always worked together, and in these one hundred and sixty-eight cones are in operation. During the course of the distillation, which occupies thirty to thirty-six hours, the consumption of wood as fuel amounts to seven hundred and fifty cubic feet, and the proceeds average eight hundred pounds of metallic zinc.

Considerable loss of time, fuel, and retorts is incurred from the intermittent nature of the process. After collecting the metal which falls upon the plate-iron flooring, indicated by *rr*, in the foregoing figures, it is refined from oxide and other grosser impurities by fusion in pots placed in a furnace, represented in plan and section in Figs. 634 and 635. After melting the metal in the series of pots shown in these furnaces, the scum of oxide, carbonaceous matters, *et cetera*, rises to the surface, and is removed by the ladle, and the purified metal is cast into moulds for the market.

Silesian Method.—In Upper Silesia the reduction of zinc ores is carried on by a distilling process in a muffled furnace, as will be described presently. The principal seat of the smelting is in Silesia, where, in 1848, there were no fewer than thirty-five establishments for the distillation of the metal. In the Rhine Province, at the same period, there were five, and in Westphalia one. With the growing demand for zinc, however, these establishments have, during the last ten years, been enlarged and rendered more effective, so that

Fig. 636.

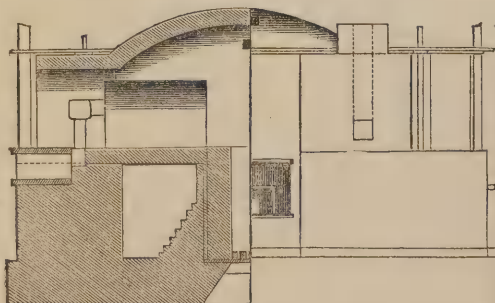
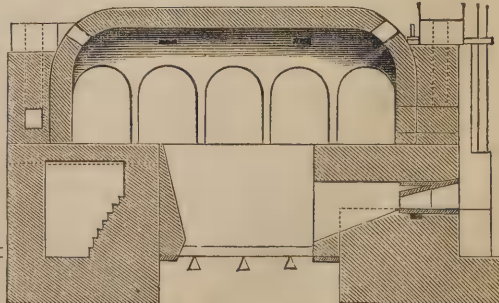


Fig. 637.



their capacity for working is greatly increased. It may be remarked that the *materiel* of the muffles consists of fire-clay, obtained from Ruda Krzeszowitz and Kattowitz in Upper Silesia, as also from Murau

in Poland, and which, after the necessary preparation, is mixed with reduced broken muffles, the whole being properly blended together to give the articles the necessary cohesion and compactness. The proportion of clay and potsherds is invariably two of the former to one part of the latter. These muffles are always made by hand, and submitted to a gradual course of

desiccation, then annealed at first at a very moderate temperature, and finally at a full red heat in a furnace especially constructed for the purpose, somewhat in the manner of making glass-pots.

Figs. 636, 637, 638, 639, 640, represent the ordinary furnaces, called *double ovens*, adopted in Upper Silesia for the reduction and distillation of zinc from its ores.

Fig. 638.

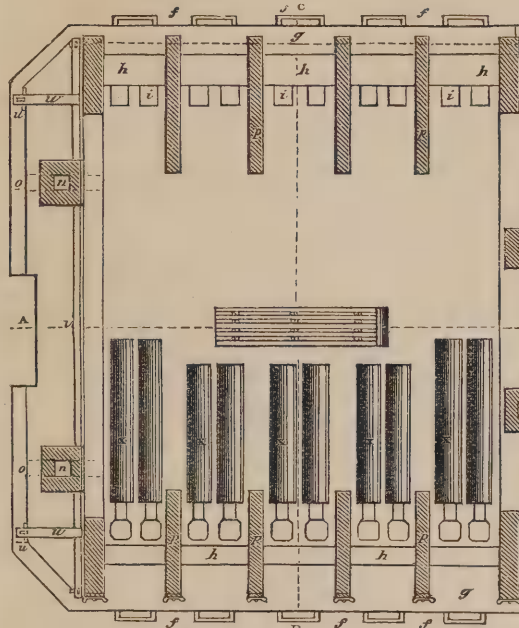
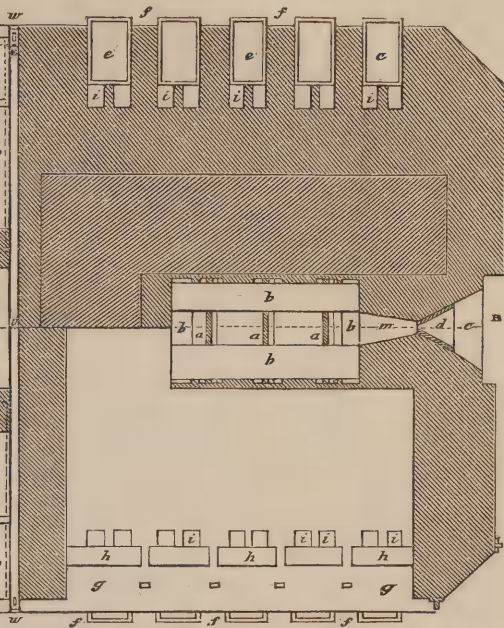


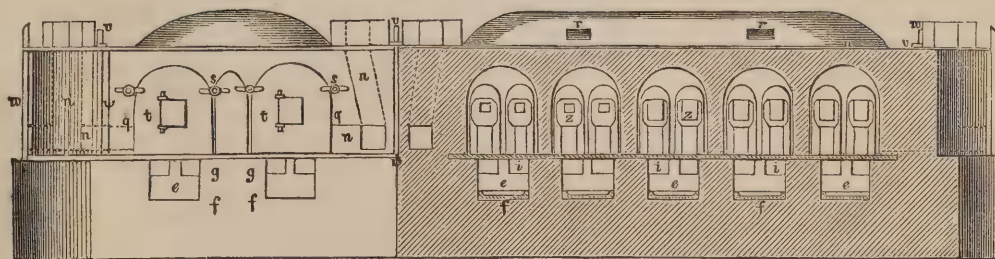
Fig. 639.



They have ten primary large chambers; but these in working are divided into twenty smaller parts, the large muffles being so constructed that the back wall is common to the two ranges. Fig. 636, is a section representing a longitudinal view to the left hand, following the line A B, and to the right the line C D in Fig. 637. Fig. 638 shows a ground plan at $a' b' c' d'$ in Fig. 636, and $d'' d''$ in Fig. 637, in the upper half of the left side, and in the under half at $a' b' c' e'$ in Fig. 636, and $e'' e''$ in Fig. 637. The portion to the right

exhibits the furnace vertically under the dome. The same letters indicate like objects in the several figures. Three triangular cast-iron bars, $a a a$, secured at each end in the walls of the furnace, bear four iron plates, $b b$, laid transversely, to form the fire grate; the whole constituting a rose over the air channel and ash-pit. The fire-door, c , which is lined near the grate with a cast-iron box, d , is closed with a door of plate-iron, the sole of the aperture being likewise secured by a similar plate; $e e$, *et cetera*, are inclosed troughs, into

Fig. 640.



which the distilled zinc trickles from the apertures of the retorts. The base of these is of iron plates, $f f$, to which deep iron bands are fixed for preventing the overflowing of the metal as it falls from the mouths of the retorts opening into them. All these receivers are closed by a single plate, $g g$, extending the whole

length of the oven, and called the *hearth-plate*. They are but one foot wide, and protect, therefore, only the front part of the receivers; the interior of the latter being secured by supplementary closely fitting plates, $h h$, touching the hind part of the openings, $i i$, and towards which is the connection between the dropping aper-

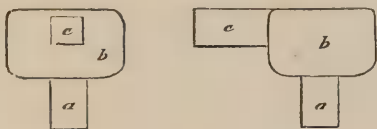
tures and receivers. These hearth-plates, in order that they may not be warped by the heat, are fastened by three cast-iron fluted anchors of the form of the letter Z. The walls, *l*, of the fire-chamber are constructed of the best fire-bricks; the connection between the fire and fire-door being an inclined canal, *m*. The upper rim of the fire-chamber is a few inches higher than the receiving troughs, so that the hearth slightly inclines from the middle to the side walls of the oven. The space between the posterior walls of the two adjoining ovens is filled with sand and rubbish; *nn* are side draughts for heating the rim muffles, and *oo* horizontal entrances for cleaning the same, which, however, are closed during the firing; *ppp*, *et cetera*, are pillars from three to five inches in thickness, constructed of clay, and furnished exteriorly with iron plates, *q*, secured to the hearth-plates, *gg*. These pillars form the support of the arches of the muffles which receive the retorts, as also of the overspanning dome. They should be as low as possible, so that the distance from the apices of the interior arches and the hearth be not more than three feet. The dome of the oven is constructed of a composition consisting of one-third part clay and two-thirds sand; its thickness when dry is eight or nine inches; *rr* are six cap or draught holes, by opening or closing which the heat can be directed towards any of the retorts which should happen to be working unsatisfactorily; *ss* hinges or clasps for fastening the doors, *tt*; *u* long bracing bars or anchors; *v* oblique ones, and *w* upright anchors, all applied for the purpose of giving solidity to the oven.

The retorts or muffles, *xx*, are set two and two within the muffle arches in the spaces between the pillars, *pp*, and placed as far back as possible, with their open faces to the front. When placed in their proper positions, the spaces between their walls and the pillars are blocked up with clay cement so as to confine the flame. The mouth of the retort is closed with a piece of clay called the bridge, *y*, and shown somewhat enlarged in Fig. 641. It has two openings; the under one, *a*, closed with a clay stopper during operations, for drawing out the residuary matter of the distillation, and the upper one, *b*, for receiving the neck of the conduit by which the vapors of zinc pass to the receivers. The latter part of the apparatus is seen in Fig. 642; the under part, *a*, is a clay pipe; the upper part consists of the head, *b*, and the neck, *c*. An opening in the head of this receiver serves for introduc-

Fig. 641.



Fig. 642.



ing the small charging shovel—Fig. 643—to spread the charge within the retort. It is closed like the opening, *a*, in Fig. 642, during the distillation.

Before the muffles are placed in the distillatory oven, they are subjected to a strong red heat in the furnace

employed for annealing them. They are then placed two and two in the arched chambers of the zinc oven, and charged with a mixture of sixty-six pounds of

Fig. 643.



roasted calamine and an equal volume of cinders or small coal—forming about five per cent. of the weight of the ore—together with a few pounds of oxide of zinc and abstrich or semioxydised skimmings from the collected zinc. All these are intimately mixed together before their introduction through the upper opening of the muffle bridge, the lower aperture meantime being secured with a plate and lute of clay. When charged, the neck and condenser are fixed in their places, and all apertures and cracks safely coated with luting. The iron doors in front are closed to retain the heat, and the firing proceeded with. Scarcely a quarter of an hour after the closing of the front doors of the muffles elapses when the metal begins to pass over; nevertheless the distillation is not in full activity till six to eight hours after commencing. As in the other distillatory processes already described so in this: the zinc, deprived of its oxygen by the coal in the body of the retort, passes off into the neck and head of the conduit in the form of vapor, and then condensing falls through the descending pipe into the plate-iron receivers. The combustion of a portion of the zinc cannot be avoided, as it is impossible to prevent the admission of some air into the receivers and conduits. It is owing to this, that a portion of white oxide is always found in the receivers, averaging from two to four per cent. of the metal obtained. At the close of twelve hours all the metal is extracted, and a second charge is introduced, without, however, clearing out the residue in the retort until at the end of the second operation, at which period a new bridge plate may be supplied if necessary, or any other repairs made. Care should be taken to change the muffles of both working sides of the oven every six hours after their setting in.

When the calamine contains much cadmium, it is found that the first portions of the distillate are very rich in this metal; and the oxide produced by the combustion of portions of the metal in the neck of the retort is likewise richer in oxide of cadmium, both effects being due to the volatility of the cadmium being greater than that of zinc. Six hundred pounds of roasted calamine are worked off by a furnace of ten large muffles in twenty-four hours, with charges for each retort averaging six pounds. The estimated consumption of coal per every hundred of zinc obtained is twenty-eight cubic feet; the loss of the metal is estimated at eight per cent., and of large muffles twenty-eight for every thousand pounds of zinc obtained. The average produce from the calamine operated on is about fifty per cent. in the form of metal and oxide. But as the ore varies in its content of oxide of zinc, so also does the yield. To purify the metal resulting from the first distillation, it is melted in iron

pots, and the scum of oxide and other impurities separated. This amounts to eight per cent. ; but as it contains about seventy per cent. of metal, and is submitted to a new reduction, a considerable amount of it is recovered.

At Kloster, where blende is worked, the apparatus and system of reduction are the same as that just described, with the exception of the roasting furnaces, in which the sulphide of zinc is converted into oxide. These are also the same as those that have been previously described, and consequently need not be further referred to.

PATENT PROCESSES.—The only patents connected with the manufacture of zinc which are of any importance, are those of TROUGHTON and GRAHAM; the former sealed in 1839, and the latter in 1845. Other patents have been secured, but the Editor deems it unnecessary to dwell upon them.

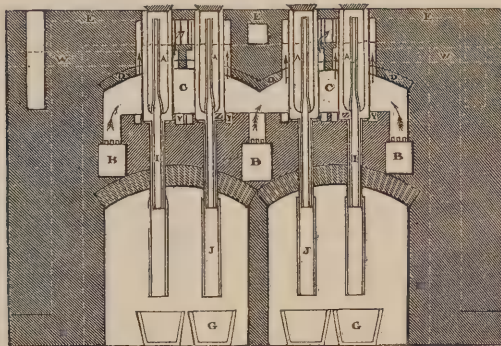
TROUGHTON's patent professed to deal with blende, and prescribes a form of furnace for the roasting, as also for the reduction. The first of these is in form like an ordinary reverberatory, with, however, three floors or hearths, on each of which the ore is spread, the heated gases and flame passing from the under chamber into the middle, and thence to the upper one, after which the gases proceed into the chimney. The connection between the several floors is made by apertures, covered by fire tiles during the roasting, but which are removed when it is necessary to transfer the ore through these openings from the upper to the lower ones. By apertures at the sides the contents of each floor are rabbled in the usual way. The charging of the ore is effected through hoppers at the top, and when roasted it is raked out into receptacles beneath the lowest hearth, by the workable openings already mentioned. A close fire, charged with fuel, which may be anthracite coal, and urged by a blast, affords the requisite heat; the opening for introducing the fuel being secured by a cast-iron cover, with a flange descending into a groove which may be kept filled with water or sand to prevent the escape of hot gases.

The fire by which the smelting of the roasted ore is effected is similarly constructed, and the combustion maintained by a blast of hot air. Though the plan as detailed in the English system is followed, yet the details are very different; the receptacles for the reception of the roasted ore and coal are constructed in the form of a trapezoid, the front part being movable when it is necessary to charge or clean out the retorts; but during the distillation it is securely luted in its place. Two ranges of retorts are placed back to back in a gallery, and the heat from the fire conducted beneath and over them by a proper disposition of the flue; and for the purpose of economizing heat, the patentee directs that the retorts be so fixed that they may be heated by a fire from both ends of the gallery. A pipe opening into the retorts, and leading to receivers in a confined arch beneath the hearth, serves to carry off the distillate or zinc. When charged and in working condition, the retorts are closed in by an iron door before each; the space above the retorts wherein the ore is previously heated, is likewise approached by sliding doors, with the view of

rendering the introduction of ore and its withdrawal more easy.

In GRAHAM's patents, sealed in 1844 and 1845, the system of distillation *per descensum* is adopted; improvements being claimed for the arrangement of the apparatus and furnace, as well as for the method of making the cylinders or retorts in which the decomposition of the prepared ore is carried out. The mixture which the patentee finds most suitable for the body of the refractory cylinders just mentioned, consists of one and a half hundredweight of Ceylon black lead; six hundredweight of Stourbridge clay; and one hundredweight of potsherds. These ingredients should be well pugged and tempered, and cut into pieces of convenient size, care being taken that no excess of moisture be used that would prevent the proper cohesion and tenacity of the mass when ramming it into the mould. Fig. 644 represents the furnace and the position of the cylinders and other objects. A, A, are a series of pots, of which the number shown in the furnace is sixteen, but more or less may be employed, according to circumstances. The heat from the fireplaces, B, B, enters into the

Fig. 644.



arched chambers, C, C, and circulates round the cylindrical retorts let down through the arches, D, D, and thence into the flues, as shown by the arrows, and finally by the openings, F, F, into the chimney. The pots, A, A, rise above the arches, D, D, and pass through the covering of brickwork, E; in like manner their outlet penetrates the bed of the arched chamber of the furnace, and opens into the receivers, G, G, beneath, through movable pipes, J, J, and stationary ones, I, I, the latter are constructed of iron and lined with clay, or have a movable clay cylinder fixed within them; they have an iron flange of two inches built in and through the bed of the furnace, in which is a projecting ring or groove, Z, Z, to receive an iron ring that forms the projecting rim just referred to, and which fits into a corresponding depression in the bottom of the pot, and thereby forms, with the aid of a little luting, a tight joint. Y, Y are rings made of fireclay and potsherds, built into the bed of the furnace, flush on the outside, leaving a space of one inch and a half inside, as shown, to form a seat for the pot. W, W are holes in the walls of the furnace, which admit of making an inspection of the pots when necessary.

In charging the pots, the pipe, J, is stopped from

beneath the furnace, and a man holds steady the internal tube, H—which has its top covered—until some of the charge is introduced; the remainder is then filled in without fear of disturbing the position of the pipe. The cover is now placed on the pot and luted, and the plug securing the pipe, J, withdrawn, and the distillation allowed to proceed by urging the fires, B, B, B. When all the metal has been drawn off, the refuse matter remaining in the pots may be cleared away by removing the cover and the internal pipe, and poking it out through the pipe, J, into the subjacent chamber.

In the other details the directions which the patentee gives are analogous to the general routine, already sufficiently described.

Mr. CROCKFORD of Holywell, Flintshire, has latterly patented a method of roasting blende preparatory to its smelting, by which all the sulphur is obtained as sulphuric acid. This he effects by employing a furnace the heat of which passes beneath the floor on which the powdered blende rests. At one end of this furnace, the blende is continually introduced in small portions at a time; and in its passage from this to the discharging end of the chamber, in addition to the heat from the floor, it is acted upon by a current of superheated air, in order to convert the sulphur into sulphurous acid. The eliminated gases may be conducted into an ordinary leaden chamber, and nitrous vapor and steam supplied from other departments in the usual way, to convert them to sulphuric acid.

After the depuration of the zinc distilled from the ore it is sold to the manufacturer, or immediately applied to one or other of the many purposes for which this metal is now so generally used. The working of zinc into useful articles was formerly regarded as a difficult operation, owing to its brittleness when worked at a high temperature; by later improvements, however, it can now be rolled and modelled into any desired shape as easily as any other metal. Preparatory to rolling the zinc, the ingots which come from the smelter are melted in pots placed in a reverberatory, such as is represented in Figs. 630 and 631. The iron pots, which are very thick, are rapidly attacked by the zinc, an alloy of the two metals being formed, which is considerably less fusible than the zinc alone, and therefore adheres to the sides of the melting pot. Besides being less fusible than zinc, it is considerably harder and more brittle, and hence, when a small quantity of it gets diffused through the metal in the casting of the plates, those portions do not laminate under the rollers, but break, and thus a hole is produced. All the fusible metal is first cast into moderately thick rectangular plates, which are passed under rollers of the ordinary kind as they cool. During the lamination it is necessary to heat the metal from time to time to a temperature ranging between 270° and 300°, passing it, after each heating, under the rollers. By repetitions of these operations, and keeping the metal as near 212° as possible, the sheets may be reduced to any degree of thinness. Sheets of zinc, manufactured in this way, are in very extensive use for roofing, and generally for applications requiring much exposure to the influence of the air. The metal is also formed

into water-tanks, baths, spouts, pipes, *et cetera*, and is much used for covering or *galvanizing* iron, so as to render it less liable to oxidize when exposed to the action of the air. It is valuable for the positive plates in galvanic apparatus, for the engraver in the department known as zincography, and latterly it has been advantageously applied in the separation of silver from its alloys with lead.

ALLOYS OF ZINC.—The principal alloys of zinc are those which it forms with copper, iron, and tin. Those with copper, the reader will find described under *Brass*, in the article COPPER, and the others will be briefly described here. With iron zinc forms a hard, brittle alloy, at a moderately low temperature, but in proportion as the amount of one or other of the metals is increased, these qualities disappear, and the zinc retains its ductility, or the iron seems to acquire greater tenacity. The ductile state is exemplified in the ordinary zinc of commerce, which retains a quantity of iron, sometimes from one to two per cent., and the second or tenacious state is well illustrated by the experiments of NASMYTH upon galvanized iron, the results of which showed that this alloy welds well, and is not only fully as ductile as the best iron, but acquires greater strength or tenacity.

The experiments were made with some zinced wire rope, which was worked up and welded into a bar. It was observed that, although the iron wire was quite covered with the zinc, the portion of the latter metal which was retained at the welding temperature of the iron, or even the portion of oxide of zinc produced, offered no impediment to the welding. The metallic bar produced was remarkably tough, silvery-grained, and withstood punching, twisting, splitting, and binding, in a manner which showed that the iron was not only excellent, but actually improved in quality in a considerable degree. Another trial was made by welding a pile of clippings of zinced iron plates, as in the preceding experiment. The presence of the zinc seemed to offer no impediment to the welding of the iron, and the bar produced presented, on being fractured, a beautiful silvery grain, as good, if not superior, in aspect to the finest samples of *low-moor*, or *bowling* iron. Bars or *blooms* of the alloyed iron, rolled into rods and tested in the cable-proving machine, indicated from five to ten per cent. more strength than the best samples of wrought-iron; thus evidently showing that, so far from being injurious, a small amount of zinc alloyed with iron has the contrary effect. Bars of iron, prepared according to the last-mentioned process, were heated to the temperature of welding, as when converting them into sheathing in the usual manner, on drawing them from the fire, a handful of zinc filings was thrown on the welding surface, and the welding proceeded with. In this severe test no apparent impediment to the process resulted, the iron welding as well as if no zinc were present. Judging from the appearance of the metal welded up from the zinc-covered iron scraps, not only as respects its clear silvery aspect, but as to the increase of strength which it exhibited under proof, it may not be unreasonable to infer that some important improvement might be made in the manufacture of iron by the actual introduction of metallic zinc in some one or other of the

stages of its production; as, for instance, in the puddling furnace. What may be the nature of the action of the zinc has not yet been defined, but the foregoing experiments prove that, so far from being prejudicial to the quality of iron, the zinc appears to have rather an improving effect, and that to such an extent as to lead to the hope that some of the intelligent iron manufacturers may give the inquiry attention, so as to prove by experiment in the puddling furnace, or at any other stage of the process, whether the benefits above mentioned can be realized on a large scale. It may be stated, as a curious corroborative fact, that the strongest cast-iron made in Belgium, and selected for the manufacture of guns, is made from an iron ore in which a compound of zinc forms a considerable portion. Whether the superiority of this iron is due to the presence of zinc, is a question; but the results above detailed would tend to lead to the supposition that such may be the case.—*Ure*.

The results of NASMYTH, recorded above, are opposed to those of GEHLEN, who states that when cuttings of zinc and iron are ignited together, part of the zinc evaporates, while the rest penetrates the iron and makes it denser and very brittle. Doubtless the difference in the results must be attributed to the relative proportions of the respective metals in the alloy. The hard, brittle compound of zinc and iron produced in the pots where zinc has been melted for a long time, or in which the zining of iron plates has been effected, was examined by BERTHIER, who describes it as a bright crystalline body, having a mammillated texture, and composed of concentric layers, very hard and brittle, and less fusible than pure zinc. It dissolves readily in dilute nitric acid, and leaves a micaceous residue of a non-metallic nature, which he terms pure plumbagine, produced, doubtless, either from the carbon employed in the reduction of the zinc ores, or from the cast-iron of the pot. Its density was 6·7, and its composition—

	Centesimally,
Zinc,	94·76
Iron,	5·00
Plumbagine, or graphite,	0·24
	100·00

Galvanized Iron.—The composition which forms such an extensive article of commerce and general application in the construction of corrugated roofing, and, in fact, entire buildings, spoutings, ships' sheathing, buckets, and various articles in household use, consists of iron plates coated with zinc, and sold under the above inappropriate title. Iron, though possessing so many admirable qualities, such great tenacity, infusibility, and the very important one of welding, is, unfortunately, rapidly acted upon by air, moisture, and dilute acids, to such an extent as greatly to impair its utility. It possesses the property, however, of combining with other metals, and hence it can be readily coated with such; but those metals which possess the persistent qualities that iron wants, are too dear, and therefore their general application is opposed by the great expense which their use would involve the manufacturer and consumer. Coated iron is familiar to most

people in the form of tinned iron plates, or *sheet tin*; but even this material would be too expensive for many of the applications in which iron might be employed with advantage could its oxidizing tendency be overcome. Zinc offers a cheaper substitute, and of late years the production and application of galvanized iron is on the increase. Although MELOUIN discovered the method of preparing zined or *white iron* so early as 1742, still its application did not receive much attention, till of late years SOREL drew attention to the manufacture; but MELOUIN's directions, with slight modifications, are followed even at present in the manufacture of this article. The iron to be covered is deprived of its coating of oxide by an acid bath, composed of sulphuric acid and water, or of hydrochloric acid, or a mixture of equal volumes of the two acids and water, in which it is immersed for a short time; it is then scrubbed with sand or emery powder until the surface is cleaned; after which it is immersed in a concentrated solution of chloride of ammonium, taken out, and subsequently introduced into a bath of melted zinc, covered with fatty matter, or colophony, to prevent oxidation, and stirred in it till the zinc forms an alloy at its surface. The coated metal is then, in some instances, introduced into a second bath consisting of melted tin, such as is used for tinning thin sheet-iron, when a slight coating of tin is formed on the exterior of the plate or bar. Of late years this second bath is generally dispensed with, a few pounds of tin being added to the zinc bath to produce the same effect.

According to MALLET's specification, the plates or bars are immersed in a cleansing bath, composed of equal parts of sulphuric acid, hydrochloric acid, and water in a warm state. After immersion the scales are detached by hammering and scrubbing the plates with emery and sand, and a thoroughly clean surface produced. It is now to be immersed in the preparing bath, composed of a saturated solution of chloride of zinc and sulphate of ammonia; after which it is transferred to a bath formed of six parts and a half of zinc and one of mercury, heated to the melting point of the former metal; in addition to which the patentee directs the addition of one pound of potassium or sodium to every ton of the preceding amalgam. When the immersed iron has attained the temperature of the bath, namely, 680°, it is withdrawn, and is found coated with a metallic layer, of which zinc forms the principal constituent. The affinity of the above alloy for iron is so great that it entirely disintegrates the iron plates, or other articles of this metal when they are thin, or possess but little body; and to guard against this inconvenience, the patentee suggests that some wrought-iron should be allowed to dissolve in the triple alloy previous to the introduction of small articles, such as wire, nails, light chains, and similar objects for galvanizing. Another means of coating iron with zinc is by electricity, and the use of a bath formed by the solution of freshly precipitated oxide of zinc in a saturated aqueous solution of sulphurous acid, or of that of the double chloride of zinc and ammonium. A moderately dilute bath and a weak current answer best. This method is not advantageous in a manufacturing sense,

the simpler mode of immersion being more expeditious and less costly.

Though iron coated with zinc is unquestionably better calculated to resist atmospheric influences without rusting than when it is without such covering, still zincing it is very far from being a uniformly successful protection against its oxidation, and in some cases it increases rather than diminishes this tendency of the iron. Professor CALLAN proposed an alloy of lead and antimony as a substitute for the zinc; but though the disadvantage experienced in many instances as resulting from the employment of zinc are certainly diminished by the use of the alloy, still the cost of the latter precludes its adoption.

Applications of Zinc.—Besides its long-practised application in the production of brass and other alloys, such as German silver, tutenag, *et cetera*, which the reader will find described under COPPER, zinc has been employed extensively in the form of sheets for the manufacture of baths, water tanks, buckets, pails, roofing, spouts, pipes; as a cheap and more durable substitute for sheet and japanned iron, such as architectural ornaments, street lamps; and for making nails, bolts, wire for preserving iron, applied in the form of wire plates to the numerous uses which are everywhere to be witnessed; as a substitute for bronze in statuary, for which purpose it has been found, irrespective of its color, to answer exceedingly well. It is also extensively employed for the positive plates of electrical batteries, for engraving music, in anastatic printing, and numerous other forms, alone and compounded with other metals. In its oxidized and salified state it has another extensive field of application, both in the industrial arts and in medicine, as will be noticed afterwards.

Assay of Zinc Ores.—The estimation of the amount of zinc in any of its ores by the dry method of analysis, is exceedingly difficult. As, however, the metallurgist may desire to have an approximation of the quantity of metal which he can probably extract from any ore, the following brief statement of the operation is submitted here, reserving fuller instructions for the analysis of zincous bodies in general for the end of the article.

BERTHIER, who has made numerous experiments on the subject of the assay of zinc ores, divides the latter into four classes, for each of which a particular method must be pursued. These are, firstly, ores in which the zinc exists as *oxide*, or *carbonate of the oxide*; secondly, those in which the zinc exists wholly or in part as *silicate of the oxide*; thirdly, ores in which the zinc is entirely or in part in the form of *sulphide*; and fourthly, *alloys of zinc*.

To reduce ores of the first class, it is only requisite to mix them intimately with charcoal, and expose the assay for a sufficient time to a white heat in an earthen retort, having a long neck kept sufficiently cool to condense the metallic vapors that are expelled by the heat from the reducing mass. Care must be taken that no air be admitted into the retort, for this would induce the combustion of the metal while in a state of vapor; its neck should therefore terminate in a small opening, or an adaptor of glass drawn to a point be fixed to it

by luting. During the reduction the following simple interchange takes place:—



Even when the reduction is thoroughly effected, it is most difficult to detach the incrustation of metal sufficiently complete for accurate determination. To facilitate this the neck of the retort is coated interiorly with plumbago to diminish the adhesion of the distilled zinc to the body of the apparatus. When all the metal is reduced and driven over, the assayer is often necessitated to break off the neck of the retort to enable him to collect the metal, and not unfrequently to dissolve the adhering particles with nitric acid, and evaporate and calcine the residue, adding the four-fifths of its weight to that of the metal already estimated.

Another process by which the estimation of the zinc may be indirectly made is given as follows:—A certain portion of flux is added to the weighed ore, submitted to the test, and the whole heated at the temperature at which the assaying of iron is usually conducted in a lined crucible. The button of slag containing granules of iron resulting from the ferruginous matter in the ore, is weighed, then ground in a mortar, and the iron, separated by a magnet, likewise weighed. After deducting the iron thus estimated from the total weight of the button of fluxed matter, the remainder is added to the oxide of iron, corresponding to the amount of this metal found as above. The combined weight, deducted from that of the dry ore and flux, leaves a difference corresponding to the zinc expelled during the assaying in the fire. Again, if the quantity of the fixed flux employed be taken from the weight of the button of slag obtained minus the iron, the difference will show the silicious, earthy, and other unreducible matters associated with the zinc.

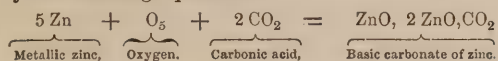
In the examination of ores of the second class, charcoal alone is insufficient to effect the decomposition, and therefore a flux is employed which, by combining with the silicious matter, liberates the oxide of zinc, and renders it subject to reduction by the carbonaceous matter. Lime or magnesia are the agents usually adopted.

When ores of the third class are under examination, the weighed sample is roasted, to convert the whole of the sulphur into sulphuric acid and partly expel it by the heat; after which the reduction is effected in the same way as directed for the determination of the metal in the first class of ores.

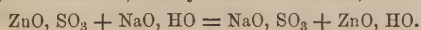
Alloys of zinc with fixed metals, or the compounds of the fourth class, are examined by adding a determined weight of fixed flux, mixed with some charcoal, and heating in a lined crucible at the temperature of the iron assay; all the zinc is volatilized, and from the loss of weight so sustained the amount of zinc is estimated approximatively. If the alloyed metal be of a volatile nature, this course will not afford true results, and the estimation of the constituents of the compound must be effected by the humid assay, which indeed is the most trustworthy, and in the end the most expeditious for the analysis of all zincous compounds.

COMPOUNDS OF ZINC.—Zinc is capable of uniting with almost the whole of the metalloids and salt radicals, producing compounds, which in all instances are of great importance in the arts, and have consequently a very extended application. Its oxygen salts, like those of magnesia, have the property of forming saline compounds with other substances, the importance of which is entirely confined to the department of scientific chemistry connected with stoichiometry. Another remarkable behavior of zinc is, that it readily combines with several organic radicals, such as ethyl, methyl, and radicals of the alcoholic series of compounds, as shown by the very scientific researches of FRANKLAND and others. Several of the combinations of this metal are employed in medicine; and, by a remarkable coincidence, these so employed are most useful in many industrial applications. It will be sufficient to describe here the oxide, the carbonate, sulphate, acetate, and chloride of this metal.

OXIDE OF ZINC.—This compound has various designations, most of them given by the alchemists. Its ancient synonyms were *nihil album*, *lana philosophica*, *flowers of zinc*, *pompholyx*, and occasionally it is still known as *flowers of zinc* or *flores zinci*. When submitted under certain circumstances to the influence of air and moisture, zinc is acted upon in various ways, all of which result in producing the oxide, or a compound from which the oxide can be readily prepared. Thus, when the metal is heated to redness in a free current of air, it burns with a brilliant bluish-green flame producing oxide of zinc. Again, if the zinc be exposed to air and moisture, it is transformed into the same compound; or if carbonic acid should be present, into a basic carbonate of the oxide. In these cases, simple and direct oxidation takes place, the oxide combining, in the latter instance, with a certain amount of carbonic acid. This is the nature of the change which is produced on the surface of zinc exposed to the air, as in roofings, *et cetera*, and which conduces so much to its preservation. It is illustrated by the following equation:—



When zinc is dissolved in sulphuric or nitric acid, the oxide is freely formed, though only in the proportion requisite to produce a salt with the acid employed. In this state it exists in the salified state, but on abstracting the acid by interposing a stronger base, such as soda, the hydrated oxide falls, thus—



The same change takes place when the solution of zinc in hydrochloric acid is acted on, although the oxide does not pre-exist in the menstruum, for at the period of the removal of the radical of the salt the oxygen of the precipitant is assimilated by the zinc, as shown in the equation—



Oxide of zinc is prepared either by the ignition of the metal in a current of air, or by its solution in acids and subsequent precipitation by any convenient agent. If pure oxide be required, the first method will not yield it unless the metal be free from all extraneous metalliferous

matters, which is never the case with the commercial article. In the second method the impurities existing in the zinc can be removed previous to the precipitation of the oxide, and consequently this method is preferred when it is important that no foreign matter should exist in the preparation.

In operating by the first method, a hessian crucible is filled with zinc to one-eighth its capacity, and then placed in a wind furnace so inclined that the lower part rests upon its edge on a piece of tile at the bottom, whilst the upper part is supported by the rim of the furnace. The fire is then urged till the crucible and contents attain a strong red or white heat. At this period a scum of oxide appears on the metal, and must be removed with an iron spatula as fast as formed, till the combustion of the zinc is completed, when a fresh charge may be introduced. The oxide as collected is placed upon an iron plate to cool, and is afterwards rubbed up with water to the consistence of a thin pasty mass, which is next diluted largely, allowed to settle for a few minutes and then decanted, more liquid being agitated again with the subsided matter, and treated, after a minute or two's repose, in the same manner. By continuing the treatment so long as the decanted liquors flow off milky, all the oxide is separated from the metallic matter which escaped ignition in the crucible, and which may be introduced with another portion of zinc to undergo fresh combustion. All the decanted liquors are collected together and allowed to subside perfectly, when the clear water is poured off, the deposit thrown upon a cloth filter to drain, and finally it is dried at a gentle heat. The yield of zinc oxide obtained in this way, when the whole of the metal is burned, will be somewhat more than the weight of the zinc employed.

When the oxide is to be prepared by the liquid process, rectified sulphuric acid, diluted with ten times its weight of water, is poured upon the zinc previously rolled into thin sheets, or granulated by pouring it whilst in a molten state into a vessel of water, employing an excess of the metal with the view of causing the foreign matters, such as lead, tin, cadmium, bismuth, arsenic, *et cetera*, to be precipitated; or a solution of crystallized sulphate of zinc in thirty parts of water may be taken, immersing in it for forty-eight hours a few thin plates of zinc, which act in the removal of any foreign bodies in the same way as the excess of metal in the foregoing method. The clear solution is decanted in either case, or strained, if necessary, and a hot concentrated solution of carbonate of soda is added to it as long as a precipitate forms. This precipitate, which settles much more readily when thrown down from hot solutions than from cold ones, is now washed with hot distilled water by decantation, till no further trace of sulphuric acid is detected in the washings with a solution of chloride of barium. After thorough washing it is collected on a cloth filter, allowed to drain, pressed and dried, and finally heated to redness in a hessian crucible, till the whole of the carbonic acid is expelled, as evidenced by its not effervescing on the addition of dilute acid.

Properties.—Oxide of zinc is a white, tasteless, inodorous powder, which at red heat acquires a yellow

color, that vanishes on cooling. When subjected to a higher heat it melts into a yellow glass, and at a sustained white heat volatilizes. It is insoluble in water, but readily soluble in acids, giving rise to the corresponding zinc salts. When freshly precipitated, oxide of zinc is readily soluble in alkaline solutions, as also in concentrated ones of sesquicarbonate of ammonia, producing compounds in which it assumes the characters of a salt radical that are called *zincates*. Heated with charcoal it is readily reduced to the metallic state.

Uses.—Oxide of zinc is employed principally in medicine. Latterly, however, it has been successfully introduced as a substitute for carbonate of lead—white lead—in the manufacture of paint; and to meet this extended use several processes have been devised for its preparation, to which reference will be made presently. The oxide has been prescribed in some cases of epilepsy, chorea, hysteria, catalepsy, and whooping-cough, as well as in some painful affections of neuralgia and gastrodynia, with occasionally good effect, though its frequent failure has shaken the confidence of practitioners in its efficacy. It has been found serviceable in five-grain doses, combined with extract of henbane or hemlock, in colliquative perspiration. It is useful as a desiccant to allay or prevent excoriation in children, as well as in cases of chronic skin diseases, attended with profuse secretion, and also in other ailments of a similar nature. In large doses, oxide of zinc acts as a slight irritant and causes vomiting, and by long-continued use it acts as a slow poison.

Oxide of zinc is composed of—

	Atomic weight.	Centesimally.
1 Eq. of zinc,	32.0	80.0
1 Eq. of oxygen,	8.0	20.0
	40.0	100.0

Its chemical symbol is ZnO.

CHLORIDE OF ZINC—*Muriate of zinc; butter of zinc.*

—This compound of zinc has long been known and applied in medicine. It is prepared by adding hydrochloric acid of specific gravity 1.130 to granulated zinc portionwise, and applying heat till the latter is dissolved. Four parts and a half of acid are required for every part by weight of metal for its perfect solution. A few fragments or thin plates of zinc are introduced into the solution, and set aside for twenty-four hours, during which time any lead, tin, antimony, cadmium, or other metals of this class that may be present in the liquid, are precipitated; after this, the clear liquid is separated by filtration from the deposit that may have formed, and about one-sixteenth of its bulk precipitated, with a very slight excess of carbonate of soda, the basic carbonate separated and well washed while on the filter, and then introduced into the remainder of the liquid. Chlorine, generated in the usual way from binoxide of manganese and hydrochloric acid, is now passed into the menstruum till it smells of the gas. A further period of twenty-four hours is given to the liquid to stand, and if, after this period, a portion of the clear solution exhibits any indication of the presence of iron, either by giving a bluish-black color with tincture of galls, or by striking a deep blue with ferricyanide of potassium—red prussiate. A further

portion of the liquid is taken and precipitated with carbonate of soda, as above, and the mass so obtained, after thorough washing, is added to the liquor containing the zinc, allowed to digest for a further period, and afterwards tested for the presence of iron in the manner indicated. If necessary, the process is to be repeated a third and a fourth time, or until the whole of the iron is separated in the form of sesquioxide; but it rarely happens that this metal remains after the second digestion. After filtering from the formed deposit, the liquid is evaporated in a porcelain or hard stoneware dish on the sand-bath, taking care, as it becomes denser, to keep the contents of the vessel constantly stirred, till the whole of the water is expelled. Chloride of zinc remains, and should be transferred, whilst still hot, to well covered vessels for use. When it is necessary to deprive it of the whole of the water, the residue from the evaporation should be introduced into a glass vessel with a narrow neck, and heated at a higher degree, till the chloride of zinc begins to distil, at which period the fused matter is poured out on a slab, and when cooled broken into fragments, and preserved in well-stopped bottles.

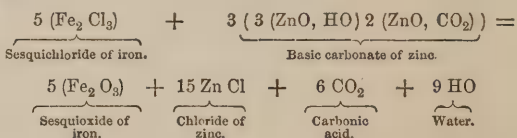
In the preceding process the action of the acid is simple and well understood, its chlorine uniting with the metal, while its hydrogen is disengaged, thus—



The action of the chlorine is to convert the iron, which always exists in commercial zinc, from the state of protochloride to which the hydrochloric acid reduces it, to that of sesquichloride, as shown in the equation—



with the view of precipitating it subsequently with the basic carbonate of zinc—3 (ZnO, HO) 2 (ZnO, CO₂)—produced by the carbonate of soda in the portion of the liquid submitted to its action. The manner in which its separation is chemically effected may be represented thus—



that is, three equivalents of the basic carbonate convert five of the iron salt into five equivalents of insoluble sesquioxide, being themselves reconverted into fifteen equivalents of the chloride of zinc by the assimilation of the chlorine from the iron compound.

Chloride of zinc may be prepared by other processes, such as heating equivalent weights of oxide of zinc and chloride of ammonium, or by distilling a mixture of dry sulphate of zinc and chloride of sodium in a retort, the substances being employed in the ratio of their equivalent weights. In either case chloride of zinc results, the change in the former being $\text{NH}_4 \text{ Cl} + \text{ZnO} = \text{NH}_4 \text{ O} + \text{Zn Cl}$; and, in the latter, $\text{ZnO, SO}_3 + \text{Na Cl} = \text{Zn Cl} + \text{NaO, SO}_3$. The salt in the first formula remains after the expulsion of the ammonia; but in the second instance it distils over, leaving the

sulphate of soda in the retort. Preference is, however, generally given to the method of preparation by solution.

Properties.—Chloride of zinc, deprived by fusion of all moisture, is a whitish-grey, semitransparent soft mass, like wax, that melts at a temperature below redness, and at a higher degree of heat sublimes, being at the same time partially decomposed into a basic chloride of zinc and an acid salt, which collects in crystalline needles in the receiver, and oxide of zinc retaining a little of the chloride that remains in the retort. Exposed to the air, the salt rapidly attracts moisture and deliquesces. It has a burning, nauseous, saline taste, even in highly dilute solutions. Alcohol and ether readily dissolve it, the solutions manifesting an acid reaction. It unites with chloride of ammonium and chloride of potassium, and forms definite compounds with them, likewise with albumen and gelatin, producing difficultly soluble precipitates. The alkalies and alkaline carbonates decompose it, giving rise to precipitates of oxide and basic carbonate of zinc, according to the agent used, but which precipitates, as stated under *Oxide of Zinc*, are soluble in an excess of many of these reagents, owing to zincates of those bases being formed. Sulphuric acid readily converts the chloride into a sulphate of zinc, with evolution of hydrochloric acid. The pure salt has a composition corresponding to the symbol Zn Cl , being composed of—

	Atomic weight.		Centesimally.
1 Eq. of zinc,.....	32.0	....	47.407
1 Eq. of chlorine,.....	35.5	....	52.593
	67.5	....	100.000

The composition of the hydrated salt is Zn Cl, HO ; it is crystalline, and contains, according to SCHINDLER, in one hundred parts—

		Centesimally.		Schindler.
Zinc,.....	32.0	=	41.83	.... 39.80
Chlorine,....	35.5	=	46.40	.... 43.81
Water,.....	9.0	=	11.77	.... 16.39
	76.5		100.00	100.00

Uses.—Owing to its physiological effects, the chief use of chloride of zinc is in medicine; but latterly it has been successfully introduced as a disinfectant, and likewise for impregnating wood in order to preserve it from decay or putrefaction. Its use has been much extended in the first application by its qualities as a caustic or escharotic, destroying the life of the part with which it comes in contact, owing to its combination with the albumen and fibrin of the tissue, which substances appear in the form of an eschar some time after. Many prefer chloride of zinc in this capacity to nitrate of silver, and even to chloride of antimony, as it penetrates further, and leaves the wound or sore in a more healthy state after the removal of the eschar. When taken into the system, chloride of zinc acts, in large doses, as an irritant or caustic poison, and affects the nervous system. It produces a burning sensation in the stomach, nausea, vomiting, anxiety, short breathing, cold sweats, fainting, and convulsions. In very small doses, none of these effects are attendant upon its use.

Sir WILLIAM BURNETT introduced a concentrated

solution of this compound some years ago, as a disinfecting and antiseptic fluid. The liquid contained about one-fourth of its weight of the salt, and had a specific gravity of 2.0. Its antiseptic qualities depend upon its power of uniting with animal tissues, and forming permanent bodies with them; and hence its use in preserving anatomical subjects for dissection; its disinfecting quality arises from its power of decomposing sulphide of ammonium and sulphide of hydrogen to some extent. It is inferior, however, in this respect to a solution of chloroxide of calcium—bleaching powder—and several other combinations, as stated under *Disinfectants*—owing to the latter being not only capable of arresting gaseous emanations, but also of disseminating a disinfecting gas into the air which arrests any foul odor immediately.

SULPHATE OF ZINC—*Zinc vitriol*; *white vitriol*.—This salt, which is said to have been known at the end of the thirteenth century, has been long manufactured on a large scale at Goslar in Germany. It was long erroneously considered as a modified sulphate of iron, but this notion was abandoned when the true metallic nature of zinc became known. It is much more important than any other saline combinations of the metal, as well for its cheapness as for being the means of preparing the other compounds of zinc, and likewise for the extended uses to which it is applied in the arts and in medicine.

Preparation.—At Goslar, where sulphate of zinc was first extensively manufactured, as well for the preparation of Nordhausen vitriol as for application in the medicinal art, the following process was adopted:—

The natural deposit of ore, consisting of sulphates of zinc, lead, copper, silver, and iron, was assorted to obtain the portions richer in zinc; these were submitted to a roasting operation in heaps, during which the sulphur was converted into sulphuric acid, and by this the metals were changed into the corresponding sulphates; the mass was then lixiviated, and the soluble salts, consisting of sulphates of zinc, iron, cadmium, copper, and silver, washed out, and afterwards evaporated till the sulphates crystallized. The impure salt, after slight washing, was heated to the melting point, and the whole, or chief, part of its water of crystallization expelled. On allowing the mass to cool at this stage, it formed a white opaque granulated substance resembling sugar. At a later period this product was freed from portions of its impurities by re-solution in water, and introducing into the lie fragments or plates of zinc, which were allowed to remain in contact with it for a longer or shorter time. After drawing off the clear liquid, it was evaporated, and the zinc salt crystallized out as before. This method is still practised, not only at Goslar, but in several other localities where blende is abundant.

Sulphate of zinc is obtained at present as a secondary product from the acid liquors of galvanic batteries employed in developing electricity, as also from the liquors remaining after the precipitation of copper on the large scale from its solutions, by metallic zinc.

The pure salt may be obtained by treating commercial, or purified zinc, in a divided or granulated state, with sulphuric acid diluted with fifteen times its weight

of water, in a leaden vessel, using the acid while still warm; three parts of rectified acid of specific gravity 1·84, are required to convert two parts of the metal into a sulphate. The mixture is sustained at a gentle heat in order to promote the solution, and with the same view the contents of the vessel are agitated occasionally. After the solution is effected, a quantity of metal, about one-eighth of the portion dissolved, is introduced into the liquid, and left to repose during thirty to forty-eight hours, the slight heat being still maintained. By this treatment the lead and other less oxidizable metals are precipitated, and are separated by filtering the liquid while still hot. The filtrate is now largely diluted with water, and a portion of it taken, precipitated with carbonate of soda, as stated under the preparation of chloride of zinc, filtered, washed, and added to the remainder of the solution of the sulphate. Chlorine is then transmitted into the mixture till the protosalt of iron present in it is converted to a sesquisalt; after which the whole is allowed to stand till the iron falls in the form of sesquioxide. The various changes by which the purification of the salt is effected in this instance, are analogous to those specified under *Chloride of Zinc*, and therefore need not be detailed. After filtering the liquid from the deposit of sesquioxide of iron, it is evaporated till a pellicle begins to form on the surface, when it is permitted to rest to allow the salt to crystallize. A second crystallization removes all traces of impurities, but this is rarely required.

Properties.—Sulphate of zinc crystallizes in colorless, transparent, right rhombic prisms, containing seven equivalents of water of crystallization. In this state it is very soluble in water, requiring somewhat less than its weight of cold, and considerably less than its weight of the boiling liquid; thus, according to KARSTEN, one thousand parts of water at 63·6°, dissolve nine hundred and twenty-three parts of this salt, forming a solution, the specific gravity of which is 1·4353. DUMAS states that one hundred parts of water, at the ordinary temperature, take up one hundred and forty parts of the sulphate; while other authorities assert that not less than two and one-third parts of water are necessary for the liquefaction of one of the salts, which is evidently erroneous. Boiling water takes up a much larger quantity of the salt, and even alcohol dissolves traces of it. Sulphate of zinc, according to the circumstances under which it is prepared, is found associated with different quantities of water of crystallization, varying from one to seven equivalents; but the compound crystallizing from its solutions at temperatures below 80° to 86°, always assimilates seven equivalents of water. This salt effloresces slightly in the air; exposed to a heat of 212° it loses 37·3 per cent. of moisture, or six equivalents, the last equivalent being obstinately retained till the heat rises to 451°. By the sudden application of a high temperature the compound at first fuses, and after the expulsion of the contained water, decomposition of the salt follows; anhydrous sulphuric acid, sulphurous acid, and oxygen being eliminated, while a highly basic salt remains. On continuing the heat, however, till it approaches to whiteness, only pure oxide of zinc is left. Heated with charcoal at a red

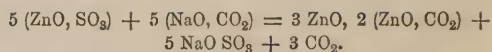
heat, it is reduced to the form of sulphide; but at a sustained white heat, the metal is isolated and volatilized in the form of vapor. Anhydrous sulphate of zinc, on being exposed to moist air, readily assimilates its full complement of water of crystallization with reagents. It affords the usual reactions of oxide of zinc in a salified state, and is capable of forming numerous double salts with other bodies. Sulphate of zinc, in its crystallized form, is represented by the formula $\text{ZnO}, \text{SO}_3, 7 \text{HO}$, and is composed of—

	Atomic weight.	Centesimally.
1 Eq. of oxide of zinc,	40·0	= 27·972
1 Eq. of sulphuric acid,	40·0	= 27·972
7 Eqs. of water,	63·0	= 45·056
	143·0	100·000

Uses.—This salt, is used in medicine, in consequence of its physiological effects, which are, when administered in small doses, of an astringent, antispasmodic, and tonic nature; whilst taken in large quantities it is poisonous, causing vomiting, purging, coldness of the extremities, and a fluttering pulse. In full doses it acts as a safe emetic, but care should be taken that it be thrown off the stomach, for if retained for any length of time it occasions nausea and prolonged retching. In this capacity of emetic it is of great use where poisoning is suspected, as it acts rapidly. Sulphate of zinc is frequently used, owing to its astringent and caustic properties, in diseases of the eyes, and generally with good effect. In some cases it is used by dyers as a mordant; also as an *oil drier* for painting.

CARBONATE OF ZINC.—The preparation of the neutral carbonate of oxide of zinc is somewhat difficult, owing to the feeble affinity of the oxide for carbonic acid. If, however, the precipitate which occurs on adding a solution of bicarbonate of soda or of potassa to a solution of zinc be, after washing, disseminated in water, and carbonic acid charged into the liquor, the precipitate is dissolved in the form of a bicarbonate, and on evaporating the liquid in an atmosphere of carbonic acid, the neutral or monocarbonate of oxide of zinc is obtained. Its formula is ZnO, CO_2 .

The ordinary carbonate of this oxide is a basic compound, containing five equivalents of base to two of acid. It is obtained by adding a solution of carbonate of soda to one of sulphate of zinc, taking care that the latter is in slight excess. The change which succeeds may be exemplified thus—



When the precipitant is in excess, a portion of it combines with the basic salt and cannot be removed by washing. For this reason carbonate of ammonia is sometimes preferred, only an equivalent quantity being employed, so that excess of the salt, which would dissolve a part of the zinc carbonate, is avoided. The precipitate in either case is washed well and dried at 212°.

Properties.—It is a loose white powder resembling the carbonate of magnesia of the shops, almost insoluble in water, easily soluble in acids with evolution of carbonic

acid, and converted by a red heat into oxide of zinc. Like the oxide it is readily reduced by carbon at a red heat. MOORE asserts that several of the varieties sold in the shops as calamine or carbonate of zinc contain no zinc whatever, but mixtures of carbonate of lime, sesquioxide of iron, and sulphate of baryta. When a sample of the zinc carbonate is suspected to be fictitious, its purity is readily ascertained by dissolving it in dilute hydrochloric acid, and adding an excess of carbonate of ammonia to the liquor. It should be wholly soluble in the acid, and the precipitate at first formed in the second case should be dissolved by the excess of the ammoniacal salt. A residue on the one hand, or a persistent precipitate on the other, indicates adulteration.

Uses.—Physiologically the carbonate of zinc has the same properties as the oxide, and is applied medicinally in like cases. In the arts, this compound has of late years, together with the oxide, acquired some importance as a substitute for white lead in painting.

ACETATE OF ZINC.—The reader will find this salt described in Vol. I. page 48. It may be stated here, however, that it can be conveniently prepared from the carbonate of this base and acetic acid. Two parts of the carbonate are heated with successive portions of acetic acid of specific gravity 1.045—containing sixty-four per cent. of water—till complete solution is effected. About five parts of acid are required. The solution is filtered while warm, and set aside to cool for a day or two, after which period it is decanted and concentrated to the crystallizing point, when, on cooling, the acetate will deposit. Acetate of zinc possesses a slight odor of acetic acid and a bitter saline nauseous taste. On being heated it fuses with the loss of water, and at length blackens, giving off the usual empyreumatic products resulting from the igneous decomposition of the acetates; and if the temperature be very elevated, the oxide of zinc will be likewise reduced.

Acetate of zinc is soluble in three parts of cold and in half a part of boiling water; in thirty parts of alcohol of eighty per cent. at the normal temperature, and in one part at the boiling point. The solutions have an acid reaction.

Uses.—Physiologically considered, the acetate of zinc is reputed to have the same properties as the sulphate, but some French writers deny that it has a poisonous effect even when administered in large doses. The salt is used by dyers as a mordant.

ZINC-WHITE.—This pigment, to which considerable attention has been given of late years, is either the anhydrous oxide, the hydrate oxide, or hydrated basic carbonate of zinc. Its whiteness is equal to that of white lead, and not being tarnished like the latter by sulphurous vapors, it has been proposed to introduce it as a substitute for white lead in painting, especially as it affords a more permanent color, is cheaper, and does not involve the great risk and sacrifice of life which, however carefully the preparation of the carbonate of lead may be conducted, is occasioned among the workers engaged in that manufacture. The principal objection to its general adoption is, that the paint compounded with it is less drying than those in which lead constitutes the basis, and also that it does not cover or spread so

perfectly as white lead; or, in the language of the painter, that it does not possess sufficient *body*. With regard to its non-drying qualities, improvements have been suggested which, if acted upon, would, in a great degree, obviate this objection; and as to the want of body, the painter can well afford to spread a thicker layer of the zinc-white, seeing that a given weight of the latter is considerably more bulky than the same quantity of the former, in consequence of the lesser density of zinc, as well as its much lower atomic weight, which is to that of lead in the proportion of thirty-two to one hundred and four.

GUYTON DE MORVEAU was the first to propose the substitution of oxide of zinc for the basic carbonate of lead in painting. LASSAIGNE likewise drew attention to the subject about 1821, and has lately communicated the fact that an oil painting finished at that time with oxide of zinc has hitherto retained its brilliant whiteness. The manufacture of the zinc-white owes much, however, to M. LECLAIRE, who was among the first to establish its manufacture on a large scale for this purpose. More recently several patents have been taken in England for the preparation of the oxide of zinc for the painter's use, and some of these will be referred to further on.

Manufacture.—At first metallic zinc was the material from which the zinc-white was prepared, the simple change effected being merely the dissipation of the metal in the form of vapor. While in this state, and still at a high degree of heat, the introduction of a current of air causes the metallic vapor to ignite, producing oxide of zinc in a finely-divided white powder, which, when collected, forms the substance in question. The arrangement by which this change is effected is shown in Figs. 645 to 646. In Figs. 645 and 646, the retorts from which the zinc is distilled are represented in section and elevation. They are similar to gas retorts, and are depressed cylinders, *a, a*, of refractory clay, such as that of which glass pots are made. Their length is about

Fig. 645.

Fig. 646.

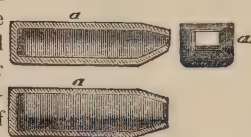
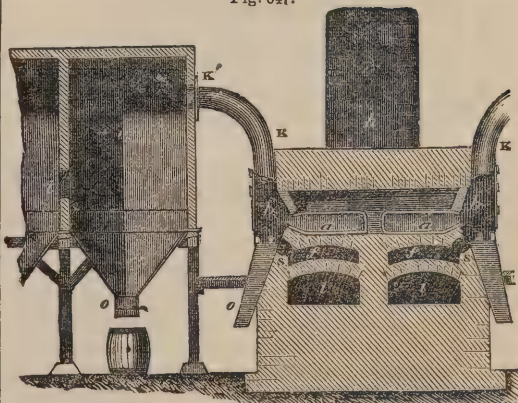
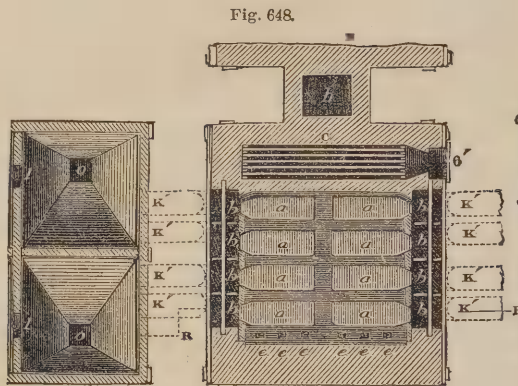


Fig. 647.



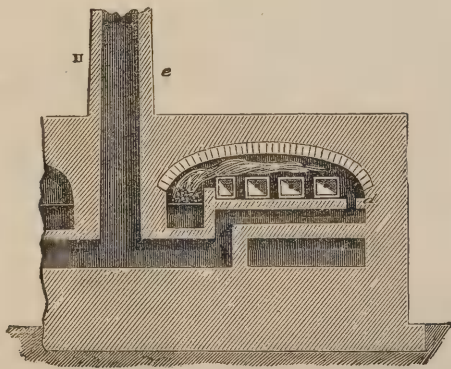
twenty-eight inches, their breadth ten inches, and their height about six inches; the walls are two and a

quarter inches in thickness; the aperture, *b*, which serves the double purpose of introducing the pigs of zinc, and allowing the metallic vapors to escape, is four inches in breadth and two in height. Eight or ten of these are placed in a double range, back to back, in a reverberatory, represented in plan and section in Figs. 648, 649,



and 650. The fire is at *c*, the heat and flame of which pass over the cylinders and return beneath the floor of the reverberatory by the flue, *c*, *d*, *f*, *g*, *h*, into the chimney, as seen in Fig. 649. When the interior of the furnace and the retorts are observed at a reddish white heat, one or two bars of zinc are introduced into each of the retorts. The metal soon melts and enters into ebullition, the vapor being disengaged by the aperture, *b*, of each retort, where it comes into contact with a

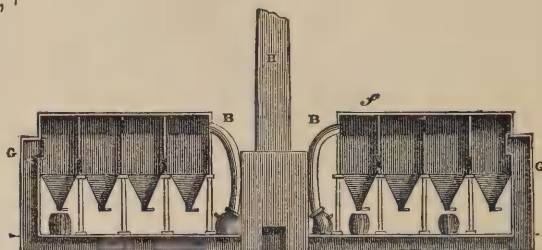
Fig. 649



current of air heated in the cast-iron pipes, *ss*, to about 570° by the waste caloric of the furnace, and enters into combustion. The metallic oxide so produced is carried along by the current of gas into the pipes, *kk*, which surmount the mouth of the retort, and is deposited in the chambers, *LL*, four of which are in connection with each other by apertures alternately at the lower and upper part of their partition walls. The disposition of the condensing chambers and other parts of the apparatus is shown in Figs. 650 and 651. Here *A* indicates the furnace, *B* the pipes leading to the chambers, the last opening in the outer one of which is covered

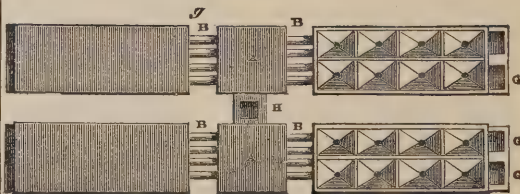
with a fine metallic gauze stretched on an iron sash or framework, for the purpose of intercepting all the particles of the zinc-white, whilst the meshes of the

Fig. 650.



wire affords sufficient space for the egress of the nitrogen and other gases into the flue or passage, *G G*, leading to the chimney, *H*. In this conduit two other screens, similar to that above described, may be fixed, but somewhat finer, to prevent the loss of as little as possible of the powder. After a while the wire gauzes become covered with the powder, but before the meshes are closed they are cleaned and replaced.

Fig. 651



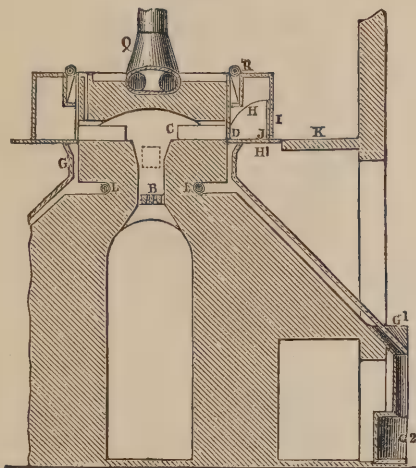
The oxide of zinc thus produced is always of good quality, unless indeed an excess of impurities exists in the metal employed. That which is inferior is always deposited in the first chamber, being impregnated with the oxides of the metallic bodies contained in the zinc, and also with a finely-divided powder of the zinc itself, in consequence of some of its vapor being carried over before it underwent combustion. In consequence of these impregnations, the powder collected from the first chamber should always be screened, and the product devoted to the commoner kinds of painting. It is necessary during the formation of the oxide of zinc, to clear the openings communicating with adjacent chambers, lest the deposition of the powder on the walls should accumulate so as to block up the passage. This is done by means of an iron rod passed through the wall, and commanding the opening. After the conversion of the charge is completed, the oxide of zinc deposited in the chambers is removed simply by placing a barrel beneath the mouth of the hopper-shaped opening in the chamber, and drawing the sliding-plate which is used to secure it while working. The zinc-white is then easily scraped into the receiver, and there reduced by pressure to the least possible volume. It is now ready for the market, or for compounding with the oil as in the manufacture of paint. Three furnaces like those described, each furnished with eight retorts,

work off from twenty-eight to thirty hundredweight of zinc in the twenty-four hours. This quantity ought to produce from thirty-five and a half to thirty-seven hundredweight and a half of zinc-white; but in practice the average yield amounts to only thirty-one and a half to thirty-four hundredweight.

Of late years several improved methods have been devised for the preparation of this substance, the most important of which, in the Editor's judgment, will now be briefly stated.

M. LECLAIRE's mode of operation is indicated in the following description and figures, taken and abridged from *Le Génie Industriel*. Figs. 652, 653, and 654 show

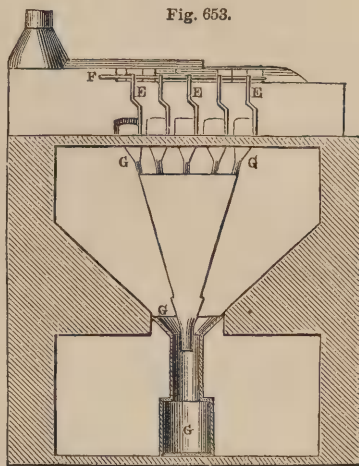
Fig. 652.



the distillatory furnace in longitudinal and transverse vertical sections and in plan. In these figures, A represents the fire-door, B the fire, and C the retorts, which are made of refractory material. Five are generally ranged at either side of the grate, but the number can be varied according to circumstances. The volatilized metallic vapors escape by the orifice, D, of the retort, before which are disposed a series of plates, E, called scrapers, attached to a horizontal iron rod, F, by similar pendant ones. By motion communicated by hand or machinery to the horizontal rod, the scrapers, E E, are moved backwards and forwards, and coming at each movement against the door of the retort, any oxide which adheres to the aperture is knocked off. The oxide and metallic vapors issuing from the retort are received in small receptacles, G G, which open into an inclined channel that terminates in another funnel-shaped conduit, G¹, and this leads them into the receiver, G². It is evident that the small conduits, G G, receive only such matters as solidify in the mouth of the retort, and which from their density cannot be drawn off to the receivers by the force of the current of gases passing through this arrangement to the chambers wherein the oxide of zinc is collected. A small plate-iron cage or box, H, is fixed over the mouth of each of the retorts in order to isolate them. It rests upon a framework of metal, H¹, fixed into the wall of the furnace, and so constructed that it may be

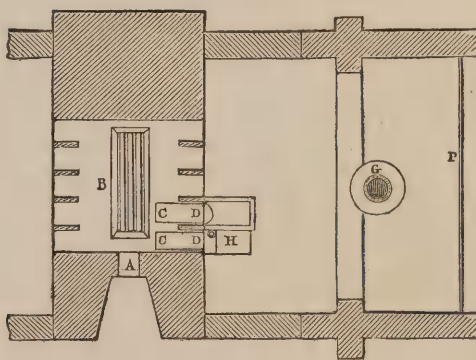
removed at will by means of a crane, or by making it slide or roll on a framework or small railway. The anterior aperture is directed towards the orifice of the

Fig. 653.



retort in such a manner that the products of the distillation empty themselves into it, and the posterior part has a door which may be opened at will. A trap-door, J, is contrived in the suspended plate, K, and which can be raised or lowered at will by an iron-wire rope passing through the posterior plate, I, of the box, H, without opening the door in this part of the latter. Sometimes, instead of lifting the trap-door, it is so formed that it can be drawn backwards when it is necessary to open

Fig. 654.



it. K designates the suspended plate upon which the box or cage is placed; it is isolated in its construction from the chamber of oxidation. Currents of cold air may be directed upon this plate in order to cool it, so as to resist the temperature of the chamber. The hot air, admitted for the combustion of the metal, enters from the pipe, L; it communicates with the passage from the retorts to the receivers, and so drives the oxide of zinc formed into the latter. In the receivers the inventor places cloths for sifting or screening the products, the floor of each being a kind of hopper, or inclined plane, whereby the product gliding over the cloth is separated into its various qualities of fineness, and received at once into separate boxes placed beneath

the sifter. In order to retain the finely-divided particles of zinc-white which arise from the agitation, cloths are suspended at regular distances. These, while they afford a passage to the gases, retain the particles of metallic oxide, and so prevent a loss of material.

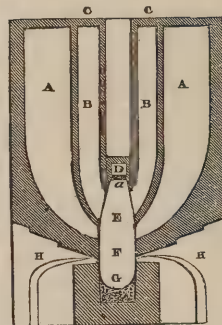
A draught pipe, Q, draws off the air and gases as well as the finely-divided oxide from the oxidising chamber through the whole arrangement. Another pipe, R, placed at the top of each retort, draws into it by a funnel-shaped opening all vapors and powder emitted from the retorts whilst they are being charged, and the draught of which, whenever it is isolated from the oxidising chamber is sufficient to draw the products through a series of chambers not shown in the drawing, having cloth screens as usual to retain the oxide of zinc. The ventilation of both the draught pipes, Q and R, is effected by means of the waste heat of the furnace.

The same inventor combines the principle of the reverberatory furnace in the distillation of zinc for the purpose of making zinc-white. In this arrangement he so disposes the retorts that the flame from the coal fire circulates round them, and then passes into a chamber over the dome inclosing the retort, where pipes may be laid for raising the temperature of the air which is forced into the space surrounding the mouths of the retorts to oxidise the zinc vapors. The oxide so produced is conducted to receiving chambers in a manner somewhat similar to the two methods already described.

ROCHAZ'S patent, dated in 1849, describes a construction of furnace suited either to the conversion of metallic zinc, or of ores of this metal, into the oxide. In the first case he uses clay crucibles, and arranges them in three rows in a furnace, supporting them by two intermediate fire-brick walls and by the side walls of the furnace, and so securing the crucibles at the surface that no vapors or smoke from the fire can issue from the chamber beneath them, but must pass off through passages in the bearing walls by small flues into the chimney. A loose slab or clay tile is used as a cover for the vessel wherein the distillation is effected, and the whole is inclosed by a flat roofing of refractory tiles, well cemented and raised a few inches above the crucibles, for the introduction of air from without, for oxidising the metallic vapors. This space leads to a large chamber, in which plates of iron are suspended in a slanting direction, so as to cause the current of vapor, loaded with oxide of zinc, to take a sinuous and zigzag course in passing through it. In addition to these he fixes bands of hemp, or other textile material, at intervals transversely in the chamber, with the view of intercepting the last portions of the zinc-white. Further he contrives that the upper end of these bands shall pass through the walls of the chamber and dip into a trough of water, so as more effectually to condense the zincous vapors in the interior. He directs that the chambers more distant from the furnace be constructed of sailcloth, which affords the advantages of being easily accommodated to space, and of keeping the walls cooled by means of a copious sprinkling of water, applied exteriorly, and which causes the oxide of zinc to deposit more readily. The same patentee

claims a method for preparing the oxides from the ores by a previous roasting, and introducing them, thus prepared, with charcoal or slack, into cylindrical or square clay crucibles, somewhat similar to those employed for the reduction of the metal at Vieille Montagne, but without the condensers, opening into a closed channel in the front, through which a current of air is introduced, and which carries the oxide of zinc, resulting from the combustion of the metal, into a chamber disposed similarly to that described; likewise a blast furnace, represented in Fig. 655, for the same purpose. In this figure the mixture of roasted ore and fuel is introduced into the passages, A A, B B; others are filled with

Fig. 655.



coke or other fuel; all of which are covered with tiles, C C; E, the cavity of the furnace, which is always kept filled with fuel from the passages, B, B, and in which the reduction of the ore is effected by means of the blast introduced through the tuyere pipes, H, H, more especially in the region of F. The slags and residue descend into the cavity, G, whilst the vapors of zinc pass off by the channel or flue, D, into the condensing chamber, as soon as the stopper, a, inclosing the mouth of the chamber, E, is removed. In the latter flue they meet a stream of air that effects their oxidation. The chamber is evidently required to be more extensive in this instance, owing to the gaseous products of the combustion of the fuel being carried along with the oxide of zinc produced in the flue, D; but, excepting this inconvenience, the patentee asserts that no other will result, for all the carbonaceous or sooty products, produced in the region of the blast, are entirely reduced or consumed in passing through the column of incandescent fuel above F, so that only pure gases, which are not calculated to discolor the product, are evolved.

KNOWLYS secured a patent in 1850, in which, among other claims, is a method of preparing the zinc-white from its ores, by dissolving the oxide in sulphuric acid, and, after clarifying the solution by filtration or subsidence, precipitating the metallic oxide with a solution of carbonate of soda. The precipitate, after being washed and collected, is then dried by means of heat and pressure, and the compound so produced is either used in this state or reduced by ignition to the oxide and then compounded into paint in the ordinary way.

PROTHEROE employs an ordinary cylindrical retort, having inlets for the passage of a current of air at the

posterior end, and another for raking out the heavy oxide which forms on the surface of the metal and the walls of the retort, the lighter and finer particles being conveyed by a pipe with the current of air to a condensing chamber, which is divided by partition walls of brick, or other material, into several compartments. In each division he disposes two frames or sashes, on which fine wire gauze is stretched for the purpose of intercepting the particles of powder in their course through the several divisions. Metallic zinc is preferred as the substance to operate upon, and a reverberatory furnace is employed to reduce the metal to vapor. The quantity of heavy oxide skimmed off the surface of the metal and from the walls of the retort, is drawn out by a rake into a passage which conducts it to a receiver in an inclosed chamber beneath the level of the sole of the furnace.

In the method patented by SCOTT, a clay retort of the usual form is used, imbedded in sand, potsherds, or pumicestone, and so placed in the furnace that the products of the combustion pass freely round it. The metallic zinc, which is directed to be used, is introduced through an inclined aperture, which is usually closed by the unmelted portion of the block of zinc. The air which oxidises the vapors of zinc issuing at the top of the retort, is admitted to an intermediate chamber, where both meet, and the product is carried by the current through a passage into a depositing chamber, the roof of which is constructed of zinced iron, and is capable of being converted by a raised ledge, into a shallow cistern, for the purpose of cooling the interior. The bottom of the chamber is divided into a number of funnel mouths, which, by attaching cloth or other material to the narrow part, lead the zinc-white at once into casks placed beneath to receive it.

GEYELIN'S patent, sealed in 1853, is based upon the same principles, only the apparatus is slightly modified, and a jet of steam is employed to effect the rapid oxidation of the metallic vapors as they rise from the retort, and also to aid in producing a certain amount of caloric expended in the operation. The jet of steam is introduced at the farther end of the retort, and passing over the metal, it is decomposed, the oxygen combining with the zinc, and the hydrogen passing off to be consumed in the air channel outside the distillatory apparatus.

TITTERTON prepares the zinc-white from the dross and dregs of the purifying pots of the zinc-smelting establishments by heating them alone, or mixed with a certain quantity of coke or charcoal, according to their composition. He employs two condensing chambers, the first intended for retaining oxide of cadmium, or other impurities, and the second for collecting the light white oxide of zinc. This patentee employs pressure, and a subsequent heating process, with the view of obtaining a denser compound, and therefore better suited for painting.

ZINC-WHITE PAINT.—Like white lead, the oxide of zinc requires to be mixed with an oily vehicle, to be applied in painting. As oxide of zinc does not readily form a saponaceous compound with fats or oils like oxide of lead; the paint which is prepared with it and ordinary linseed oil, does not dry or harden for a long time. This peculiarity was at first one of the principal

drawbacks to the more general use of the zinc instead of the lead paint. Another of its defects is said to be its transparency, owing to which a layer of the zinc-white paint does not exhibit so much *body* or opacity as a similar one of white lead. Both these defects, which can be almost entirely overcome, are more than compensated by the permanency of the oxide of zinc as a pigment under all circumstances, and its comparative innocuousness both in the manufacture and the application; whereas the poisonous qualities of white lead constitute a fundamental objection to it. At first, manufacturers of zinc paint were led to the adoption of the practice of boiling the oil with a large quantity of litharge, for the purpose of causing it to be more siccative; but by this method the color of the paint is rendered liable to tarnish on exposure to sulphurous emanations. Instead of litharge, experiments have led to the choice of salts of zinc, such as the chloride and sulphate, a small per centage of which, on being mixed with the oil or oxide, confers upon the paint the property of readily hardening. The same result is obtained by employing an oil dried by boiling it with about five per cent. of peroxide of manganese, or even magnesia has been recommended, and is said to answer quite as well as the manganese; in either case a paint retaining its white color permanently is obtained.

Manufacturers classify the several qualities of the zinc-white into four kinds, namely, *snow white*, *zinc white*, *stone grey*, and *grey oxide*; the first two are employed where a pure unalterable white color is required; the third is used for a ground color for the walls of houses, iron painting, and the like; and the fourth is peculiarly adapted for the painting of ships and wood-work, and likewise for the ground of more expensive colors on stone or cement. Various shades may be given to paint of which zinc-white constitutes the basis, by grinding up with the oil, used as the vehicle, several metallic and other compounds of an unalterable nature in different proportions. Thus, an orange-yellow is obtained by using kermes—sulphide of antimony; a citron-yellow by employing chromate of zinc; a green by adding a mixture of chromate of zinc and a few per cents. of cobalt blue. In like manner oxides of iron and of manganese, ultramarine, lampblack, *et cetera*, communicate tints to the paint; all of which, owing to the absence of lead, are unaltered by atmospheric influences, sulphide of hydrogen, or other emanations.

Sometimes a very permanent and useful paint is prepared from the natural ores of zinc without subjecting them to any of the manufacturing processes already referred to for preparing the oxide of this metal. This is the case with the zinc-stone of Virginia in the United States, which has an average composition of—

Oxide of zinc,	25-00
Carbonate of magnesia,	11-21
Alumina,	17-00
Silica,	28-00

This mineral constitutes a solid rock on the surface of the ground, and when pulverized and mixed with oil in proper proportions, forms on the surface to which it is applied a hard closely-adhering stone coating, impervious to water or fire. Its ordinary tint varies from a

light drab to dark brown. This paint is capable of receiving a high polish.

Oxide of zinc, or zinc-white, besides its application in painting, is valuable for paper-staining, card-enamelling, the bleaching of lace, the glazing of pottery and porcelain ware; and the lighter white portions are used for producing the down on artificial feathers.

Analysis and Testing of Minerals and Compounds of Zinc.—A short summary of the method followed in the assaying of zinc ores has already been laid before the reader. It is almost needless to state that in consequence of the numerous sources of error almost inseparably connected with it, the process so described leads to no very accurate results. Hence in all cases where great precision is required, the liquid process must be adopted. Considerable difficulties are encountered in the analysis of zinc ores, and the compounds of this metal with others with which it is alloyed, in many valuable mixtures used in the arts—arising from the fact that sulphide of hydrogen does not separate members of the fifth and sixth group of bases, namely, mercury, silver, copper, cadmium, arsenic, *et cetera*, from zinc in acid solutions, as was for some time supposed; nor does potassa or ammonia, on the other hand, serve to isolate it from iron, nickel, and other members of the fourth group. These considerations have led to several processes for removing the cause of error, and conducting to more accurate determinations. As regards the action of sulphide of hydrogen, most of the analytical manuals to which the chemical student has access give details which are highly erroneous, and which, at best, serve only for qualitative rather than accurate quantitative determinations; for, in direct contradiction to what is commonly taught, sulphide of hydrogen does precipitate considerable portions of zinc in the form of sulphide from highly acid solutions. This fact was a few years ago very conclusively decided by Mr. C. CALVERT, whose research shows that the above agent cannot be employed in the manner detailed in the manuals to separate copper and other metals of its class from zinc. Again, potassa, which was for a long time supposed to be capable of parting zinc from iron, nickel, cobalt, and manganese, by dissolving the zinc in its excess, leaving the others permanently precipitated as sesqui- and protoxides, is now known to do so only partially; so that under almost every circumstance in which the precipitation is effected, more or less oxide of zinc is found in the separated oxides. Without going, therefore, into long details of the several processes recommended, the most trustworthy, and, at the same time, most expeditious method for the analysis of zinc ores and alloys will here be given.

The ore or alloy should be dissolved in nitric acid, and evaporated to dryness at a moderate heat, exercising the usual amount of care in the operation. If the subject be an alloy into which tin or antimony may have entered, these metals will be converted into insoluble binoxide in the case of tin, and into antimonious acid in case of antimony, particularly if the assay be treated with some fuming nitric acid, as it becomes nearly evaporated. After thorough desiccation the mass is treated with boiling water, filtered

and washed; the binoxide of tin or antimonious acid dried, burned, and weighed with due precaution, and the filtrate with the washings containing copper, cadmium, or other substances with the zinc, as the case may be, treated further. According to FLAJOLOT, the best process is to slightly acidify with hydrochloric acid, and boil the solution, and add hyposulphite of soda in excess to it whilst hot; sulphides of copper, cadmium, *et cetera*, are precipitated entirely free from zinc, by the decomposition of the hyposulphite. After thorough washing, the precipitated sulphides may be dissolved in acid, and the quantity of copper is determined by the processes already detailed under *Copper*; or if cadmium be present the solution may be treated with carbonate of ammonia in excess, and the vessel left exposed for some time, when carbonate of cadmium falls to the bottom, and the copper remains in the solution, to which it gives a deep violet or blue color. After the carbonate of cadmium is filtered off, washed with a solution of carbonate of ammonia and dried, it may be burned and weighed as oxide. The copper may be estimated with a standard solution of cyanide, or of monosulphide of potassium in the usual volumetric way. The zinc, iron, and nickel, with other matters capable of being separated by the reagent, may be thrown down from the solution with protosulphide of ammonium, the precipitate collected, washed, and dried at 212° till it ceases to lose weight; its entire weight is then noted, and the chief part introduced into a German glass tube on a platinum mattress or boat, where it may be heated to redness, whilst a current of sulphide of hydrogen is passed through the apparatus. When the heat has been sustained for a quarter of an hour, the lamp is removed, but the current of gas is still maintained till the tube and its contents are cooled. The platinum boat is then removed, and its contents emptied into a beaker, and treated with dilute hydrochloric acid, containing one part of strong acid in ten or twelve parts of water; sulphide of zinc is dissolved while the sulphides of cobalt, nickel, and iron remain intact. The quantity of the latter may be determined according to the processes which have been given respectively under *Cobalt*, *Iron*, and *Nickel*, and the zinc in the solution may be estimated by bringing the liquid to a boiling heat, and adding sparingly a solution of carbonate of soda, as long as a precipitate is formed, boiling the menstruum for some time to expel all carbonic acid, and then collecting the basic carbonate of zinc on a filter, washing with hot water, drying, igniting, and weighing the residue. During the ignition all the carbonic acid is expelled from the basic carbonate, so that only oxide of zinc remains, from the weight of which that of the metal may be calculated, since 40.0 parts of it contain 32.0 of zinc.

The oxide of zinc contained in ores of this metal may be determined by heating a weighed portion of them, finely ground, to redness for some time, and then treating the powder with a solution of carbonate of ammonia as long as anything is dissolved; the filtered liquid is next evaporated to dryness, and the residue heated to redness and weighed; this weight indicates the amount of oxide of zinc existing as oxide or carbonate in the ore. SCHWARZ, instead of evaporating

the ammoniacal solution of zinc, as in the foregoing, precipitates the metal as sulphide, either by passing sulphide of hydrogen through the liquid, or adding sulphide of ammonium to it. The sulphide of zinc is collected and washed with water, mixed with a little ammonia, and then introduced with the filter into a wide-mouthed flask, where it is treated with an acid solution of sesquichloride of iron, and slightly heated. Decomposition of the sulphide of zinc takes place in this case, and a reduction of a proportionate quantity of the iron salt to the state of protosalt, as explained by the formula—



that is, for every equivalent of sulphide of zinc one of the sesquichloride of iron is reduced to the state of protochloride, while sulphur is separated from the former, and chlorine from the iron salt assimilated. The liquid, as soon as it becomes clear by the deposition of the sulphur, is filtered off, and the quantity of iron in the state of protoxide estimated volumetrically by means of standard solutions of permanganate or of bichromate of potassa, and the amount of zinc deduced therefrom, since 56 parts of iron will represent 32.0 of zinc.

In the analysis of brasses, PELOUZE'S volumetrical method may likewise be resorted to; and, according to CALVERT, with perfect accuracy. The brass is treated with an acid till perfect solution takes place, ammonia is added in excess, and a standard solution of monosulphide of potassium introduced from a burette, whilst a black precipitate forms in the liquid, and until a white one begins to appear. The quantity of copper being found from the volume of liquid used in the precipitation, that of the zinc may be taken as the difference.

Zinc is separated from nickel in many ways. If the alloy containing the two metals be dissolved in sulphuric acid, and the sulphates so produced be treated with acetate of baryta, a sulphate of baryta, with the corresponding acetates of nickel and zinc, will

be produced, with a little free acetic acid in proportion to the quantity of uncombined sulphuric acid which existed in the solution. Sulphide of hydrogen passed through this mixture, throws down the zinc as sulphide, leaving the nickel in solution. The precipitated sulphide of zinc and sulphate of baryta are filtered and washed, then treated with dilute nitric acid to dissolve the sulphide of zinc, and after removing this by filtration and washing from the insoluble baryta compound, the oxide is thrown down as a basic carbonate by treatment with a solution of carbonate of soda at a boiling temperature, then filtered, washed, and estimated as oxide, in the manner already detailed. The nickel can be thrown down as oxide, after expelling the sulphide of hydrogen with caustic soda or potassa, and its weight estimated in the usual way. WÖHLER separates the two metals by adding an excess of potassa to the solution containing them, then a sufficient quantity of hydrocyanic acid to dissolve the precipitate so formed. Double cyanides of the metals with potassium are thus produced, and which behave differently with protosulphide of potassium, the zinc salt only being decomposed by this reagent. By treating the solution, therefore, with protosulphide of potassium, sulphide of zinc separates completely, and may be removed and estimated in the usual way. The filtrate and washings should be evaporated to dryness with strong nitric acid to destroy the cyanogen compound, and the nickel determined by precipitating it with potassa or soda as already indicated.

STATISTICS.—Zinc was not an article of commerce previous to 1822, when it was imported in moderately large quantities, but only to be exported for the most part to India. The applications of the metal in the industry of the nation became gradually extended, till at present the home consumption averages about twenty thousand tons annually. The following table exhibits the imports and exports of the metal from 1823 to 1851; since that period the home consumption has been greatly on the increase, whilst the export remains about the same:—

Years.	Imports.	Exports to India.	Total Exports.	Home used.	Stock in January.	Highest and lowest prices.
1823	5400	4536	4700	—	970	£22 to £23.
1824	9199	7185	8068	24	1140	£24 to £23.
1825	5556	4835	6112	171	413	£22 10s. to £41 10s.
1826	4839	7374	8330	22	924	£28 to £15 10s.
1827	5999	5535	6929	290	1262	£16 10s. to £14.
1828	4566	4806	4943	536	2447	£14 10s. to £11 10s.
1829	4230	3505	3964	684	2012	£12 to £9 7s. 6d.
1830	4422	3385	3479	843	1750	£9 10s. to £11.
1831	3821	2896	3134	941	1512	£11 5s. to £9 5s.
1832	3140	2044	2995	1093	1490	£10 10s. to £11.
1833	2800	1225	1883	1355	1020	£10 10s. to £12.
1834	2100	882	1419	1756	710	£12 to £14 10s.
1835	6500	2497	3943	2205	1350	£15 to £17.
1836	8600	1490	6269	2184	3110	£16 10s., £23 10s., and £19 10s.
1837	4380	1811	3200	2335	2750	£18 10s., £12, and £15.
1838	6265	528	1858	3596	2553	£15 10s. to £20.
1839	8910	1538	3391	4560	3650	£18 5s. to £21 15s.
1840	4965	2637	4091	4181	1536	£20 to £23 10s.
1841	6509	990	1406	3665	2111	£23 10s. to £40.
1842	5500	1584	1900	2641	2800	£36 to £24.
1843	10,173	3459	6445	4125	3750	£23 to £22.
1844	10,393	5826	5925	5388	4021	£22 5s. to £22 10s.
1845	12,903	2969	3084	7459	3296	£22 5s. to £22 15s.
1846	11,434	4875	4967	8450	6800	£22 to £19 10s.
1847	12,729	3301	3631	11,794	2250	£22 to £19 10s.
1848	13,525	2831	3773	9344	2000	£19 15s., £13, and £15.
1849	15,915	3927	5397	8726	2020	£15 to £16 5s.
1850	18,626	3121	4537	11,262	4000	£16 10s., £17 10s., £15, £16 10s.
1851	—	—	—	—	6827	£16 5s. to £15, May 1.

The duty on imported zinc from 1823 to 1825 was twenty-eight pounds ten shillings per ton; this was reduced in 1826 to fourteen pounds; in 1827 to twelve; in 1828 to 1832 to ten, and in 1833 to 1842 to two pounds per ton. The duty levied in 1843 and 1844 was one shilling per ton, and since then all tax upon the imported metal was abolished. The average annual production from 1842 to 1848 was thirty-two thousand five hundred tons, of which—

Silesia made sixty-five per cent.,	or	21,000 tons.
Belgium made twenty	" or	6,500 tons.
Poland made eight	" or	4,000 tons.
Cracow made four	" or	
England made three	" or	1,000 tons.
Total,.....		32,500 tons.

The smelting of zinc declined in England from 1850 till within the last few years that it has been a little more spirited in the several localities mentioned in the commencement of this article; during the same period the Continental establishments, more especially those of Belgium, have greatly enlarged their production. The quantity of zinc produced in the latter country in 1858 was twenty-five thousand six hundred and seventy tons.

The following represents the quantity of zinc smelted in the Prussian States from 1837 to 1848, inclusive:—

1837, ..21,546,600 lbs.	1843, ..36,047,200 lbs.
1838, ..20,983,200 lbs.	1844, ..41,314,100 lbs.
1839, ..21,636,600 lbs.	1845, ..43,861,200 lbs.
1840, ..20,879,800 lbs.	1846, ..43,961,000 lbs.
1841, ..19,977,900 lbs.	1847, ..44,221,800 lbs.
1842, ..27,612,600 lbs.	1848, ..39,873,600 lbs.

Of this quantity there were produced in the upper district:—

	1846.	1848.
In Silesia,.....	35,538,200 lbs.	36,193,100 lbs.
In Westphalia,	189,900 lbs.	75,000 lbs.
In Rhenish Prussia,..	5,322,900 lbs.	3,605,500 lbs.

In France the quantity entered annually for home consumption to about 1848, amounted to eighteen or twenty thousand tons. Estimating the present consumption of that country at thirty thousand tons, that of England at twenty thousand tons, the other Continental nations and America at twenty-five thousand tons, the gross production would appear to average at present from seventy to seventy-five thousand tons annually, a quantity which approximates to the present yield of the several smelting works in operation.

SUPPLEMENTARY MATTER,

BY

PROFESSOR HORSFORD OF AMERICA.

ACETIC ACID.—Insert at foot of column 1, page 3, Vol. I.—The oxidation of the glycerin in fats also appears to be a source of acetic acid. By melting rancid Chinese vegetal tallow—palmitate and oleate of glycerin—in a flask, a strong smell of acetic acid is observed. REDTENBACHER found that an aqueous solution of glycerin is decomposed by the presence of ferments, and yields acetic and metacetic acids. By doubling the formula $C_6 H_8 O_6$ of glycerin, and subtracting 4 H, one obtains $C_{12} H_{12} O_{12}$, that is, three equivalents of the hydrated acetic acid. The oxidation of H_4 by the oxygen of the air, would produce the same result. From this it follows, that the acid reaction of rancid fats and oils, is for the greater part produced by the presence of acetic acid formed by the slow combustion of glycerin.—H.

Insert at foot of column 1, page 16.—A very neat apparatus for making small quantities of vinegar from alcohol, constructed by Dr. SPITALER, has been used in Germany for several years. It consists of a cylinder of glass, ten inches high and eight inches wide, filled up with coarsely-powdered charcoal. A glass cover, with a moderate aperture for the admission of air, closes the top of the cylinder, while a small cock is adapted near the bottom for the removal of the fluid. The apparatus must be kept at a temperature between 63° — 77° . Every evening six ounces of a mixture of one quart of alcohol, specific gravity 0.859, and eleven quarts water, are poured slowly and in a fine stream evenly over the charcoal, after which the cover is laid on. The following morning the corresponding quantity of vinegar may be drawn from the cock.—H.

Insert at foot of column 2, page 16.—It may here be interesting to mention an indirect mode of producing vinegar from wood. During the last few years, especially during the crisis caused by the ravages of the potato disease, serious experiments on a large scale have been instituted, with a view to substitute saw-dust and woody fibre in general for potatoes in the distillation of spirit. Many years ago, BRACONNOT found that saw-dust, cotton and flax fibres, *et cetera*, are converted into sugar by concentrated sulphuric acid. The sugar thus obtained is fermented in the usual manner, and the alcohol generated may be easily converted into acetic acid by any of the processes mentioned in the text. The cheapness of sulphuric acid, and the universal command of woody fibre, open a promising future to the new and ingenious process.—H.

Insert after PYROXYLIC SPIRIT or WOOD NAPHTHA,

page 25, column 2.—It may be well to remind the American readers, that the high duty on alcohol in England, renders the extraction of the pyroxylic spirit from wood a matter of great importance to the chemist. It is usual in England to burn wood spirit in lamps, and to use it generally as a substitute for alcohol, whenever its empyreumatic flavor is not objectionable, as tolerably pure wood spirit can be obtained cheaper than alcohol.

At page 27, middle of column 2, the reader is directed to use either *sulphuric* or *hydrochloric* acid for the purification of wood vinegar. It is far preferable to use hydrochloric acid for decomposing the lime-salt. Sulphuric acid forms with the lime gypsum, which converts the fluid to be distilled into a paste which it is very unpleasant to distil, as it boils irregularly and sometimes with explosions.—H.

The chloride of barium vinegar-test, mentioned at page 34, column 2, may perhaps be objected to, as calculated to mislead those unacquainted with chemical manipulations. In view of this, BÖTTGER has recommended a concentrated solution of chloride of calcium, for detecting the adulteration of acetic acid by sulphuric acid. He found that all kinds of vinegars, whether prepared from wine, alcohol, fruit, or beer, notwithstanding the small amount of sulphates which they contain, are perfectly indifferent to a concentrated solution of chloride of calcium. By adding to two drachms of vinegar a piece of crystallized chloride of calcium of the size of a small nut, and heating the whole to the boiling point, a precipitate of gypsum will fall down on cooling, if the *liquor contains only one-thousandth part of sulphuric acid*.—H.

In connection with the mordant made by decomposing alum by acetate of lead—see page 37, column 1—it may be stated that the preparation of acetate of alumina by double decomposition of sugar of lead and sulphate of alumina, gives rise to immense quantities of sulphate of lead, which is in many localities treated as a worthless refuse. By digesting it with a strong solution of carbonate of soda, it is converted into an inferior kind of white lead, which might be profitably disposed of, or else dissolved in acids for the preparation of lead salts.—H.

At page 41, foot of column 2, it is stated that the vinegar sold contains a small quantity of acetic ether, with the view, no doubt, of improving its taste and odor. It may be added, however, that an interesting formation of this compound was observed in a sour

and decomposed sugar-cane which had been sent from Andalusia to Paris. On splitting the cane open, a very strong smell of acetic acid and acetate of oxide of ethyle was perceptible. It is obvious that the presence of this compound, under the given circumstances, must be explained by the contemporaneous formation of acetic acid and alcohol from the sugar, both of which combine in the nascent state to form acetic ether.—H.

At page 42, column 1, it is stated that for commercial purposes, the protoacetate of iron is manufactured by introducing the materials into a large cast-iron boiler. By employing a copper kettle or boiler, the solution of the iron is effected more rapidly by galvanic action. As long as there is any iron left undissolved in the kettle, the copper will not be acted upon by the acid. A few drops of a solution of bichloride of platinum, added to six or eight ounces of concentrated hydrochloric acid used for dissolving tin, will induce a very violent action, and the tin will dissolve, requiring but little aid by heat. The same takes place when bichloride of platinum is added to the acetic acid for preparing protoacetate of iron.—H.

Insert, in connection with white acetate of lead, page 44, column 1.—It is a well-known fact among phytochemists, that sulphide of lead has a great affinity for coloring matters. Based on this observation, a German chemist proposed to decolor a colored solution of acetate of lead, by the addition of a small quantity of sulphide of potassium or sulphide of calcium. After boiling and filtering, the menstruum is clear and without hue.

ALCOHOL.—At page 50, top of column 1, it is stated that alcohol is never produced except by the vinous or alcoholic fermentation of particular substances. There is one exception to this rule. Pure olefiant gas is absorbed by agitation with concentrated sulphuric acid, with formation of sulphovinic acid; and by diluting the latter compound with water, and distilling the fluid, alcohol is obtained. This fact was discovered twenty-seven years ago by HENRY FLENNEL, though, singular to say, the discovery has lately been claimed by BERTHELOT.—H.

Insert at foot of column 1, page 107.—*Dunder* fulfils two important offices in the distillation of rum. In the first place, the large quantity of acetic acid contained in it, and formed at the expense of alcohol during fermentation of the wash, serves to decompose the sugarate of lime, contained in the generality of West India molasses in considerable quantities. It is for this reason that *dunder* increases the yield of rum. Sugarate of lime does not ferment, and when present in considerable quantity, actually opposes the fermentation of the wash; so that without *dunder*, fermentation would proceed so sluggishly that most of the alcohol would be converted into vinegar. This occurrence might be avoided by adding the diluted molasses containing sugarate of lime, to its own bulk of strongly fermenting wash. The carbonic acid of the fermenting liquor would then perform the office of the acetic acid of the *dunder*, by precipitating the lime as carbonate of lime and liberating the sugar. The American Editor disproved the idea that *dunder* is connected with the fine flavor of rum, by two experiments. In

one trial, molasses—from which all the lime was precipitated by sulphurous acid—and water only were used. The resulting rum was a very fine-flavored spirit, and the yield was perceptibly greater than from molasses not thus treated, though from similar cane. Another trial was made by partially filling the rectifying vessels or retorts, as they are called in Jamaica—they are like the wash-heater, as prepared B, Fig 78, and connected with the still in the same manner—with *dunder*, with a view to increase the flavor of the rum, as might be expected if the flavor proceeded from that source. The rum, however, thus obtained had the disagreeable flavor of the *dunder* totally different from that of *Old Jamaica*. The flavor of the rum appears to depend entirely on the presence of a fusel-oil, the formation of which is immediately dependent on the proportion of the surface of the wash exposed to the air during fermentation, to its entire volume. It is well known that two contiguous sugar plantations will produce very different qualities of rum, though operating in the same identical way. But it has been observed that in such cases the size and the exposed surface of their fermenting vats were different, or if not, the stills were of different capacity. The protracted boiling of the wash in very large and deep stills, injures the flavor by increasing the empyreumatic products. From the above observation it would follow, that the origin of the genuine flavor is intimately connected with the more or less complete oxidation of the molasses ferment induced by the greater or smaller surface of the wash—compared with the bulk—exposed to the air. Large cubical cisterns, holding one thousand and more gallons, yield an inferior rum, as compared with smaller vats having a larger exposed surface. Similar observations made by LIEBIG with regard to Rhenish wine appear to confirm this opinion.

The second office fulfilled by *dunder*—an office of some importance for the more rapid development of fermentation—is by its richness in ferment. The colonial distiller does not employ any yeast for inducing fermentation of his wash; he is consequently obliged to work upon more dilute solutions of molasses and skimmings—collectively called *sweets*—than are used by his continental competitors. Any, even the slightest source of ferment, must therefore be welcome for his purpose. *Dunder* is such a source. Ferments, it is well known, are destroyed by boiling-heat of water, and recent *dunder* is in that respect perfectly inert; but by exposure to air in shallow tanks, an oxidation and regeneration of the *killed* ferment takes place, and it is to this circumstance that a part of the favorable action of *dunder* must be ascribed.

Without the assistance of *dunder* a more rapid fermentation of the wash may be obtained by converting the cane-sugar contained in molasses into grape-sugar, by treatment with a small quantity of acid, which is subsequently neutralized. It has been stated that less ferment is required for converting grape-sugar into alcohol than cane-sugar, a fact which will render it less miraculous to hear that some plantations manufacture a superior rum while their sugar is nearly as dark as coal-tar. Molasses from such sugar contain chiefly grape-sugar. Allusion has already been made to the

fine flavor of rum made from molasses which were obtained by boiling sugar with an excess of bisulphite of lime.

Cleanliness in the operation of the distilling is a standard admonition of the theoretical world, woefully disregarded by the practical. In fact, it appears that a premium is offered to malpractice in this instance, as many of the most detestable colonial distilleries turn out very creditable produce. Whether the exception proves the rule in this case, must be left undecided. However, if cleanliness is not absolutely required for improving the flavor of the spirit, it would be a charity to the still-house bookkeeper, who is condemned to pass part of his lifetime in these disgusting dungeons.—H.

Page 117, column 2, *Alcoholometry*.—To the analytical chemist it happens sometimes that only small quantities of the alcoholic fluids are at his command. In such cases it is almost impossible to obtain a correct result, by determining the specific gravity of the few drops of alcohol obtained by distillation. It is safer to subject the alcohol obtained to an organic analysis by combustion with oxide of copper, and calculate the quantity of absolute alcohol from the resulting carbonic acid and water. This is of course only applicable when the alcohol does not contain other volatile bodies, like ethereal oils, *et cetera*.

ARSENIC.—At the top of column 2, page 215, Vol. I., insert—In the presence of oxide of iron, minute quantities of arsenic cannot be detected by the blow-pipe. In that case, the oxide of iron must be treated with a boiling solution of potash, which is afterwards neutralized by sulphuric acid, and tested in MARSH'S apparatus.

In same page and column the reader is directed to drop a few fragments of pure zinc into MARSH'S tube-apparatus. It deserves to be remarked, however, that pure zinc, especially when in large pieces, frequently dissolves so slowly in dilute sulphuric acid, that it is impossible to obtain a steady hydrogen flame. The addition of a drop of bichloride of platinum, or of a small quantity of platinum black, will remedy this difficulty. If the fluid to be tested contains any considerable quantity of arsenic acid, this alone is sufficient to produce a violent reaction of the acid on the zinc.—H.

BALSAM.—Vol. I., column 1, page 223.—*Canada Balsam*.—This balsam is mostly used by optical instrument-makers for cementing together the different parts of achromatic lenses, NICHOL'S prisms, *et cetera*. It may be here added that Japan varnish is a balsam derived from *Rhus vernix*, and serves to impart a brilliant lustre to metallic and other objects, hence denominated *japanned articles*.

BEER.—In connection with the analysis of beer, pages 281–284, the following may be given:—

ANALYSIS OF VARIOUS KINDS OF CELEBRATED BEER.

	Water in 100.	Extractive matter.	Alcohol.	Carbonic acid.	Analyst.
Barclay's ale,	86.93	.. 6.02	.. 6.90	.. 0.15	Raiser.
Burton ale,	79.62	.. 14.50	.. 5.88	.. 0.04	Hoffmann.
Pale ale,	89.85	.. 4.50	.. 5.65	.. 0.07	"
Barclay's porter, . .	88.74	.. 5.98	.. 6.10	.. 0.18	Raiser.
London porter, . . .	86.28	.. 6.80	.. 6.91	—	Balling.
Bavarian ale,	90.95	.. 4.70	.. 4.34	—	"
London ale,	76.03	.. 15.88	.. 8.08	—	"

BENZOL.—Insert at foot of column 1, page 286, Vol. I.—The rectified volatile oil from coal-tar, distilling between 212°–320°, and consisting mostly of benzol, toluol, and cumol, has been strongly recommended for oil paint in the place of oil of turpentine. It has the advantage of evaporating rapidly, whereby apartments painted with oil paint are rendered much sooner inhabitable.

A curious and interesting application has been made of benzol by the well-known photographer, M. DE ST. VICTOR, based upon the property of this fluid, to be lighter than water and insoluble in it, and to be kindled with the greatest facility by a small flame in contact with air even at low temperatures. He found that benzol, to which have been added a few pieces of potassium or phosphide of calcium, readily inflames when thrown on water. An experiment was made on the Seine in Paris, in which three hundred grammes of benzol were inclosed in a glass-bottle, with half a gramme of potassium. The bottle was floated down the river, and suddenly broken. The potassium ignited and set fire to the benzol which burned with an immense flame, which, though smoky, had great intensity, and lasted fully a minute in spite of a strong breeze.

A repetition of this experiment in the fountain of the garden of the Palais Royal gave the same result. In spite of a heavy rain, the flame lasted over a minute.

M. DE ST. VICTOR proposes a mixture of benzol with sulphide of carbon in which phosphorus has been dissolved, as a close imitation of the famous liquid Greek fire.—H.

BISMUTH.—Insert at foot of column 1, page 288.—An alloy for galvanoplastic moulds is prepared by fusing together eight parts of bismuth, eight parts lead, three parts tin. This mixture melts at 225°. For preparing the mould, the alloy is fused and poured into a paste-board boat of about one quarter inch depth; it is then stirred with a heated iron-wire until its surface is perfectly even and bright. As soon as it has acquired a pasty consistence, the medal to be moulded is slightly heated, and immediately pressed on the alloy, and kept under pressure until cool.—Böttger.

BLEACHING.—Insert at foot of column 1, page 315, Vol. I.—Mr. L. BENNER, chemist of KÖCHLIN'S print-works at Darnetal, near Rouen, has lately recommended the use of sugarate of lime—sugar-lime—in place of caustic lime for bleaching of cotton fabrics. He describes his process as follows:—For one scouring operation, two hundred pieces of fourteen pounds each are worked upon, and the operation is performed in large kiers, heated on the open fire, and under a pressure of about twenty-two pounds to the inch. As soon as the pieces are singed, they are passed through a washing-machine—similar in principle to ROBINSON'S—in order to moisten them sufficiently to prevent any danger of combustion. After this they are wound by a mechanism into a tub in which they are spread in large folds. During the latter operation a milk of lime, containing forty pounds burnt lime, runs on the pieces in such proportion that the forty pounds of lime will be used up by the two hundred pieces. From this liming tub the pieces are mechanically transferred to the bucking kier, in which

they are arranged in separate layers. After covering and fixing the fabrics by wooden cross-bars, as much water is added as will cover the pieces to the height of twelve inches, after which the sugar-lime is added. The latter is prepared by mixing in a tub thirty pounds burnt lime with seventy-two pounds boiling water; after slaking, thirty-six pounds more of hot water are added to dilute the lime-paste. To this milk of lime are added fifteen pounds of molasses, previously diluted with thirty-six pounds of hot water. The whole is well stirred and thrown into the bucking kier, whereupon the cover is fastened, and the charge kept boiling for eight hours. The fire must, however, be increased very gradually, so that the operation is finished in about ten hours.

This operation ended, the pieces are taken out, passed twice through the washing-machine, and brought back again into the bucking kier. The pieces are folded up as before, covered with twelve inches of water, which is mixed with the sugar-lime prepared from thirty pounds of burnt lime and ten pounds of molasses. The charge is again boiled during eight hours; the pieces are then removed, passed twice through the washing-machine, and steeped in hydrochloric acid of specific gravity $1.010 = 2^\circ$ Twaddell during four hours. They then undergo two washings—are brought back to the bucking kier a third time to be finished for bleaching by a single soda-ley.

The sugar-lime being readily soluble in water, and acting in all respects like free lime, has, of course, the great advantage of intimate contact with all the particles of grease and resinous substances which are fixed on the fibre; while the caustic lime, in consequence of its restricted solubility, especially in boiling water, is less complete in its saponifying functions.

The bleaching process is carried out as follows:—After packing the pieces in the bucking kier, and covering them with twelve inches of water, a solution of sixty pounds of soda-crystals is added, the cover of the kier fastened, and the charge boiled for three hours. The fire is then withdrawn, the steam allowed to escape, and the cover removed. The soda liquor is drawn off and replaced by cold water, to which a resin-soap, prepared of one hundred pounds of soda ash and one hundred pounds of resin, is added. The cover is replaced, and the charge boiled for twelve hours, after which the soap-ley is withdrawn, the kier filled up with cold water as before, a solution of sixty pounds of soda crystals added, and the charge again boiled for three hours. The pieces are now removed to undergo the washing process twice, before being wound into the bleaching solution of chloroxide of calcium, where they remain a few hours; hence they pass through water, then receive a scouring in weak hydrochloric acid, and pass twice through the washing-machine.

Pieces which have not been treated with solution of chloroxide of calcium, are equally as well adapted for dyeing purposes; and the treatment with bleaching liquor may therefore be dispensed with for the greater part of the pieces.

The first scouring with soda crystals is intended to remove traces of acid, and most of the resinous matter, to prepare and aid the action of the resin-soap.

The second boiling with soda crystals is to remove

the remainder of resinous substances, and also to free the fibre from adhering rosin-soap.

This method of giving two scourings with sugar-lime offers the great advantage over those methods, where only one scouring with a comparatively strong ley of lime is employed, of weakening the fibre in a less degree.

ANTICHLORINE.—The property of cotton and other woody fibre to condense gases and colors on its surface by a peculiar physical attraction, is well understood. This action, which it has in common with all solid bodies, is so powerful in some instances, that it may even counteract chemical attraction. Cotton and other vegetal fibre which has undergone the bleaching process by chlorine, for instance, has the property of powerfully retaining some chlorine gas. The difficulty of removing this effectually from the bleached fibre is almost insurmountable, requiring a great sacrifice of time, when rapidity is so essential, besides large volumes of water and increased machinery. Now, in order to insure the proper rapidity of the manipulations, either an appreciable amount of chlorine must be left in the bleached fabric or paper-pulp, or else this chlorine must be removed by substances bringing superior chemical affinity into play.

The expedient of only partially removing the chlorine from cotton cloth is certainly in favor of the manufacturer, to the evident disadvantage of the consumer. Chlorine acts gradually on the fibre; it combines with its hydrogen and disorganizes it, renders it brittle, aided by the hydrochloric acid formed. The same is the case with paper-pulp. The action of chlorine left in the bleached pulp is particularly illustrated by the paper manufactured in France soon after the introduction of chloroxide of calcium into the paper-mills. The paper, on running over the hot drying rollers of the machine, becomes brittle; the books printed on it gradually become full of brown spots, and acquire a uniform brownish tint. Every bookseller is acquainted with the inferiority of the modern printing paper in this respect. This deterioration must be entirely ascribed to the action of free chlorine, adhering to the fibre. It is not the paper alone that suffers; the type, too, with which it comes in contact, is affected in proportion to the amount of chlorine left in the paper. It is well to direct the attention of paper-makers and printers to this point, and so furnish them with a ready explanation of the rapid deterioration of the paper and type, and to draw their attention to those chemical agents which may be employed with advantage for counteracting these evils. Agents of this description have been introduced to the public under the general designation of *antichlorine*.

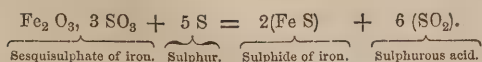
Carbonate of soda or ammonia was first proposed as an antidote for chlorine; but though the latter gas decomposes soda or ammonia in concentrated solutions, the effect in very dilute fluids is very insignificant, and requires the aid of heat. Sulphide of calcium was next introduced; but its property of being decomposed by carbonic acid, with evolution of the fetid sulphide of hydrogen gas, and the black precipitate which it produces with any salt of iron or copper which may be present in the pulp by accident, preclude the use of

this salt. Protochloride of tin—tin salt—and a mixture of protosulphate of iron and salt, have the disadvantage of introducing metallic salts into the pulp, which are about as objectionable as chlorine itself. Hyposulphite of soda is somewhat expensive, and precipitates sulphur when brought in contact with chlorine or hydrochloric acid, the sulphur giving a yellowish tint to the paper. Recently a patent was taken out by ROTH and LEA of Philadelphia, for the use of a solution of sulphite of soda as an antichlorine. Sulphurous acid and its salts are indisputably the most economical, besides being the most efficient chemical compounds for removing free chlorine. Sulphurous acid alone, however, cannot be employed for the purpose in question, on account of being converted by chlorine into sulphuric acid, which has a detrimental action on woody fibre. The sulphite of soda answers, therefore, all practical purposes, as far as its chemical action is concerned; it is, however, still liable to the objection of difficult transportation in its fluid state, in which it must be sold for reasons of economy, entailing additional expense on the consumer for water-tight casks and freight of a valueless substance—water. These considerations, which oppose a more general application of the sulphite of soda, have induced Professor HORSFORD to make the use of the cheap sulphite of lime or *antichloride of lime*, the subject of a patent for England and America.

It may appear on first consideration that neutral sulphite of lime, which is very little soluble in water, could have but little effect on the chlorine combined with the fibre; but the fact that hydrochloric acid dissolves neutral sulphite of lime with formation of soluble bisulphite of lime, will readily explain its action. Now hydrochloric acid is invariably generated whenever chlorine gas acts as a decoloring agent on organic substances.

It is the hydrochloric acid thus generated which dissolves the neutral sulphite of lime. Contact with chlorine converts the sulphite into sulphate of lime, which goes to increase the weight of the paper, and practically saves to the manufacturer nearly or quite the whole cost of the sulphite of lime. The article is prepared by agitating milk of lime by means of revolving paddles in a long close box, with fumes of burning sulphur, until the reaction is neutral or acid. It is then drained and air-dried, and packed in casks for transportation.

In connection with the formula given at page 324, column 2, it deserves to be stated that, instead of taking the protosulphate of iron— FeOSO_3 —for the preparation of sulphurous acid, it is more advantageous to employ the *sesquisulphate of iron*— $\text{Fe}_2\text{O}_3, 3\text{SO}_3$ —which is obtained by *roasting* green vitriol in the air, and then adding to it half as much more sulphuric acid as it already contains, and evaporating the resulting pasty mass to dryness. One hundred and ninety-eight parts of the dry sesquisulphate of iron are now mixed with eighty parts of sulphur, and heated, whereby one hundred and ninety-two parts of dry sulphurous acid gas are obtained:—



while one hundred and ninety-eight parts of the *protosulphate of iron* will only yield one hundred and sixty-nine parts of sulphurous acid.—H.

BLEACHING POWDER.—At page 328, immediately preceding the formula at foot of column 1, it is stated that the chlorine employed in the experiments was prepared by adding hydrochloric acid to chlorate of potassa. But BÖTTGER found that the gas thus obtained contained Cl O_3 . It is to be presumed that the mixed gases were passed through sufficient water, and at a rate sufficiently slow to permit the entire absorption of the Cl O_3 .—H.

At page 329 a description is given of FRESENIUS and WILL's method for testing the quality of manganese ore. A modification of this method, more simple, and still equally satisfactory for practical purposes, has been proposed by MOHR. It is executed in the following manner:—Three grammes of the finely-powdered and dried manganese ore are mixed in a small glass flask with a little water, and enough sulphuric acid to render the whole mass perfectly fluid. This flask and a porcelain capsule containing about nine grammes of crystallized oxalic acid, are now placed in one scale of the balance, and brought into equilibrium by a basin of sand or small shot. The oxalic acid is now thrown into the flask, where it immediately begins to reduce the binoxide of manganese under evolution of carbonic acid. To accelerate this decomposition, it is good to give the flask a circular horizontal motion, until the evolution of the carbonic acid has ceased, and the mass from black, which it was, has become light-colored. The empty porcelain capsule and the glass flask are now again placed on the balance, and so much weight placed into the capsule as to restore the equilibrium. The weight required to effect this is equal to the weight of a binoxide of manganese in the ore, because one equivalent of binoxide of manganese = 44, when treated with oxalic and sulphuric acids, cause the evolution of two equivalents of carbonic acid = 44; one part by weight of binoxide of manganese is therefore indicated by one part of carbonic acid.

Now, as three grammes of ore have been employed for the above experiment, it follows that the amount of carbonic acid lost, divided by three, indicates the amount of binoxide of manganese in one gramme of the ore; and by multiplying the latter number with one hundred, the per centage of the binoxide is obtained. The error produced by the loss of water in this method does not signify for most practical purposes, but may be remedied by closing the flask with a cork in which a glass tube filled with dry chloride of calcium is fastened. In this case, however, the carbonic acid contained in the flask when the experiment is finished must be removed by suction.—H.

BONE BLACK.—At page 336, eleventh line of first column, it is stated that solutions of sugar are better deprived of their color when alkaline than when acid. This, however, only applies to an alkalinity of sugar sirup produced by *lime*.

Some interesting reflections are suggested by the remark which follows in the same column with reference to the decoloring power of carbon, and M. BUSSEY's

experiment, showing that the reaction is strongly influenced by ordinary chemical forces, instead of being purely mechanical. As the whole universe, with all its diversified phenomena, derives its origin from one *primum movens*, and as all the phenomena connected with matter can therefore only be functions of this creative unit, one may, *a priori*, expect that which is actually observed, namely, the gradual transition and intimate connection of varied effects and causes. Where does inorganic nature cease and life commence? Where stops the action of light, and where does heat begin? Why does magnetism induce electricity? Where do the physical forces—cohesion, repulsion, heat, electropolarity, light and contact force, find a landmark which separates them from what are denominated chemical forces? Every effect must have a cause, and every distinct effect a distinct cause; but it is the defect of the human mind to be slow in distinguishing apparent from real differences. Before NEWTON it would have been undoubtedly considered good logic to conclude, that the force which made the apple *fall* was different from that which kept the earth *steady*. Thus it comes that all definitions of isolated systems fail, and undergo continual amputation and restoration with every progress of science—now hobbling on one bandaged leg, now on another—showing that nature abhors, if not the vacuum, at least systems and definitions; and it teaches that there is no gap in its mechanism, no wheel or spring wanting in its clock-work; in fine, there is no interruption in its development from a single cause or *animus* to its utmost complicity, which is observed in the perfection of organic existence. A disruption in the continuity of effects in the economy of nature would be equal to the interruption of an electric wire between two telegraph stations; because in that case the intelligent cause on one station could no more produce an intelligent effect on the other, in consequence of an apparently insignificant accident. The forces as connected with the phenomena of matter, are in the same predicament. There can be no *real* difference in the so-called forces, because such a difference would constitute a *real* gap; it would stamp the force as an individual, producing an individual effect, so that all the infinitely different effects observed must be ascribed to infinitely different forces.

The attraction of coloring matter by charcoal is denominated mechanical, while the attraction of sulphuric acid by baryta is classed with chemical effects. But animal charcoal does not only attract coloring matter; it also decomposes metallic salts, and fixes their base by that same power of retention. Now it is known that chemical combinations and decompositions are produced by differences in intensity of one only chemical attractive force called affinity. It is evident that the same force is inherent in animal charcoal. This view is corroborated by the fact that animal charcoal absorbs different compounds in different but determined quantities. NIEPCE has shown that iodine and chlorine gas are condensed by the inked portion of printed paper, while the white portion of the paper does not retain any of the gases. Charcoal absorbs heat and light most readily. It condenses

electricity on its surface, and thereby acts as a non-conductor, the same as glass, which is only an isolator in consequence of its great attraction for electricity. Metallic charcoal loses, with its power of attracting colors and gases, also the power of attracting electricity, which latter now passes through without hindrance, as through other conductors. Ordinary charcoal condenses gases, and frequently causes chemical combinations. This substance, then, shows the gradual development of chemical effects by physical forces. The effect of animal charcoal depends entirely upon its porosity and the extent of its carbonaceous surface, and is directly proportional to it; and it may therefore be presumed that if the surface of charcoal could be indefinitely increased by solution in water, it would produce all the powerful chemical phenomena of cyanogen or ozone.

If one moves on a step further, binocide of tin presents itself, a substance already more pronounced in its chemical character than charcoal. Still it is inclined to combine equally as well with bases as with acids, showing a transition character. Now, if pumice be soaked in a solution of bichloride of tin, and then dipped into a solution of carbonate of soda, the pumice acquires all the properties of animal charcoal. Very porous pumice, finely-divided silica, cotton fibre—all these show signs of chemical power depending on their extent of surface; and it may well be supposed that this chemical power would be more prominent, could they be obtained in the fluid state. Silicic acid, which is as inert as charcoal at the ordinary temperature, drives out the powerful sulphuric acid from its combinations at a temperature nearer its own melting point.

Another phenomenon is also connected with the action of animal charcoal, namely, that of endosmosis. It has been shown, as subsequently stated in the text, that a colored sugar solution containing, besides water, some salts, does not pass unchanged through animal charcoal. Pure water is the first to pass through, then comes water with salts, then sugar, and lastly, the color. From this one concludes that animal charcoal has the greatest affinity for coloring matter, less for sugar solution—because the latter is replaced by the former—still less for salt solution, and least of all for water. Could, therefore, a thin diaphragm be constructed of animal charcoal, one would observe the endosmosis to take place from a salt solution into water, and from a solution of sugar into salt, and from a solution of coloring matter into water, salt, and sugar; that is, of such tinctorial matter as has the greater affinity for animal charcoal. Thus a certain molecular attraction in animal charcoal may produce effects ascribed to a multiplicity of forces, as mechanical force—adhesion, endosmotic force, catalytic force; and chemical force—affinity. Would it not be more rational to consider all these as mere functions of the same molecular tendency the intensity of which alone gives rise to variable effects, the same as is observed in sound, electricity, and light?—H.

CORRENWINDER assumes that the decoloring effect of animal charcoal is correlative to its absorbing power for lime; and on this supposition he bases the following method for determining the commercial value of bone

black:—A solution of sugarate of lime is prepared, containing, say, twenty grammes of lime in one thousand cubic centimetres fluid, which are neutralized by one thousand cubic centimetres of a standard solution of sulphuric acid, so that fifty cubic centimetres of the acid solution indicate one gramme lime.

The samples of the bone black are now rendered of a uniform condition, by passing them separately through the same sieve, after having removed the fine dust by a paper fan. Fifty grammes of each sample are placed each in a glass flask. In each glass flask one hundred cubic centimetres of the solution of sugarate of lime are added to the bone black, and the whole allowed to digest for an hour. After this the fluid of each flask is filtered separately, and fifty cubic centimetres of the filtrate liquor are tested for the amount of lime with the standard solution of sulphuric acid. The more lime there is absorbed by the bone black, the less sulphuric acid will be required to neutralize the filtered liquor; and that liquor which requires least acid for neutralization, must have been in contact with the most valuable sample of bone black, so that the value of the animal charcoal increases directly as the amount of standard acid required for neutralization decreases.—H.

BORACIC ACID.—At page 342, it is stated that boracic acid scarcely reddens vegetal blues, and renders turmeric brown, like an alkali. This reaction affords an easy means of detecting boracic acid in its combinations, by adding to it a little hydrochloric acid; after which dip into the fluid a piece of turmeric paper, and then dry it. If a trace of the acid was present, the paper will have a brown stain after drying.—H.

BREAD.—Insert at foot of column 1, page 377, Vol. I.—The frequent failure of the grain crops, and the scarcity of grain induced by some other accidental causes, has drawn the attention of chemists to the process of bread-baking, either with a view to discover some substitute for wheat flour, or else to find the means for rendering the whole of the nutritive principles of the cereals available for consumption. The latter direction has already furnished valuable results. It is known that the bran separated from flour contains a comparatively large proportion of nitrogenized substance, namely, that constituent of the flour which contributes most to nutrition. Until quite recently the bran was lost to the nutrition of man. Now, however, it has been shown that this nitrogenized substance may be extracted from the bran without much trouble and expense, so as to obtain the whole of its valuable matter. This process, recommended by a number of chemists, was ultimately patented in France by a Mrs. DURUT. The manipulation is carried out in the following manner:—Bran is mixed up with boiling water in a kettle over a moderate fire, so that the mixture has a semifluid consistency. The mixture is now heated carefully until the bran loses its raw smell—not till it is cooked; it is then transferred into bags and pressed. The pressed cake is treated once more in the same manner, mixing it with water, allowing to boil for a short time, and pressing. The fluid obtained by this second operation is used, instead of pure water, for a fresh portion of bran. By the first pressing a sirupy

juice is obtained, completely saturated with gluten, and which is destined to replace the pure water in the process of bread-baking; thus gaining for the bread a large proportion of valuable nutriment entirely lost before. The economy of this process is thus stated:—A bag of flour of the average weight of three hundred and twelve pounds, made into bread with water in the usual manner, yields on an average one hundred and four loaves of four pounds each. A bag of flour of the same weight, made into bread with the extract of bran, yields one hundred and thirty loaves of four pounds each, or a clear gain of twenty-six loaves over the old process. Twenty-five per cent. increase in the yield of bread from the same amount of flour is a fact the importance of which cannot easily be exaggerated.

BROMINE.—The process detailed at pages 393, 394, for the separation of bromine and chlorine, may with advantage be modified in the following manner:—Precipitate the solution containing chlorine and bromine with nitrate of silver; wash, dry, and heat the precipitate to a state of semi-fusion in a weighed porcelain capsule. Weigh the capsule with the silver precipitate, then reduce the latter with the aid of zinc and sulphuric acid in excess. Wash out the reduced silver, ignite, and weigh it. If one supposes the weight of the chloride and bromide of silver to be a , and that of the metallic silver obtained from it by reduction with zinc to be b , and the amount of chlorine to be x , the amount of bromine will be $a-b-x=y$. From this we conclude:—

$$\frac{107.97x}{35.46} + \frac{107.97y}{79.97} = C.,$$

from which is deduced:

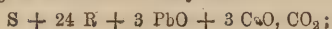
$$x = 1.38674C - 0.79667a$$

That is, multiply the weight of the reduced silver by 1.38674, and deduct from the result the product obtained by multiplying the weight of the chloride and bromide of silver with 0.79667, and the result will be the amount of chlorine in the mixture. By subtracting the weight of the chlorine plus that of metallic silver from the weight of the chloride and bromide of silver, the amount of bromine is obtained.—H.

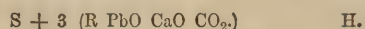
CANDLE.—Read, in connection with the processes described at pages 430, 431:—The operations of saponification of the fat, and decomposition of the lime-soap by sulphuric acid, have been hitherto effected in open vessels, under the ordinary pressure of the atmosphere. An improvement on this plan has been recently proposed by M. DELAPCHIER, of Besançon, who substitutes close vessels in order to saponify the fat. Wash and decompose the lime-soap under a pressure of about twenty-two pounds to the square inch, by which the operations are considerably facilitated, and their duration shortened. The products by this process are said to be superior to those obtained in open vessels, and a considerable economy of fluid is effected. The apparatus consists essentially of a horizontal boiler, with a man-hole and two safety valves at the top. The heat is furnished by a large steam-pipe, running in a depression along the bottom of the boiler. The

pipe is perforated with numerous holes to distribute the heat more uniformly. A horizontal iron shaft, which passes through stuffing boxes in the heads of the boiler, carries an agitator, the transversal ribs of which nearly touch the circumference of the boiler. A large pulley at one end of the shaft receives its motion from a suitable motor. The materials are charged through the man-hole, and at the end of the operation withdrawn by a large valve at the bottom of the boiler.—H.

CAOUTCHOUC.—The qualities of sulphurized caoutchouc are described in column 2, page 448, vol. 1 :—Allowing the chemical composition of caoutchouc to be $C_8 H_7$, the formula of the best vulcanized rubber car-springs is found to be very near—



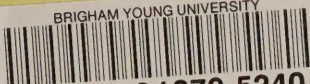
R signifying one equivalent of rubber= $C_8 H_7$. It rubber was represented by $C_{64} H_{56}$ —or eight times its present equivalent—the vulcanized car-springs would have the compact formula :—



CIDER.—At page 475, middle of column 2, it is stated that in warm seasons it is still a desideratum to discover some means of checking a too rapid fermentation of cider. The process for the prevention of fermentation in saccharine solutions, denominated *mutisme* by the French, may be very easily applied for effecting this purpose. By adding to fermenting powder from one six hundredth to one thousandth of neutral sulphite of lime, or of bisulphite of soda, the fermentation may be reduced to a minimum, or entirely checked.

END OF VOL. II.

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